Disability technology

How data and digital assistive technologies can support independent, fulfilled lives

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Disability technology: Exploring how data and digital assistive technologies can support independent, fulfilled lives.
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Cover image: *Neural Nebulous*, 2021, a light-based copper installation embedded in a tree that links the brain's neural networks to the vast unknowns of space. © Alexis Neumann. Alexis Neumann is a California-based artist, scholar, and curator whose interactive installations and mixed media art works explore her experience with disability and the intersections of culture, identity, and theology.
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Foreword

Some fifty years ago, I was introduced to Stephen Hawking and told that he would be lucky to live another year. In fact, he had a long and influential life ahead of him and became one of the Royal Society's most famous Fellows. Writing in his own foreword for a 2011 World Health Organization report, he described the removal of barriers to participation for disabled people as a 'moral duty'. In his view, achieving this would unlock the vast potential of disabled people and, as exemplified by his own life as a highly accomplished disabled academic, technology can play an important role. This report aims to push forward Hawking's vision by considering how we can accelerate the development of digital technologies to help disabled people live independent, fulfilled lives.

One of the most important facets of this challenge is data. As a statistician, I am acutely aware that categorisation in data collection can affect everything and everyone. The way disability is understood, surveyed and categorised has far-reaching effects on financial allocations, service delivery and product design. In a world of data-driven technologies, we need to continually assess how we are collecting and publishing data on disability. Approaches to data categorisation and collection are an important part of our exploration of the landscape of digital assistive technologies.

Issues of disability are of interest not only to those who are disabled. Disability can be temporary or long-term and can affect any of us at any point in our life. Disability has varying definitions across the world and can affect individuals in different ways; indeed, some people living with a disability may not recognise themselves as disabled. These are among the reasons we recommend a shift from an identity-focused approach to data collection towards one centred on understanding specific functional challenges.

In an age of artificial intelligence, global research and development largely focuses on big data. As much disability data is sparse and non-standardised, this presents a fundamental challenge for digital assistive technologies, as is also the case in areas such as personalised medicine. Progress will require methodology built using 'small data', such as few-shot machine learning. As a prompt for researchers and their funders, our report sets out potential avenues for small data approaches.

Fulfilment in life has many dimensions and technology needs to adapt to as many of these as possible if we are to truly meet the challenge of disability inclusion. With this in mind, the report sets out case studies for digital assistive technologies for work, leisure, rest and care.

The development of these technologies has a long way to go and we are conscious that in many cases technology can be a hindrance rather than a help. However, the opportunity in front of us is substantial. To be successful, it will require action from decision-makers across many sectors. I hope, after reading our report, you will be one of those who acts and helps society fulfil its moral duty.

Finally, our grateful thanks are due to the staff at the Royal Society including June Brawner, Areeq Chowdhury, Mahi Hardalupas, Charise Johnson and Isabelle Magkoeva. They have been a delight to work with.

Sir Bernard Silverman FRS
Chair of the Royal Society Disability Technology Steering Committee

Executive summary

Disabled people face barriers in their everyday lives to work, play, rest and care. Disability is estimated to affect 1.3 billion people or 16% of the world's population[1]. In the UK, there are 16 million people reporting a disability, with the prevalence increasing with age[2].

Digital assistive technologies (DigAT) promise to promote independence for disabled people, potentially reducing or eliminating existing barriers. This report defines DigAT as 'any technology that processes information to help make people's lives easier'[3]. Examples include screen-readers, speech-to-text software, or smartphone applications which support daily living. This definition does not include non-digital assistive technologies (eg white canes or sticks, manual wheelchairs, or magnifying glasses).

While this report is focused primarily on the needs of disabled people, disability access is relevant to all as everyone can experience temporary and permanent disability throughout their life. Accessibility can also benefit the whole of society as products designed for disabled people (eg automatic doors, closed captioning and voice assistants) are often valued by all.

The physical, emotional and social impact of disability, as well as attitudes towards disabled people, can affect all aspects of disabled people's lives. This includes impacts on education, employment, wellbeing and life expectancy. DigAT will not be a standalone solution for these challenges and, in some cases, technology itself causes significant challenges for disabled people.

However, if designed and deployed appropriately, these technologies can be transformative in helping disabled people live more independent and fulfilled lives. Exemplifying this, the report highlights five case studies of how DigAT can support disabled people across work; gaming; tourism; music; and social care.

In addition to exploring the landscape of DigAT, the report is focused on various challenges within the DigAT lifecycle related to measurement, inclusive design and sustainability. Furthermore, it provides an overview of small data methods. These methods, which help researchers derive insights from limited data, present significant potential across a broad range of scientific fields, including the development of DigAT.

The nature of disability is inherently diverse and complex. To ensure a more defined focus, the report has generally explored disabilities related to hearing; cognition; mobility; self-care; built-environment; vision; and communication.

The report has been guided by an international expert steering committee, many of whom have lived experience of disability. It has been informed by a series of activities undertaken by the Royal Society. These include a survey of more than 800 UK-based disabled people; a nationally representative survey of approximately 2,000 members of the British public; focus groups with UK-based DigAT users; literature reviews on disability data and small data; a case study analysis of DigAT in the UK, US, India and Kenya; and various roundtables and workshops on inclusive design, gaming, social care and technology transience.

1 The World Health Organization. 2023 Disability. See https://www.who.int/news-room/fact-sheets/detail/disability-and-health (accessed 14 April 2025).

2 House of Commons Library. 2024 UK disability statistics: Prevalence and life experiences. See https://commonslibrary.parliament.uk/research-briefings/cbp-9602/ (accessed 14 April 2025).

3 This definition was co-formulated with Disabled participants in research conducted for this report by the Research Institute for Disabled Consumers (RiDC).

The key findings and recommendations of the report are intended to be useful for policymakers across the world.

The chapters cover the core foundations of DigAT: data, analytical techniques, inclusive design and sustainability. The report does not prescribe specific examples of DigAT to be developed, although the final chapter sets out potential applications as proposed by disabled people.

Key findings

- Simple, quantitative measures to approximate complex health statuses can be inconsistent and reductive. Examples include self-identification in population surveys and perceived measures from medical datasets. This can have implications for disability-related policy interventions and comparisons of their efficacy. It may also incentivise the inappropriate prioritisation of the medical model of disability (where exclusion from activities results directly from an individual's functional challenges) over the social model (which accounts for society's failure to meet people's accessibility needs). Understanding the limitations of this data is essential for the responsible design of disability-related research, effective policy-making and to avoid misrepresentation.
- Digital assistive technologies can enable disabled people to engage independently in a range of activities including those related to employment, leisure and the home. According to a survey of UK-based disabled people, conducted for this report, more than half of DigAT users said they could not live their lives the way they do without DigAT. In addition, a nationally representative survey of the British public suggests there is an expectation for technologies to meet people's needs as they grow older and a willingness to use them if they were shown to enhance their independence.
- Inclusive design (or 'co-design') practices are essential to the development of effective and user-friendly DigAT. There are several aspects to this including the accessibility of design software and work environments; the involvement of disabled people throughout the design process; sharing accessibility information ahead of the launch of a product; and actioning feedback from disabled users post-development. This may also require developers to unlearn exclusionary design practices and to consider long-term challenges related to a product's sustainability (eg obsolescence and repairability).
- Big data techniques may fail to represent minority groups (eg disabled people) in the large datasets being analysed. This can lead to disabled people not being represented in patterns extracted by these techniques, reinforcing biases in favour of non-disabled people. Small data approaches, which focus on context-specific information from smaller datasets (eg personalised data gained via wearable technologies) can allow for more granular analysis of disabled people's experiences. These approaches, however, remain at an emerging stage of development and are likely to require longer term advancements within machine learning to be most useful for DigAT.
- The development of inclusive technologies can improve the user experience for all users, disabled or non-disabled. Assistive features designed for disabled people can often produce better experiences for non-disabled people too. Examples of this include closed captioning, text-to-speech and voice assistants. As such, a sole focus on disability prevalence when making the case for investment in DigAT may lead to an underestimate of the economic opportunity.

- Accessibility training and education for users and professionals is key for DigAT adoption in work, leisure and social care settings. This can help address DigAT adoption challenges due to lack of awareness of DigAT and digital skills gaps.
- There are various ethical concerns related to the development of DigAT, including privacy; data bias; data minimisation; informed consent; equitable access; and ideological beliefs (eg discriminatory eugenics). How these concerns are addressed and balanced against the opportunities provided by DigAT will be an important influencing factor in how widely they are adopted by disabled people.

Future research questions

The following topics and issues emerged in research activities as key considerations for disability data and digital assistive technologies:

- New sensory datasets: What new sensory datasets (eg sound, smell, haptic) need to be developed or made available to enhance multi-modal analytical techniques for improving DigAT?
- Inequities in global data for DigAT: What barriers exist to the provision of DigAT that can be applied globally as widely as possible across regions and cultural contexts? This may include considerations of the quality of data on diverse languages and built environments.
- Education and training: How best can carers and general users be educated on how to use DigAT? How can DigAT enable greater access to education for disabled people and children?
- Complex disabilities and intellectual disabilities: Many applications of DigAT are focused on specific individual types of disability. How can the development of DigAT be adapted to better consider the needs of those who experience complex disabilities (where people have a combination of different disabilities) and/or intellectual disabilities?
- Regulation of medical devices: What are the advantages and disadvantages of current regulatory approaches to medical devices if applied to DigAT?
- Funding for DigAT research and development: The nature of DigAT research is often interdisciplinary. What are the challenges in obtaining funding for research and development of DigAT? How can these be addressed by research funders?
- Personalised AI: How can AI systems which automatically adapt to individual user behaviours, preferences and needs enhance the effectiveness of DigAT?

Recommendations

AREA FOR ACTION: COLLECTING NEW TYPES OF DISABILITY DATA

RECOMMENDATION 1

National statistics bodies should shift toward collecting data on functional challenges and limitations across populations, rather than solely focusing on disability identity. This approach would provide a more nuanced understanding of how people experience limitations in their day-to-day lives, allowing for better-informed policymaking.

Disability is an inherently diverse and personal experience[4]. Simplified measurements of disability can end up misrepresenting more complex health statuses and have limited utility for policymaking or resource allocation. Self-identification of disability is motivated by several factors and can lead to an underreporting of disability by certain groups (eg older people who do not renegotiate their identity despite experiencing changes in functioning which would constitute disability)[5]. Perceived measures of disability (where researchers categorise people as disabled based on health records) rely on the medical model of disability and can contribute to interventions which do not account for an individual's environmental and social context and fail to meet their needs.

While both self-identification and perceived measures can have value, it is significantly limited if the overall objective for data collection is to design better policies, products and services for disabled people. To better understand people's accessibility needs, data collection should focus on assessing specific functional challenges and limitations people may face (eg issues with seeing, hearing, walking and remembering). It is important these questions are validated and developed in consultation with disabled communities and organisations[6].

4 Danemayer, J. and Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 14 April 2025).

5 Leahy A. 2023 Disability Identity in Older Age? - Exploring Social Processes that Influence Disability Identification with Ageing. Disability Studies Quarterly. 42, 3-4. (doi:10.18061/dsq.v42i3-4.7780)

6 Open Society Foundations. 2014 Ethnic Origin and Disability Data Collection in Europe: Measuring Inequality – Combating Discrimination. See https://www.opensocietyfoundations.org/publications/ethnic-origin-and-disability-data-collection-europe-measuring-inequality-combating (accessed 12 March 2025).

To be effective, population surveys need to capture the diversity of functional challenges people face and move away from binary classifications of 'disabled' or 'non-disabled'. The functional assessment questions developed by the United Nations' Washington Group on Disability Statistics present a method for achieving this which could be integrated into existing national data collection[7]. The most widely implemented of these, the short set (WG-SS), contains six questions on difficulties related to vision; hearing; mobility; cognition; self-care; and communication. Respondents are asked to report levels of difficulty for each category from 'no difficulty' to 'cannot do at all'.

This approach has already been adopted by many countries around the world. According to a 2023 review of national censuses and household surveys by the Disability Data Initiative, 125 countries have at least one dataset with functional assessment questions, including 70 with at least one dataset using the WG-SS[8]. The report, however, found geographical disparities with functional assessment surveys being a rarity in Europe and Central Asia compared with a greater availability in sub-Saharan Africa.

Combined with a disaggregation by factors such as age, gender, socioeconomic status and location, the collection of this data could strengthen the efficacy of initiatives designed to support disabled people. In the context of policymaking, this data can help support more targeted interventions specific to described needs. In the context of DigAT, this data could be used to incentivise the development of new technologies and improve the quality of existing tools. It may also help improve alternatives to big data research methods (eg small data[9] methods used for analysing relatively smaller datasets or demographic subgroups). In doing so, national statistics bodies can play a leading role in furthering research on small data and coordinating initiatives to benefit disabled people.

7 Washington Group on Disability Statistics. 2025 Question Sets. See: https://www.washingtongroup-disability.com/question-sets/ (accessed 14 April 2025).

8 Disability Data Initiative. 2023 Disability Data Report 2023. See: https://disabilitydata.ace.fordham.edu/disability-data-report-2023/ (accessed 14 April 2025).

9 Hackenberg *et al*. 2024 Small data explainer - The impact of small data methods in everyday life. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 14 April 2025).

AREA OF ACTION: RECOGNISING DIGITAL TECHNOLOGIES AS ASSISTIVE

RECOMMENDATION 2

Governments should consider the smartphone as an assistive technology.

Smartphones serve as a multi-purpose DigAT for disabled people, offering various accessibility features including voice-to-text; text-to-speech; screen magnifiers; captioning; navigation; and colour correction. It is estimated that more than half the global population (4.6 billion) have access to smartphones[10] with disabled people being significantly less likely to have access compared to non-disabled people[11]. This disparity is also apparent in the UK, with lower levels of smartphone ownership estimated for disabled people compared to non-disabled people (86% vs 64%)[12].

As with information communication technologies more generally (eg laptops, tablets and PCs), internet access can break down barriers to healthcare, education, employment and social connections for all. The portable nature of smartphones and their ability to integrate accessibility features with ease makes them a powerful form of DigAT. They should not be considered any less a form of assistive technology than hearing aids, manual wheelchairs, or white canes. For disabled people, smartphones can enable new methods for independence. In a social care setting, smartphones are often essential for the effective functioning of smart home devices and personalised health data collection[13].

10 GSMA. 2024 The State of Mobile Internet Connectivity 2024. See https://www.gsma.com/r/wp-content/uploads/2024/10/The-State-of-Mobile-Internet-Connectivity-Report-2024.pdf (accessed 14 April 2025).

11 GSMA. 2021 The Mobile Disability Gap Report 2021. See https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/wp-content/uploads/2021/11/Mobile-Disability-Gap-Report-2021.pdf (accessed 14 April 2025).

12 Ofcom. 2021 Use of communication services, consumer omnibus 2020. See https://www.ofcom.org.uk/siteassets/resources/documents/research-and-data/multi-sector/accessibility-research/use-of-communication-services-consumer-omnibus/use-of-communication-services-consumer-omnibus.pdf (accessed 14 April 2025).

13 Royal Society and Policy Connect workshop on inclusive design and deployment of smart home devices for social care and independent living, April 2024.

For many disabled people, their DigAT is their smartphone[14] and major mobile operating system providers such as Google[15] and Apple[16] have made progress in making their devices more accessible. In a survey of disabled DigAT users, conducted for this report, 64% said they need DigAT to access critical services. More than half of respondents said they could not live their lives the way they do without it[17].

For policymakers, the acknowledgement of smartphones as an assistive technology should shape approaches towards the provision of DigAT to disabled people as well as the provision of essential services (eg health, social care, education, banking) which are delivered or regulated by governments. For example, the use of smartphones as DigAT should inform any proposals to ban them in schools. Reliable internet access should also be considered as a key part of supporting the use of smartphones as DigAT. It may also require the categorisation of smartphones as an assistive technology for universal health coverage initiatives.

14 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 14 April 2025).

15 Android. Innovative Accessible Phones, Devices, and Settings. See https://www.android.com/intl/en_uk/accessibility/ (accessed 13 March 2025). See also: Project Relate: An App for Non-Standard Speech - Google Research

16 Apple. Accessibility. See https://www.apple.com/uk/accessibility/ (accessed 13 March 2025).

17 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 14 April 2025).

AREA OF ACTION: PRIORITISING INCLUSIVE DESIGN IN TECHNOLOGY DEVELOPMENT

RECOMMENDATION 3

Disabled people should be meaningfully involved in the design and development of new digital products and services from the outset.

Ensuring the inclusion of disabled people throughout the design process of digital products and services is important to improving their accessibility. This principle should apply both to specialised DigAT as well as mainstream technologies used by all. It should also apply for the entire lifecycle of a product, from conception, to design and deployment and to end-of-life. Accounting for the views and needs of disabled people in this way will help ensure that new technologies can be truly accessible and can lead to a better overall user experience for disabled and non-disabled people alike[18, 19].

There are many good examples of companies carefully considering accessibility needs in the development of new digital products and services. These include efforts from major technology companies such as Google[20], Apple[21] and Microsoft[22], as well as smaller companies such as those highlighted across the case studies within this report. Despite this, the need to better include disabled people across the broad range of current and future DigAT applications was emphasised repeatedly across many of the research activities conducted.

Meaningfully involving disabled people will require investment in accessible recruitment processes, financial compensation and clear processes for engagement. A failure to do this carefully and effectively can lead to disabled people being excluded from user experience (UX) design or negatively impact their involvement[23]. Examples of poor practice highlighted in the Research Institute for Disabled Consumers (RiDC) research, conducted for this report, include a non-disclosure agreement sent in an inaccessible digital format and a survey with inaccessible checkboxes.

With altruism being a motivating factor for disabled people involving themselves in UX exercises[24], meaningful involvement will also require developers providing feedback to participants on what will change, if anything, as a result of their contributions. This may also require moderated engagement and evaluation, in which developers are able to engage directly (remote or in-person) with participants to fully understand UX challenges.

18 Royal Society and Sony PlayStation roundtable on DigAT for gaming, July 2024.

19 Royal Society and Policy Connect workshop on inclusive design and deployment of smart home devices for social care and independent living, April 2024.

20 Android. Innovative Accessible Phones, Devices, and Settings. See https://www.android.com/intl/en_uk/accessibility/ (accessed 13 March 2025). See also Project Relate: An App for Non-Standard Speech - Google Research

21 Apple. Accessibility. See: https://www.apple.com/uk/accessibility/ (accessed 13 March 2025).

22 Microsoft. Accessibility Technology and Tools. See https://www.microsoft.com/en-us/accessibility (accessed 13 March 2025).

23 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 14 April 2025).

24 *Ibid*.

Continuing the involvement of disabled people in the design of updates to products and services, post-deployment, is another important factor of inclusive design. This is easier with software and online services as feedback can be gauged in real-time (eg through social media platforms) with new versions designed and installed. An example of this being done well was highlighted during the Royal Society and Sony PlayStation roundtable with some developers using Discord as a platform to receive real-time feedback from disabled gamers, prior to making amendments to the gameplay in version updates[25].

Given the integration of technologies across daily activities and people's reliance on them, the end-of-life for a product should also be considered throughout the design process. When DigAT become obsolete, due to products no longer being maintained by their providers or due to companies closing, the disruption to people's lives can be severe and immediate[26]. This may involve the consideration of releasing the source code of obsolete DigAT devices (under an open-source license), patent pools and escrow provisions. It may also require initiatives related to the repair of a device, particularly in the event of product discontinuation. For policymakers, it could require legislative action (eg strengthening right to repair laws and regulations).

The principle of meaningful involvement should extend to the development of the product or service as a designer. This means that it should be possible for disabled people to pursue careers in software and hardware design. If achieved, this will help embed the lived experience of disability into the teams developing these products. This aspiration will require investment in skills and training for disabled people and potential employers, as well as investment in the development of accessible design software and hardware. This could involve the redesign of existing design platforms and hardware. It may also require the introduction of new design modules in colleges and universities which are accessible, inclusive and attractive for disabled students.

25 Royal Society and Sony PlayStation roundtable on DigAT for gaming, July 2024.

26 Royal Society roundtable on approaches for future-proofing essential technologies against obsolescence and user abandonment, July 2024.

AREA FOR ACTION: CREATING AFFORDABLE DIGITAL ASSISTIVE TECHNOLOGIES

RECOMMENDATION 4

Governments, technology companies and research funders should explore initiatives to promote low-cost, interoperable and sustainable digital assistive technologies.

Disabled people, across the world, are less likely to be in work and more likely to earn lower wages, when compared with non-disabled people[27]. In the UK, disabled people are almost twice as likely as non-disabled people to be unemployed[28] and the average disabled household faces over £1,000 a month in extra costs in order to have the same standard of living as non-disabled households[29]. The affordability of DigAT should be seen as a key priority for all interested in their development and adoption. It is a challenge which was repeatedly highlighted across many of the research activities conducted for this report.

There are, broadly, five approaches which can help address this. The first is to focus on addressing market failures in the provision of DigAT which emanate from a disparate and diverse disabled population with low levels of disposable income. Creating products for disabled people, therefore, may not be the most profitable or financially sustainable business proposition for private companies and their shareholders. Solving this (eg by subsidising purchases of DigAT, establishing DigAT accelerators, or by improving data collection on disabled populations) could help create a more competitive DigAT environment and lower consumer costs for DigAT products.

The second approach is to focus on improving the utility and lifespan of DigAT. Ensuring that products can be used to a high standard for many years (eg through hardware repairability or software updates) could help improve the appeal of expenditure on DigAT for disabled people. Furthermore, if these products are interoperable with other technologies (assistive or otherwise), this can also improve their appeal. For example, an accessibility controller which only works with one device (eg a gaming console) may be less appealing than one which also works with many other devices (eg televisions, personal computers). Addressing the lifespan and utility challenges could also have a positive environmental impact by reducing waste. This approach, however, will need to be balanced against commercial interests which may require products to have limited lifespans in order to generate profit and incentivise innovation.

27 International Labour Organization. 2024 A study on the employment and wage outcomes of people with disabilities. See https://www.ilo.org/sites/default/files/2024-08/WP124_web.pdf (accessed 18 December 2024).

28 The Health Foundation. 2024 Unemployment rates for disabled and non-disabled people. See https://www.health.org.uk/evidence-hub/work/employment-and-unemployment/unemployment-rates-for-disabled-and-non-disabled (accessed 18 December 2024).

29 Scope. 2024 Disability Price Tag. See https://www.scope.org.uk/campaigns/disability-price-tag (accessed 18 December 2024).

The third approach is to consider lending models for DigAT as part of existing public libraries. This approach would enable disabled people to borrow DigAT that they would otherwise be unable to access or purchase. This could help with testing the suitability of products prior to purchasing them or to help with specific use cases (eg job interviews, playing games, or learning an instrument). Libraries, themselves, could also receive funding to be equipped with DigAT to help disabled people more easily access books and the internet.

The fourth approach involves raising awareness of existing DigAT to help disabled people review different products and obtain better value for money. Awareness of DigAT products was a challenge raised throughout the activities conducted for this report. Barriers to awareness include information on DigAT being decentralised[30], inconsistent information on accessibility descriptors[31] and lack of incentives for companies[32]. As highlighted in the RiDC research, DigAT is discovered through a wide variety of sources including social media; disability groups; friends or family; and medical staff.

Amongst non-users of DigAT, 58% of respondents said they would use DigAT more if they knew what types were on the market. This was the most popular response to a question asking what would help participants to use DigAT[33].

Finally, initiatives to lower the costs of producing DigAT can be explored. This could include the creation of open datasets to be used for the creation of DigAT (eg new audio datasets for training AI systems); the release of existing datasets (eg public sector datasets or navigation data generated by private companies); and further research into small data approaches for DigAT development. Beyond this, traditional methods of achieving lower costs (eg through tax incentives or by investment in training and skills of the workforce) could be explored.

30 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

31 Royal Society and Sony PlayStation roundtable on DigAT for gaming, July 2024.

32 Royal Society and Policy Connect workshop on inclusive design and deployment of smart home devices for social care and independent living, April 2024.

33 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

AREA FOR ACTION: SAFEGUARDING AGAINST DIGITAL EXCLUSION

RECOMMENDATION 5

Service providers should consider the social impact of replacing analogue services with digital alternatives.

For many people, analogue services will always be the preferred option. Solving digital exclusion will take time and for some disabled people, DigAT of any form may not help them to live independent, fulfilled lives. As more services move online, organisations must ensure that analogue alternatives as well as live human interaction remain available and of high quality. If this is not possible, they should ensure users have adequate support to make the transition from analogue to digital.

The transition from analogue to digital can exclude disabled people by introducing digital systems that are difficult or impossible to use given certain types of disability. When considering these transitions, there should be a comprehensive assessment of which groups may end up excluded and how this may occur. For example, a transition from keypad card readers to touchscreen card readers may not be understood to be a transition from analogue to digital, however this is a transition which can easily exclude people with vision impairments[34].

The transition to digital services can also leave behind those who are digitally excluded (ie individuals without access to reliable internet, devices, or the skills necessary to navigate new technologies). This exclusion can exacerbate feelings of loneliness and isolation, particularly for those who may rely on face-to-face or phone-based services for social interaction and essential services. A 2024 report by the UK-based disability charity, Sense, found that nearly half of people with complex disabilities face exclusion as they struggle to access and engage with services online[35]. This includes accessing health support (eg booking a medical appointment online).

As outlined in recommendation 3, to ensure products and services are accessible, it is important to meaningfully involve disabled people throughout the entire design lifecycle. Doing so can help identify potential risks that could lead to the exclusion of disabled people.

34 BBC News. 2023 Touchscreen card devices may prevent blind customers paying. See https://www.bbc.co.uk/news/disability-67239870 (accessed 18 December 2024).

35 Sense. 2024 Potential and Possibility: Addressing digital exclusion. See https://www.sense.org.uk/about-us/research/potential-and-possibility-research/potential-and-possibility-2024-addressing-digital-exclusion/ (accessed 18 December 2024).

RECOMMENDATION 6

Governments should ensure disabled people and carers, of all ages, are equipped with the skills required to most effectively utilise current and future DigAT.

The development and promotion of DigAT, alone, will not be sufficient to ensure disabled people are able to benefit from these tools. There will need to be skills training initiatives to ensure that disabled people are able to understand how mainstream technologies (including popular AI assistants) and other DigAT can be best applied for their individual requirements. These initiatives will also need to be easily accessed by paid and unpaid carers who may want to adopt DigAT in both formal social care settings and more generally.

These trainings may be delivered through formal educational settings, as part of ensuring young people with diverse needs understand the opportunities and risks presented by digital technologies, or via other settings such as libraries, community organisations and charities. They may also be delivered by private companies (eg social care providers and technology developers).

These initiatives should cover information on existing accessibility features within mainstream technologies, advice on where to find, compare and purchase DigAT and guidance on how to set up or maintain DigAT. Beyond this, there should be an ongoing focus on general digital literacy skills, to ensure that participants are able to more easily adapt to new technological innovations.

Introduction

Data-driven technologies are an increasingly common feature in everyday life. For disabled people, the use of data-driven technologies can promise opportunities to lead more independent fulfilling lives. Digital assistive technologies (DigAT), such as screen readers, wearable devices and smartphone applications, can potentially address barriers disabled people face to work, play, rest and care. However, the DigAT ecosystem can risk being technology-driven rather than driven by the needs and interests of disabled people, the primary users of these technologies. There are several points in the lifecycle of DigAT products that prevent greater adoption and more inclusive development of DigAT.

This report explores various opportunities and challenges to research, development and adoption of DigAT through the lens of how these impact disabled users. It addresses the following questions:

- What is the state-of-the-art in DigAT scientific research? What are the potential benefits and risks?
- How can we incentivise the development of transformative, sustainable, data-driven DigAT?
- What data currently exists on disability and how useful is this data for developing DigAT?
- What are the key trends and barriers in DigAT markets and how do these map onto use cases or specific needs?

Each chapter draws on evidence gathered from roundtables, workshops, interviews and commissioned research conducted for this report to answer these questions. The findings are presented as follows:

- Chapter 1 describes what digital assistive technologies are, how they are used by disabled people and what disabled and non-disabled peoples' public attitudes are towards digital assistive technologies.
- Chapter 2 outlines the importance of disability data and the challenges of appropriate data classification. It explores advantages and disadvantages of different data classification methods and challenges leading to disability representation gaps in existing datasets.
- Chapter 3 discusses the potential of small data approaches for more inclusive data analysis and developing new DigAT. It outlines analysis techniques for small data, such as meta-learning and few-shot learning and how these can be used to support disabled people.
- Chapter 4 considers several barriers to design, development and adoption of DigAT alongside ethical concerns. This includes challenges with inclusive design, sustainable deployment and digital exclusion.
- Chapter 5 centres on suggested imagined futures for DigAT drawn from focus groups with UK-based disabled people conducted for this report.

The report also includes five case studies on the use of DigAT in employment, gaming, tourism, music and social care. These case studies outline specific examples of DigAT and explore the opportunities and challenges for disabled users.

Language

The language used to describe and refer to disability is deeply personal and can vary over time and between countries, cultures and particular disabled communities. Even amongst those who have the same disability/disabilities, there will be variety in how they experience this and the functional challenges this may entail. There are a wide range of preferences and views amongst disabled people about how to describe their own personal and group identities and disabilities. This report generally uses the term 'disabled people' (often described as identity-first language) which centres the collective shared identity of disabled people rather than referring to 'people with disabilities' (described as person-first language). However, this report does not endorse this language as the necessary 'right' way to describe disability and the report may use other language, especially when drawing on other sources.

Not everyone who experiences functional challenges with everyday living will consider themselves disabled, for example, older, Deaf, or neurodivergent individuals may not identify as disabled. For the purposes of this report, those who experience functional challenges that are frequently considered disabling are still priority users of DigAT given their potential to benefit from these technologies. The use of DigAT is not exclusive to those who identify as disabled and, as this report discusses, everyone can benefit from DigAT innovations.

Background

Disability is not a static category and there is no standard definition of disability. Currently in the UK, a common way to understand disability, as defined by the Equality Act 2010, is as a significant and long-term impairment which may negatively impact one's ability to perform personal daily activities and their participation in society. However, this can be interpreted differently depending on the model of disability adopted.

Two common models of disability are medical and social models, though these are not mutually exclusive with other models combining aspects of both. Medical models of disability treat disability as abnormal, view the avoidance or elimination of disability as desirable and seek to 'fix' disability[36]. In this model, the barriers disabled people face are due to their individual impairments, which need to be addressed through medical interventions. In contrast, social models of disability view the barriers disabled people face as the product of society, social context and the built environment. For example, lack of mobility for a wheelchair user may be due to the barrier of inaccessible building design. In social models, disability is normal and does not need to be fixed. Instead, it is the societal barriers that disable people that need to be addressed.

36 Danemayer, J. and Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

In the UK, the social model has been a powerful framework for disability rights campaigns and disability advocacy organisations[37]. It also forms the basis of the United Nation's 2006 Convention on the Rights of Persons with Disabilities[38]. However, some disabled individuals, such as those who experience chronic pain, may not fully relate to the social model of disability. Other models of disability, such as the biopsychosocial model instead combine aspects of the social and medical models to recognise the multiple factors (eg social, medical, cultural, legal) that need to be addressed to improve quality of life for disabled people[39].

Aside from their importance as frameworks to understand disability, these models have consequences for technology development. The medical model focuses on the development of specialist technologies that aim to 'cure' disability or help a disabled person become 'normal'. This can be at best unhelpful or at worst actively harmful for disabled people who do not consider their disability something to be 'fixed' by technology. However, research suggests that the medical model is more dominant in assistive technology and AI ecosystems[40].

Acknowledging the social context of disability leads to a shift away from using technology to 'fix' disability and instead understanding technologies as tools disabled people can use if they choose to. Rather than creating specialist technologies, on this model, developers aim for universal design and integrating more accessibility features into mainstream products[41]. While both specialist and mainstream technologies have an important role in the DigAT ecosystem, the examples highlighted in this report focus on tools empowering people to live fulfilled lives rather than technologies that primarily seek to 'fix' or 'normalise' disabled people. This also recognises that DigAT can be beneficial to all and the users of DigAT include non-disabled people or those who don't identify as disabled.

37 Disability Rights UK. Social Model of Disability: Language. See https://www.disabilityrightsuk.org/social-model-disability-language (accessed 12 March 2025). See also Sense. The social model of disability. https://www.sense.org.uk/about-us/the-social-model-of-disability/ (accessed 12 March 2025).

38 United Nations Convention on the Rights of Persons with Disabilities. Article 1 – Purpose. See https://social.desa.un.org/issues/disability/crpd/article-1-purpose (accessed 14 April 2025).

39 Shakespeare T. 2006 Disability Rights and Wrongs. London: Routledge.

40 El Morr C, Kundi B, Mobeen F, Taleghani S, El-Lahib Y, Gorman, R. 2024 AI and disability: A systematic scoping review. Health Informatics Journal 30(3). (doi:10.1177/14604582241285743). Shew A. 2020 Ableism, Technoableism, and Future AI. IEEE Technology and Society Magazine 39(1), 40–85. (doi: 10.1109/MTS.2020.2967492)

41 Seale J (ed.). 2024 A Research Agenda for Disability and Technology. Cheltenham: Edward Elgar Publishing Ltd.

Chapter one
Digital assistive technologies (DigAT)

Left
A blind person using a computer with a braille keyboard. © iStock / zlikovec.

Digital assistive technologies (DigAT)

What are assistive technologies?

There is no consensus definition of assistive technology. According to the World Health Organization (WHO), assistive technology is an umbrella term for assistive products and their related systems and services which help maintain or improve an individual's functioning related to cognition; communication; hearing; mobility; self-care; and vision[42]. The International Standards Organization has defined the term 'assistive product' as devices, equipment, instruments and software used by or for disabled people for participation; protection, support, training, or substitution of body functions and activities; or prevention of impairments and activity limitations[43].

The UK's Medicines and Healthcare products Regulatory Agency (MHRA) provides the following definition of assistive technology: "Products or systems that support and help individuals with disabilities, restricted mobility or other impairments to perform functions that might otherwise be difficult or impossible. These devices support individuals to improve or maintain their daily quality of life by easing or compensating for an injury or disability[44]."

The Assistive Technology Industry Association defines assistive technology as 'any item, piece of equipment, software program, or product system that is used to increase, maintain, or improve the functional capabilities of persons with disabilities'[45]. The Business Disability Forum defines it more simply as 'technology designed primarily to be used by disabled people'[46].

Assistive technologies include analogue products which may not be commonly described as 'technology' (ie digital technology). Examples include manual wheelchairs, hearing aids, crutches and communication aids. They can also be broadly classified into no-tech, low-tech, and high-tech categories[47] as displayed in Table 1.

42 World Health Organization. Assistive technology. See https://www.who.int/news-room/fact-sheets/detail/assistive-technology (accessed 18 December 2024).

43 International Standards Organization. ISO 9999: 2011 Assistive products for persons with disability – Classification and terminology. See https://www.iso.org/obp/ui/#iso:std:iso:9999:ed-5:v1:en (accessed 18 December 2024).

44 Medicines and Healthcare products Regulatory Agency. Assistive technology: definition and safe use. See https://www.gov.uk/government/publications/assistive-technology-definition-and-safe-use/assistive-technology-definition-and-safe-use#definitions (accessed 18 December 2024).

45 Assistive Technology Industry Association. What is AT? See https://www.atia.org/home/at-resources/what-is-at/ (accessed 18 December 2024).

46 Business Disability Forum. What is assistive technology? See https://businessdisabilityforum.org.uk/resource/technology-toolkit/what-is-assistive-technology/ (accessed 18 December 2024).

47 Baskerville J, Pan Y, Pham T, Sutton D. 2024 Towards the adoption of digital assistive technologies in the UK: An international comparison of policy factors. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

TABLE 1

Classification of assistive technologies

Category	Technologies
No-tech	Grab rails; wet room / toilet equipment; pencil grip; post-it notes; slanted surfaces; raised line paper; weighted pencils; magnifying bars; tactile letters; covered overlays.
Low-tech	Hoists; mobility equipment / bath seat / chairs / buzzers; portable word processors; talking calculator; switches; lights; electronic organisers; apps; sensors.
High-tech	E-readers; touch screen devices; computerised testing; speech recognition software; text-to-speech; progress monitoring software; GPS; eye gaze technology.

The World Intellectual Property Organization (WIPO) defines assistive technologies as either 'conventional' or 'emerging' across the domains of hearing; cognition; mobility; self-care; built-environment; vision; and communication. Examples listed of conventional assistive technologies include alarms; timers; induction loops; prostheses; adaptive clothing; and glasses. For emerging assistive technologies, examples include smart home devices; assistive robots; navigation aids; automated lip reading; exoskeletons; health monitoring wearables; and augmented reality devices[48].

Data from WIPO suggests there are more than 3,000 unique sub-categories of conventional assistive technology. For emerging assistive technologies, there are 180 unique sub-categories. In total, there are approximately 117,000 patent filings for conventional assistive technologies and more than 15,000 for emerging assistive technologies[49].

What are digital assistive technologies?

As with 'assistive technology', there is no consensus term for 'digital assistive technology' (DigAT). For the purposes of this report, a definition of DigAT was co-formulated with disabled people as part of focus groups conducted by the Research Institute for Disabled Consumers (RiDC)[50]. A broad definition was preferred, encompassing both mainstream technology (containing assistive functions) and technology specifically designed for disabled people. The definition adopted was 'any digital technology that processes information to help make your life easier'. Survey participants in the RiDC research were provided with the definition and additional context as follows:

"Any digital technology that processes information to help make your life easier. This can include screen-readers, speech-to-text software, or applications which support daily living such as Grammarly, NaviLens, or Be My Eyes. It does not include non-digital assistive aids like canes, wheelchairs, or magnifying glasses."

48 World Intellectual Property Organization. WIPO Technology Trends – Assistive Technology. See https://www.wipo.int/tech_trends/en/assistive_technology/ (accessed 18 December 2024).

49 *Ibid.*

50 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

Similar to conventional assistive technologies, examples of DigAT can be found across many domains and be used by a diverse range of disabled people. The case studies in this report contain examples of DigAT applied for employment, gaming, tourism, music and social care.

These include video conferencing platforms with automated captions; adaptive gaming controllers; virtual reality travel simulators; live Braille translations for music composition; and smart home devices for social care. Using the seven WIPO domains for disability, Table 2 provides examples of DigAT and the user requirements they can help address.

TABLE 2

Classification of DigAT by user requirements

Application domain	User requirement	Examples of DigAT
Hearing	Increase the volume and quality of sound; translate speech or sounds into accessible formats.	Audio-to-text apps (eg Dragon Anywhere, NaturalReader), automated captioning, audio assistance apps (eg Heard That), haptic suits/wearables for tactile feedback.
Cognition	Support memory, decision-making and problem-solving tasks.	Calendar/task management apps, writing support apps (eg Grammarly), note taking apps (eg Google Keep, Remarkable), smartphone reminders/prompts.
Mobility	Facilitate movement and navigation in various environments.	Wayfinding and navigation apps (eg Waymap, Microsoft Soundscape, AccessAble), GPS locator.
Self-care	Aid in daily personal care and hygiene activities.	Wearable health devices, symptom/energy management apps, voice-controlled assistants (eg Amazon Alexa), food delivery apps, assistive gaming controllers.
Built environment	Improve access and usability of physical spaces.	Smart home devices (eg app controlled smart lighting and switches), voice-operated doorbell systems.
Vision	Enhance or substitute visual perception.	Sight assistance apps (eg NaviLens, Be My Eyes), screen magnifiers, digital overlays, DAISY players.
Communication	Enable or improve the exchange of information and expression.	Video communication software (eg Zoom, Signal), screen-readers (eg JAWS, Dolphin Supernova), Augmentative and Alternative Communication (AAC) devices.

An evidence review conducted by the RiDC for this report[51] identified the following four major categories of DigAT, mapped against access barriers (eg cost, usability) and social presence barriers (eg availability, publicity):

- **State of the art**
  These are difficult to access but have a high social presence (eg Ray-Ban Meta Glasses). This may be due to their cost or complexity of use. Their social presence is high due to publicity and marketing around new innovations.

- **Everyday technology**
  These are likely to have a secondary assistive function whilst their primary function is more general. They are easy to access and have a high social presence. They can include smartphones, laptops and voice assistants which are used by most people in society daily.

- **Outdated technology**
  These may be used due to the user's familiarity with the product and difficulty in adopting new technologies. However, these technologies may no longer be supported by the manufacturer (eg through software updates) and may be incompatible with new applications (eg new web browsers). The devices are, therefore, difficult to access and have low social presence (as they are old products).

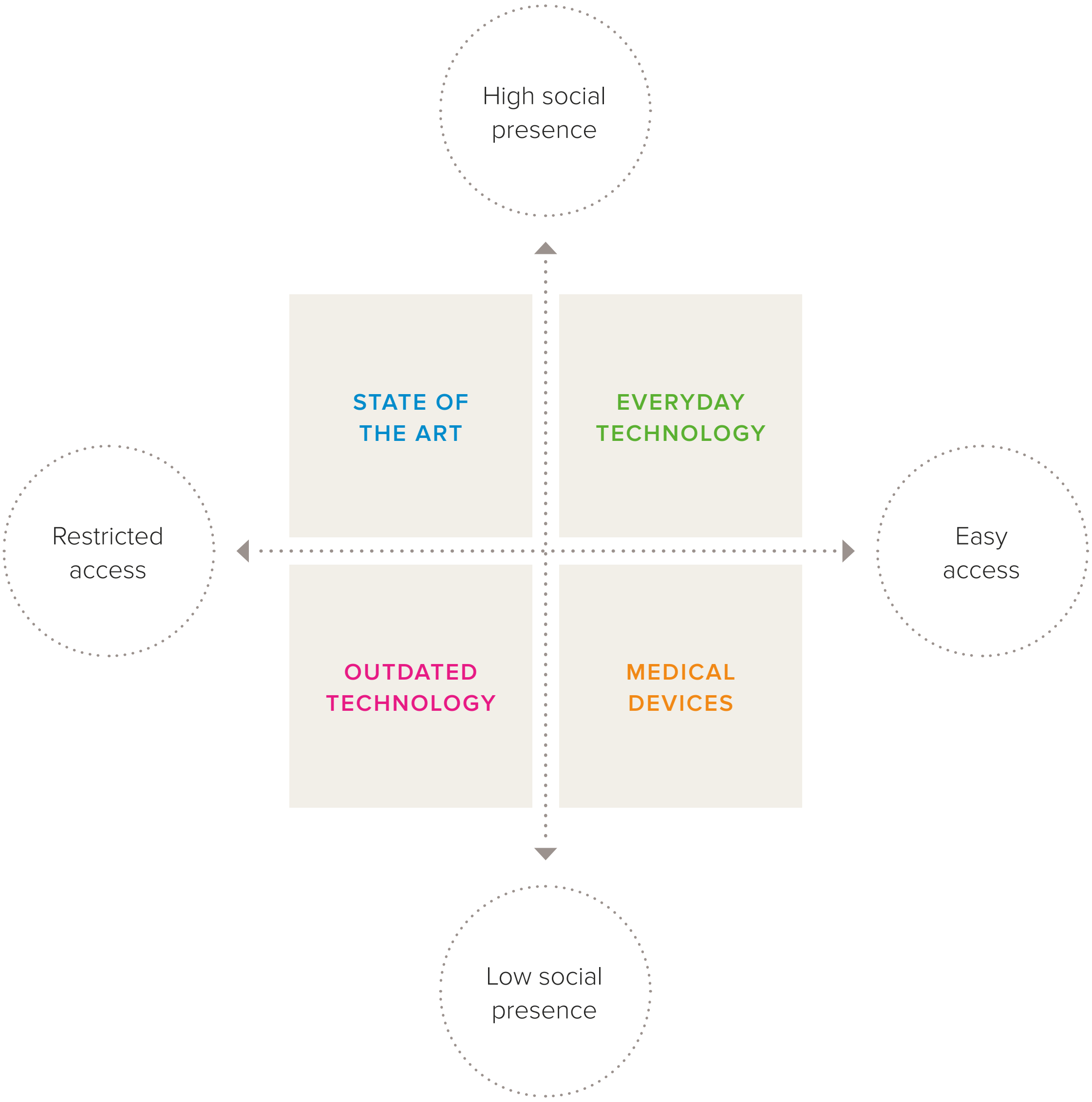
- **Medical devices**
  These devices have been categorised as easy to access in a UK context due to potential availability via the National Health Service. However, they have low social presence as it can be difficult to find information about the newest technologies and how to access them.

These classifications can be used to complement the broad definition of DigAT to determine specific applications as well as factors which may affect their uptake or continued use.

51 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

FIGURE 1

Barrier-based classification of digital assistive technologies (DigAT)



Types of DigAT used by disabled people

Based on a UK-based survey of disabled people[52], in which participants were asked to list up to ten examples they use, DigAT can be grouped into the following four categories:

- **Mainstream technology**
  This refers to smartphones; laptops; tablets; desktop computers; voice assistants; and communication applications. Examples provided by survey respondents included in-built accessibility features such as screen-readers; dark mode; screen magnifiers; font or colour adjustments; and device-enabled captions. Others included voice-controlled assistants (eg Siri, Google Assistant, Amazon Alexa) and video calling applications.

- **Task-specific technology**
  This refers to technology aimed at performing specific tasks such as managing home appliances; travelling; seeking entertainment; and ordering food. Examples provided by survey respondents included app-controlled smart heating, lighting and switches, as well as wayfinding apps (eg Google Maps, Microsoft Soundscape) and entertainment-related apps (eg e-readers, gaming software).

- **Barrier-specific technology**
  This refers to technology aimed at addressing specific barriers in an individual's environment. Examples provided by survey respondents included aids to access visual information (eg Be My Eyes, NaviLens, Seeing AI). Others included text-to-speech and speech-to-text software (eg Natural Reader, Dragon); apps to support with reading, writing, or composition (eg Grammarly); and apps to support organisation (eg calendar or task management apps).

- **Health-tracking technology**
  This refers to applications, software, or devices which track or manage health conditions, energy levels, or physical and mental symptoms. Examples provided by survey respondents included apps or devices to monitor bodily functions and movements; apps to manage medical appointments or prescriptions; and apps to support mental health.

52 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

Attitudes towards DigAT adoption

People can require assistive technologies throughout their lives, either temporarily due to illness or injury, or on a long-term basis because of ageing, chronic health conditions, or disability. As a common aspect of the human experience, the development of DigAT is relevant to everyone.

To explore attitudes towards DigAT adoption, two surveys of UK-based participants were undertaken for this report. The first, conducted by YouGov, surveyed a representative panel of approximately 2,000 members of the public (age 18+)[53]. The second, conducted by the RiDC, surveyed a panel of 850 disabled people. The methodology for these can be viewed in Appendix 3.

According to the YouGov survey, people use technology for various routine daily tasks including staying in touch with friends and family (87%), purchasing goods (85%) and managing finances (78%). Almost half (47%) of 18- to 24-year-olds said they use DigAT, which were described in the survey as 'support tools (such as speech recognition, adaptive keyboards, or magnification tools)'. This was the highest prevalence of the age groups as displayed in figure 2.

Considering the future, the majority (61%) are confident that technologies will meet their needs as they grow older and 67% are confident that they will be able to adapt to future technological changes. Confidence in their ability to adapt was significantly higher amongst 18- to 24-year-olds (76%) compared with those aged 55 and older (56%). Finally, almost three-quarters (74%) said they would be willing to adopt new technologies if they were shown to enhance their independence or access to services.

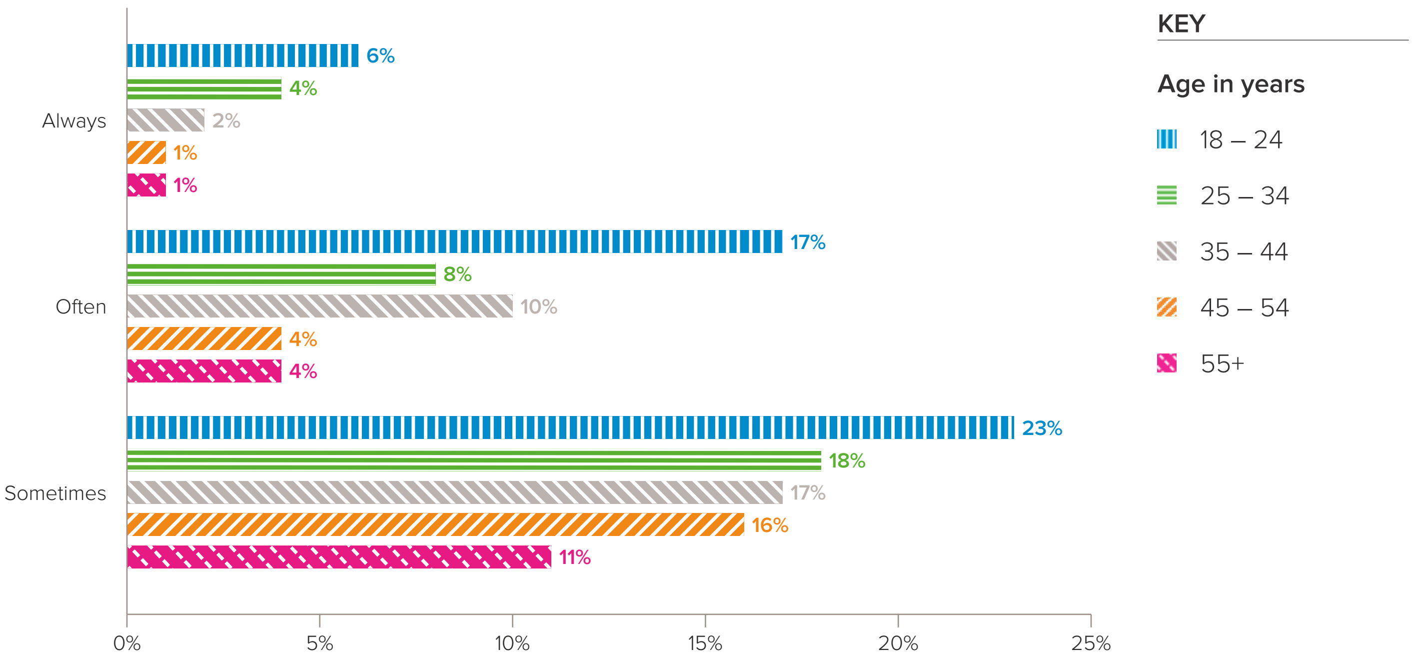
In the RiDC survey of disabled people, 62% said they use DigAT with more than half doing so throughout their day. Those with visual impairments were most likely to use DigAT throughout their day, with 44% of this group selecting this option. By age, 18- to 39-year-olds were most likely to use DigAT throughout their day. Over half of DigAT users (53%) said that without it, they could not live the way they did or that their daily life would be significantly more difficult. Of those who did not use DigAT, over half (55%) said they did not need to use DigAT for their access needs, while 19% felt they do not know enough or feel confident enough to use it. 58% said they would adopt DigAT if they knew what types were on the market, while 36% said they would adopt them if training was available to show them how to do so.

53 This survey used the term 'support tools' instead of 'DigAT'. The question related to this was "How often, if at all, do you use support tools to perform routine digital tasks on your own (such as speech recognition, adaptive keyboards, or magnification tools)?"

FIGURE 2

Frequency of using support tools to perform digital tasks

Survey results for the question: How often, if at all, do you use support tools to perform routine digital tasks on your own (such as speech recognition, adaptive keyboards, or magnification tools?



CASE STUDY 1

DigAT for the world of work

According to the Organisation for Economic Co-operation and Development (OECD), there is a persistent disability employment gap with disabled people 2.3 times more likely to be unemployed than non-disabled people in 2019[54]. In the UK, at the time of writing, the disability employment gap stands at 28.6 percentage points, with only 53% of disabled people employed[55]. While work may not be appropriate for all disabled people, many unemployed disabled people want to work and employment can reduce inequalities.

Opportunities

Remote work has long been practiced by disabled communities and the flexibility of remote work has positive impacts on disabled workers' productivity and health. In a recent survey, 70% of disabled workers said lack of access to remote work would negatively impact their health[56]. People with mobility limitations can avoid commuting, which may be more difficult or expensive. People with fluctuating conditions, such as chronic fatigue or conditions requiring medical equipment, benefit from more control of their work schedule and environments to better manage their disabilities[57]. Video communication software, such as Microsoft Teams, can support remote working with features such as the ability to mute and control audio, video and interruptions especially useful for neurodivergent users[58].

Disabled people use other types of DigAT at work or for finding jobs. Surveys of blind or low vision people (B/LV) identify screen readers and smartphones as the most commonly used tools at work[59]. Live transcription tools can also be useful for making meetings more accessible. Mainstream devices, such as smartphones, can be preferable to specialised technologies as they are multifunctional reducing the cost and maintenance of using multiple devices[60], which is especially useful for disabled workers in low-resource settings[61]. For finding work, the chatbot Zammo.ai has been designed to provide users with a more accessible way to access information on job board platforms, such as LinkedIn, by using text or audio questions[62].

54 OECD. 2022 Disability, Work and Inclusion: Mainstreaming in All Policies and Practices. See https://www.oecd.org/en/publications/disability-work-and-inclusion_1eaa5e9c-en.html (accessed 14 April 2025).

55 UK Department for Work & Pensions. 2024 The employment of disabled people 2024. See https://www.gov.uk/government/statistics/the-employment-of-disabled-people-2024/the-employment-of-disabled-people-2024 (accessed 7 January 2025).

56 The Work Foundation. 2022 The changing workplace: Enabling disability-inclusive hybrid working. See https://www.lancaster.ac.uk/media/lancaster-university/content-assets/documents/lums/work-foundation/TheChangingWorkplace.pdf (accessed 14 April 2025).

57 Schur L A, Ameri M, Kruse D. 2020 Telework After COVID: A "Silver Lining" for Workers with Disabilities? Journal of Occupational Rehabilitation 30, 521–536. (doi:10.1007/s10926-020-09936-5)

58 Tang J. 2021 Understanding the Telework Experience of People with Disabilities. Proceedings of the ACM on Human-Computer Interaction, 5, 1-27. (doi:10.1145/3449104)

59 McDonnall M C, Steverson A, Sessler Trinkowsky R, Sergi K. 2024. Assistive technology use in the workplace by people with blindness and low vision: Perceived skill level, satisfaction, and challenges. Assistive Technology 36, 429–436. (doi:10.1080/10400435.2023.2213762)

60 Martiniello N, Eisenbarth W, Lehane C, Johnson A, Wittich W. 2022 Exploring the use of smartphones and tablets among people with visual impairments: Are mainstream devices replacing the use of traditional visual aids? Assistive Technology 34, 34–45. (doi:10.1080/10400435.2019.1682084)

61 AT2030. How does mobile empower me? Joseph's story. See https://at2030.org/how-does-mobile-empower-me-josephs-story/ (accessed 14 April 2025).

62 OECD. 2023 Using AI to support people with disability in the labour market. See https://www.oecd.org/en/publications/using-ai-to-support-people-with-disability-in-the-labour-market_008b32b7-en.html (accessed 14 April 2025).

Challenges

The use of technology at work can produce barriers for disabled people. Disabled workers may struggle to afford DigAT with many disabled workers using their own money to purchase assistive technologies[63]. Disabled people are almost three times more likely than non-disabled people to have no computer or internet at home, which is needed to access and use most DigAT[64]. While remote work can have advantages for disabled people, there is a risk it could exacerbate the high social isolation levels disabled people report[65]. For this reason, it is important that the use of DigAT for remote work does not remove the need to make physical workplaces more accessible.

Even when DigAT is available, it may still exclude disabled workers. Mainstream video communication platforms, such as Zoom, can have accessibility challenges such as lack of integration with screen readers and inaccessible user interfaces[66]. Disabled people are also less likely to work in professional office-based jobs[67] where remote working is more available[68]. A recent survey found one in five disabled workers requesting adjustments for remote working were refused[69].

Other challenges include lack of awareness and training, both for disabled employees who may not be aware of or need training to use DigAT and for colleagues and managers to foster a more inclusive accessible work culture.

Example

Riziki Source

Riziki Source is an online platform developed to address the disability employment gap in Kenya by linking disabled people with prospective employers. Through an app, users can create profiles to apply to jobs at employers who have training in implementing reasonable adjustments for disabled candidates. This reduces the risk of disabled people not being adequately supported in the workplace and ensures employers access a diverse group of candidates[70].

Conclusion

Supporting DigAT in the workplace can improve access to employment for disabled people and increase the representation of disabled people across organisations. Support and training for employers and employees will be required to ensure the implementation of DigAT does not inadvertently increase barriers for disabled people in the workplace.

63 The Work Foundation. 2022 The changing workplace: Enabling disability-inclusive hybrid working. See https://www.lancaster.ac.uk/media/lancaster-university/content-assets/documents/lums/work-foundation/TheChangingWorkplace.pdf (accessed 14 April 2025).

64 OECD. 2022 Disability, Work and Inclusion: Mainstreaming in All Policies and Practices. See https://www.oecd.org/en/publications/disability-work-and-inclusion_1eaa5e9c-en.html (accessed 14 April 2025).

65 McNaughton D, Rackensperger T, Dorn D, Wilson N. 2014 ‘Home is at work and work is at home’: Telework and individuals who use augmentative and alternative communication. WORK 48, 117-126. (doi:10.3233/WOR-141860)

66 Tang J. 2021 Understanding the Telework Experience of People with Disabilities. Proceedings of the ACM on Human-Computer Interaction, 5, 1-27. (doi:10.1145/3449104)

67 UK Department for Work & Pensions. 2024 The employment of disabled people 2024. See https://www.gov.uk/government/statistics/the-employment-of-disabled-people-2024/the-employment-of-disabled-people-2024 (accessed 7 January 2025).

68 Schur L A, Ameri M, Kruse D. 2020 Telework after COVID: a “silver lining” for workers with disabilities? Journal of occupational rehabilitation 30, 521-36.

69 The Work Foundation. 2022 The changing workplace: Enabling disability-inclusive hybrid working. See https://www.lancaster.ac.uk/media/lancaster-university/content-assets/documents/lums/work-foundation/TheChangingWorkplace.pdf (accessed 14 April 2025).

70 AT2030. Riziki Source Case Study. See https://at2030.org/riziki-source-case-study/ (accessed 14 April 2025).

Chapter two
Disability data

Left
A person wearing a sunflower lanyard, a globally recognized symbol indicating that the wearer has a non-visible disability. It's a discreet way to signal that someone may need extra support, understanding, or time in shops, at work, on transport, or in public spaces.
© iStock / nambitomo.

Disability data

What is disability data and why is it important?

Disability data refers to information regarding an individual's disability (eg type, severity and support requirements); a disabled person's other personal data (eg demographic details, medical history, behavioural data and individual preferences); and national or international information on disability prevalence within a population.

Disability prevalence data can be used to better estimate support needs for a population, evaluate policies and interventions and understand demand for DigAT products and services[71]. This data is often commissioned by policymakers to understand service provision needs and by innovators to investigate potential markets. Given its relevance for ensuring disabled people's needs are met, it is important the data collected is trustworthy and reliable. The following six criteria, adapted from a list created by the Data Management Association[72], provide guidance on the characteristics underpinning high quality data:

1. **Accuracy**
   Data is accurate when it reflects reality. For disability data, this can refer to details being correct for an individual's health condition, demographic information, or support needs.

2. **Completeness**
   Data is complete when all necessary information is included. For disability data, this can refer to disabled people being properly represented in large population-level datasets, as well as the data collected reflecting critical relevant information about their disabilities.

3. **Uniqueness**
   Data is unique if it appears only once in a dataset. For disability data, this can refer to duplicate records of disabled people arising from merged datasets or double counting in data collection.

4. **Consistency**
   Data is consistent when there are no conflicts within or across different data sets. For disability data, this can refer to an individual's disability being recorded inconsistently (or not at all) across datasets held by different public bodies.

5. **Timeliness**
   Data is timely if it is available when expected and needed. For disability data, this can refer to an individual's health data being tracked on a real-time basis, rather than through ad hoc health appointments.

6. **Validity**
   Data is valid if it conforms to the expected format, type and range. For disability data, this can refer to specific conditions being listed in a format recognisable by other systems.

In addition to these guidelines, creating data according to the FAIR principles[73] (where data is findable, accessible, interoperable and reusable) may aid the development of AI-based DigAT trained on data from a diverse range of sources. Data linking can potentially enable the creation of more comprehensive DigAT products as well as mitigating issues with small datasets, however this needs to be done in ways that avoid potential reidentification of individuals in datasets.

71 Danemayer, J. and Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

72 UK Government Data Quality Hub. Meet the data quality dimensions. See https://www.gov.uk/government/news/meet-the-data-quality-dimensions (accessed 18 December 2024).

73 GO FAIR. Fair Principles. See https://www.go-fair.org/fair-principles/ (accessed 18 December 2024).

Approaches to disability data collection

There are, broadly, two approaches to disability data collection[74]. The first is perceived measures, where researchers or analysts apply their own definition of disability to individuals within a population dataset. This approach involves identifying certain clinically assessed conditions and labelling individuals with these as disabled. It is based in the medical model of disability where disability is considered a health condition to be avoided, managed, or eliminated. The second approach is self-reported measures, in which individuals self-identify as disabled based on their experience of difficulties in undertaking specific activities. In this approach, individuals describe to researchers (eg through surveys) how disabling a condition is in the context of their daily life. This approach accounts for both the medical model of disability as well as the social model (where an individual is impacted by societal barriers in their environment).

Disability-adjusted life years and quality-adjusted life years

Perceived measures draw upon health records and registries for disabling conditions. Health records can include information held by hospitals and general practitioners. Registries can include social welfare initiatives where individuals are required to be registered as disabled to receive specialised support (eg accessible documentation, welfare payments). Information derived from these datasets is used for calculating disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs). One DALY represents the loss of the equivalent of one year of 'full health' due to disability[75]. One QALY represents the equivalent of one year of life in perfect health[76].

These units are used to determine the 'burden' of disability and inform decisions related to resource allocation. They are also used to evaluate health interventions with a reduction in DALYs or an increase in QALYs considered to be a success. These approaches have been criticised for dehumanising disabled people. By optimising for QALYs and DALYs and considering disability a 'burden', they are defining disabled people's lives as less valuable than non-disabled people's lives[77, 78]. In particular, evaluating interventions by how they decrease DALYs can result in disabled people having less claim to resources than non-disabled people by limiting the types of support and interventions available to them[79]. These issues are particularly important to consider, in view of the widespread use of QALY and DALY measures in global public health through the 'Global Burden of Disease' study[80] and cost-effectiveness evaluations[81].

74 Danemayer, J. and Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

75 World Health Organization. Disability-adjusted life years. See https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158 (accessed 20 January 2025).

76 National Institute for Health and Care Excellence. Quality-adjusted life year. See https://www.nice.org.uk/glossary?letter=q (accessed 20 January 2025).

77 Danemayer J, Holloway C. 2024 Disability and Assistive Technology in Population-Based Data. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

78 Arnesen T, Nord E. 1999 The value of DALY life: problems with ethics and validity of disability adjusted life years. BMJ (Clinical research ed.) 319, 1423–1425. (doi:10.1136/bmj.319.7222.1423).

79 Danemayer, J. and Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

80 Institute for Health Metrics and Evaluation. 2021 Global Burden of Disease. See https://www.healthdata.org/research-analysis/gbd (accessed 15 April 2025).

81 Danemayer J, Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

Perceived measures for data collection have also been used by statistics agencies. As of 2021, 43 countries rely on self-reported health conditions in census data collection to ascertain disability prevalence[82]. The UK government's research and decision-making is frequently based on a medical model, reflected in the Office of National Statistics' Census question requiring a respondent to confirm whether they have "…a physical or mental health condition or illness expected to last more than 12 months," before proceeding to answer about activity limitations. If an individual does not identify as having a condition or impairment, but does have activity limitations, they will not qualify as disabled[83].

Disability data based on health records and registries can result in inaccuracies and bias. For example, reported estimates may be underestimates due to health diagnostic services being difficult to access due to user costs, lack of resources in the healthcare system, or inaccessible health facilities[84]. Other factors, such as distrust in medical services, privacy concerns and stigma around registry data collection, can affect the accuracy of this model of data collection.

Self-identification
Disability can form part of people's perception of their identity, akin to gender, ethnicity and age. This identity can be subjective and motivated by numerous factors[85]. It is, therefore, too inconsistent to be used as a method for making decisions on resource allocations. For example, older people who experience changes which introduce functional challenges to their everyday lives may not renegotiate their identity or consider themselves 'disabled'[86].

Wearable sensors

Wearable technologies (eg smart watches, sensors on prosthetics) can be used to collect data on the prevalence and nature of disability[87]. The use of these technologies has been applied to analyse wheelchair users' quality of mobility[88, 89], detect dementia[90] and to capture levels of pain[91]. In recent years, major technology companies including Google, Apple and Samsung, have developed proprietary health platforms through which to securely collect, visualise and automate reports on health-related activity[92].

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82 Mitra S, Chen W, Hervé J, Pirozzi S, Yap J. 2022 Invisible or Mainstream? Disability in Surveys and Censuses in Low- and Middle-Income Countries. Social Indicators Research 163, 219-249. (doi:10.1007/s11205-022-02879-9)

83 UK Government Statistical Service Harmonisation Team. 2019 Measuring disability for the Equality Act 2010 harmonisation guidance. See https://analysisfunction.civilservice.gov.uk/policy-store/measuring-disability-for-the-equality-act-2010/ (accessed 15 April 2025).

84 Danemayer J, Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

85 *Ibid*.

86 Leahy A. 2023 Disability Identity in Older Age? - Exploring Social Processes that Influence Disability Identification with Ageing. Disability Studies Quarterly. 42, 3-4. (doi:10.18061/dsq.v42i3-4.7780)

87 Danemayer J, Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

88 Fu J *et al*. 2014 Characterization of wheelchair maneuvers based on noisy inertial sensor data: a preliminary study. Annu Int Conf IEEE Eng Med Biol Soc. 2014, 1731-1734. (https://doi.org/10.1109/EMBC.2014.6943942)

89 Herrera R *et al*. 2018 Towards a wearable wheelchair monitor: Classification of push style based on inertial sensors at multiple upper limb locations. 2018 IEEE International Conference on Systems, Man, and Cybernetics, 1535-1540. (https://doi.org/10.1109/SMC.2018.00266)

90 Holloway C *et al*. 2022 STEP-UP: Enabling low-cost IMU sensors to predict the type of dementia during everyday stair climbing. Front Comput Sci 3. (https://doi.org/10.3389/fcomp.2021.804917)

91 Olugbade T *et al*. 2024 The EmoPain@Home dataset: Capturing pain level and activity recognition for people with chronic pain in their homes. IEEE Transactions on Affective Computing. (https://doi.org/10.1109/TAFFC.2024.3390837).

92 Danemayer J, Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

Functional assessments

The diverse, inconsistent and non-standardised approaches to disability data collection present significant challenges to policymakers and the developers of new DigAT. Some methods offer simplicity over utility, while others risk misrepresentation and exclusion. To overcome this, the United Nations' Washington Group on Disability Statistics developed a functional assessment (known as the Washington Group questions) designed to be integrated into existing national data collection[93]. The questions aim to focus on difficulties people may have undertaking functional activities, applicable across all nations, cultures and societies. There are several question sets, including sets focused on children, education and work. The short set (see Box 1) includes six questions.

As of 2023, 70 countries have used the short set in at least one wave of national data collection[94]. It has also been integrated into the World Health Organization's Rapid Assistive Technology Assessment survey[95].

BOX 1

The Washington Group Short Set on Functioning

Respondents are asked to answer the following questions with one of four options: 'no difficulty', 'some difficulty', 'a lot of difficulty', or 'cannot do at all'.

Vision
[Do/Does] [you/he/she] have difficulty seeing, even if wearing glasses?

Hearing
[Do/Does] [you/he/she] have difficulty hearing, even if using a hearing aid(s)?

Mobility
[Do/Does] [you/he/she] have difficulty walking or climbing steps?

Cognition
[Do/Does] [you/he/she] have difficulty remembering or concentrating?

Self-care
[Do/Does] [you/he/she] have difficulty with self-care, such as washing all over or dressing?

Communication
Using [your/his/her] usual language, [do/does] [you/he/she] have difficulty communicating, for example understanding or being understood?

93 Washington Group on Disability Statistics. Question Sets. See https://www.washingtongroup-disability.com/question-sets/ (accessed 18 December 2024).

94 Disability Data Initiative. 2023 Disability Data Report. See https://disabilitydata.ace.fordham.edu/disability-data-report-2023/ (accessed 15 April 2025).

95 World Health Organization. Measuring access to assistive technologies in countries. See https://www.who.int/tools/ata-toolkit/rata (accessed 15 April 2025).

Another global standard is the World Health Organization's International Classification of Functioning, Disability and Health (ICF)[96]. This framework adopts the biopsychosocial model of disability (encompassing biological, psychological and social factors)[97] and contains detailed, comprehensive questions which can be used by healthcare professionals, as well as policymakers, to design interventions or rehabilitation plans for patients.

The self-report bias that can occur with the Washington Group questions, the ICF and other functional assessments, has led to criticism of the approach due to the potential of estimating a higher prevalence of needs compared to clinical assessments[98]. Furthermore, the subjective nature of the questions can lead to inconsistencies in how the responses are interpreted (ie 'some difficulty' or 'a lot of difficulty')[99]. However, they have advantages compared to perceived measures. By avoiding explicit mention of disability identity or diagnosis, functional assessments can reduce misreporting resulting from stigma[100] or from those who have functional challenges but do not identify as disabled, such as older people[101].

Functional assessments are also more easily linked to specific supporting interventions, such as DigAT for mobility, rather than assuming the same needs apply across all individuals with the same disability[102].

Challenges leading to representation gaps

Irrespective of which approach is used to measure disability, major challenges exist with the collection of data from disabled people. Drawing on the Danemayer and Holloway review[103], the following five core challenges to disability data representation have been identified.

Exclusionary survey designs

Surveys can lead to representation gaps when they do not account for a broad range of disabled respondents from diverse backgrounds. This includes a failure to support respondents who may have intellectual and communication disabilities, which may require sign language interpreters or adapted survey modules. Other factors include an overreliance on institutionalised populations (eg those in education or work) and accessibility barriers at physical or online data collection points. Data collection may prioritise more common disabilities at the risk of excluding those with rarer disabilities, where data is harder to collect or less easy to represent in datasets.

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96 World Health Organization. ICF Checklist. See https://www.who.int/publications/m/item/icf-checklist (accessed 15 April 2025).

97 Engel G. 1977 The need for a new medical model: A challenge for biomedicine. Science (New York, N.Y.) 196, 129–136. (https://doi.org/10.1126/science.847460)

98 McTaggart I *et al*. 2016 Measuring disability in population-based surveys: The interrelationship between clinical impairments and reported functional limitations in Cameroon and India. PloS ONE 11, e0164470. (https://doi.org/10.1371/journal.pone.0164470)

99 UK Government Statistical Service Harmonisation Team. 2023 Review of disability data harmonised standards. See https://analysisfunction.civilservice.gov.uk/policy-store/review-of-disability-data-harmonised-standards/ (accessed 15 April 2025).

100 Leahy A. 2023 Disability Identity in Older Age? - Exploring Social Processes that Influence Disability Identification with Ageing. Disability Studies Quarterly. 42, 3-4. (doi:10.18061/dsq.v42i3-4.7780)

101 Danemayer J, Holloway, C. 2024 Disability and Assistive Technology in Population-Based Data. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

102 *Ibid*.

103 *Ibid*.

Furthermore, in some cases, disabled people may be ineligible to enrol in population cohort studies altogether. Disabled people may have less time or energy available for tasks and be more selective about how to spend their time, for example, by opting-out of long surveys if these are perceived to not directly benefit them. Co-design of research with disabled people can help address issues around inclusivity and consider creative methods of data collection[104].

Social stigma

Internal stigma surrounding disabilities can lead to some respondents not wishing to share their own or their children's disability to researchers. Meanwhile, external stigma from researchers may lead them to exclude disabled respondents from their study or to not consider questions which may be relevant to the lives of disabled people. Due to discrimination, disabled people may also be underrepresented in the organisations conducting research which may contribute to low prioritisation of inclusive research design.

Machine learning trained on biased data

AI systems using machine learning algorithms trained on unrepresentative data can lead to poor quality outputs for disabled people. If disabled people are absent or underrepresented in the data used to train and develop AI applications for research or decision-making, the outputs are likely to also be unrepresentative and exacerbate further exclusion of disabled people in future research projects.

Low resources of disabled people

Disabled people are less likely to be part of the labour market than non-disabled people and when they are, they tend to earn less[105]. Overall, an estimated 80% of disabled people globally live in low-resource settings. Digital exclusion, where disabled people lack access to the internet or internet-connected devices, can make it challenging to develop sufficient image and language datasets for disability. It also presents difficulties for creating inclusive datasets based on wearable technologies. Data collection using wearable technologies or DigAT needs to account for differential access to technology and differential capacity to use it.

Trust and engagement

Without effective methods for community engagement, it can be difficult to identify, reach, or gain consent from disabled people for a research project or public sector data collection. In addition, historical experiences of discrimination from institutions or disillusionment based on participation in previous research activities can contribute to lower levels of trust and engagement from disabled people. For example, disabled people may be cautious about sharing information with public sector bodies or researchers due to concerns about how this data may be shared or used by other government bodies (such as for disability benefit assessments). Overcoming issues related to trust will require clear data governance and consent policies alongside contextual factors related to cultures, regions and nations.

104 Liddiard K, Runswick-Cole K, Goodley D, Whitney S, Vogelmann E, Watts MBE L. 2019 "I was Excited by the Idea of a Project that Focuses on those Unasked Questions" Co-Producing Disability Research with Disabled Young People. Children & Society 33, 154–167. (doi:10.1111/chso.12308)

105 International Labour Organization. 2024 A study on the employment and wage outcomes of people with disabilities. See https://www.ilo.org/publications/study-employment-and-wage-outcomes-people-disabilities (accessed 15 April 2025).

CASE STUDY 2

DigAT for gaming

Disabled people are a large but currently underserved part of the gaming community with nearly a third of gamers in the UK and US identifying as disabled, with mental health conditions the most reported disability[106]. Two thirds of disabled UK gamers report experiencing challenges related to gaming[107]. With the average age of gamers rising, a significant proportion of future gamers will need more inclusive gaming options. This case study draws on a roundtable jointly organised with PlayStation conducted for this report in July 2024.

Opportunities

Developers are increasingly using DigAT to create more accessible gaming hardware and software options for disabled people. At the Game Developer's Conference in 2024, in a significant increase from previous years, nearly half of surveyed attendees reported their current products including accessibility measures, such as closed captioning or colourblind modes[108]. More customisable features allow disabled players to adjust gameplay, visuals and controls. For example, Grounded includes an arachnophobia safe mode, designed to make gameplay safer for people with phobias and Sea of Thieves includes additional audio settings for Blind and partially sighted gamers[109].

Examples such as PlayStation's Access Controller, the Xbox Adaptive Controller and the Microsoft Proteus Controller allow players to tailor controllers to their needs. This can be particularly helpful for gamers with limited mobility who can use alternative controls, such as large buttons or foot pedals, to interact with games in more accessible ways. Community feedback, through Discord, is being used by developers to seek ideas for accessibility upgrades to continuously improve gaming products.

Disabled gamers often struggle to determine whether games are accessible and meet their needs. A 2021 survey suggests 40% of disabled gamers have purchased games they are not able to play due to poor pre-purchase accessibility information, with some gamers unable to return inaccessible games[110]. Improving the availability of accessibility information before purchase would allow disabled gamers to make informed decisions. Dedicated platforms, such as the Game Accessibility Nexus and 'Can I Play That?', enable disabled gamers to check accessibility data before purchasing and avoid them having to extensively research different sources. Accessibility Tags also allow game developers to provide detailed insight on their games' accessibility features with over 300 games in the PlayStation Store using accessibility tags to help users make decisions.

106 Newzoo. Diversity, Equity & Inclusion in Games: Gamers Want Less Toxicity in Games and Want Publishers to Take a Stance. See https://newzoo.com/resources/blog/newzoos-gamer-sentiment-diversity-inclusion-gender-ethnicity-sexual-identity-disability (accessed 15 April 2025).

107 Scope. 2021 Accessibility in gaming. See https://www.scope.org.uk/campaigns/research-policy/accessibility-in-gaming (accessed 15 April 2025).

108 Game Developers Conference. 2024 State of the Game Industry. See https://reg.gdconf.com/state-of-game-industry-2024 (accessed 15 April 2025).

109 Accessibility in Sea of Thieves. See https://www.seaofthieves.com/accessibility (accessed 15 April 2025).

110 Scope. 2021 Accessibility in gaming. See https://www.scope.org.uk/campaigns/research-policy/accessibility-in-gaming (accessed 15 April 2025).

Challenges

Although DigAT for gaming has seen significant advances in recent years, there remain challenges with regards to access to DigAT. According to a 2020 survey, the most significant challenge for disabled gamers is the affordability of assistive technology, with 30% reporting it as a barrier[111]. Companies, such as Ubisoft, Sony and Microsoft, often use inconsistent terminology for accessibility, which can lead to difficulty in making appropriate purchases. Organisations, such as Makers Making Change in Canada and the Controller Project, have initiatives to increase access to gaming assistive technologies such as the GAME Checkpoints program for disabled gamers to trial gaming devices with trained professionals before purchasing or using 3D printers to provide free assistive controller add-ons[112].

Since there is no legislation mandating minimum accessibility standards for games, disabled gamers are reliant on industry-led initiatives which can vary across companies and regions. Progress is often driven by internal accessibility advocates which can lead to burnout when companies are not welcoming to disabled designers.

Making internal business cases for DigAT for gaming can also be challenging, where companies often use data on disability prevalence. This can be misleading as it fails to acknowledge how assistive features are used more widely, such as subtitles often being used by non-disabled gamers. Retroactive accessibility updates are particularly challenging due to obsolescence where the original game developer is no longer in business and there is no ability to update the game.

Interoperability of DigAT is key to allowing users to switch to different platforms and devices without having to reconfigure their accessibility settings. However, interoperability of assistive controllers can enable them to be used in applications beyond gaming, such as e-sports, where there are risks of players cheating by adapting their controllers. Gaming developers can also be reluctant to use tools which may improve accessibility, such as generative AI, due to ethical concerns with how they're developed.

Example

Eye-tracking technologies for gaming

SpecialEffect, a gaming charity supporting physically disabled gamers, has created a suite of games called Eye Gaze Games, which uses eye-tracking software for gaming[113]. They also offer solutions that can be adapted to other games such as Minecraft by creating an overlay that sits on top of the game.

Conclusion

Gaming showcases the opportunities of an innovative industry recognising that games designed to be accessible are good for all gamers, expanding access to DigAT. However, there are challenges around industry incentives, inconsistent approaches to accessibility and affordability.

111 Scope. 2021 Accessibility in gaming. See https://www.scope.org.uk/campaigns/research-policy/accessibility-in-gaming (accessed 15 April 2025).

112 The Controller Project. See https://thecontrollerproject.com/about/ (accessed 15 April 2025). Makers Making Change. Adaptive Gaming. See https://www.makersmakingchange.com/s/adaptive-gaming (accessed 15 April 2025).

113 SpecialEffect. Eye Gaze Games. See https://www.specialeffect.org.uk/how-we-can-help/eye-gaze-games (accessed 15 April 2025).

Chapter three
Small data and few-shot machine learning

Left
Disabled people working together in an office. One is in a wheelchair and using a compact eye-tracking device to control their computer with their eyes.

Small data and few-shot machine learning

> "...people are individual people and not an 'average'[114]."
>
> Gary Marsden, Andrew Maunder and Munier Parker

Small data analysis is the use of tools and techniques for data analysis in settings where there is only limited amounts of data and information. While disabled people are a large group at 16% of the global population[115], the wide variety of disabilities and how they are experienced means in practice datasets for specific disabilities are typically small. This contrasts with dominant approaches in technology development which emphasise the importance and use of large datasets, typically referred to as 'big data'. Small data is an alternative to this paradigm, where advancements in small data methods and techniques could offer opportunities to create new DigAT and enable more inclusive analysis of data.

What is small data and its benefits?

Small data analysis refers to the ability to derive insights and analyse detailed context-specific information from smaller datasets. These approaches have always been important to scientific research with early scientific discoveries, such as early astronomical observations, relying on small numbers of observations. However, since the early 2000s, big data approaches, relying on the ability to search and analyse vast datasets, have become increasingly popular due to advancements in computing power and access to large quantities of data.

Small data techniques can be invaluable in situations where large datasets are simply not available, such as research on rare diseases or creating products for niche markets. Big data approaches often rely on the misleading assumption that bigger datasets lead to more reliable conclusions[116]. In practice, these techniques often fail when confronted with outliers or unique scenarios. For example, AI models used for self-driving cars have failed to recognise backward-propelled wheelchairs despite being trained on wheelchair-representative datasets[117]. Small data techniques can preserve more contextual information and improve reliability when datasets are smaller and contain large variations.

114 Marsden G, Maunder A, Parker M. (2008). People Are People, but Technology Is Not Technology. Philosophical Transactions: Mathematical, Physical and Engineering Sciences 366, 3795–3804.

115 The World Health Organization. 2023 Disability. See https://www.who.int/news-room/fact-sheets/detail/disability-and-health (accessed 14 April 2025).

116 Boyd d, Crawford K. 2012 Critical Questions for Big Data: Provocations for a cultural, technological, and scholarly phenomenon. Inf. Commun. Soc. 15, 662–679. (doi: 10.1080/1369118X.2012.678878)

117 Treviranus J. 2019 The value of being different. Proceedings of the 16th international web for all conference, 1-7.

Small data and more personalised approaches can better capture the unique and diverse experiences of individuals. Big data approaches can lead to an overemphasis on the average needs of a population, neglecting those who fall outside the 'norm'. This can be particularly concerning when big data and statistical averages are used for decision making and policy making. While averages can be useful summaries, they mask important variations and can lead to decisions that prioritise the needs of the majority without adequately addressing the needs of all individuals, particularly disabled people who may have less common needs[118].

What are the techniques for small data? [119]
Small data research is currently undertaken across many disciplines meaning there is a range of different methods used. In applying small data methods, three key concepts are used: similarity, transfer and uncertainty.

- **Similarity**
  Determining the similarity between different datasets is important when working with small data. Several quantitative methods[120] have been developed to assess similarity between different datasets, which can help with assessing whether datasets can be combined and whether insights from one group can apply to another. For example, in rare disease research, assessing similarity between different patient groups can help with leveraging evidence from similar cases to improve treatment prediction.
- **Transfer**
  Transfer of information is key for small data, when there is a transfer of information between similar datasets or when a small dataset can be enriched with information from other external sources, such as databases or other models. These methods can include techniques for few-shot learning, representation learning and neuro-symbolic AI.
- **Uncertainty**
  Uncertainty is particularly important in small data settings due to the limited information available for modelling. Several methods can be used to quantify and estimate uncertainty in model parameters though more work is needed to assess uncertainty from model selection. One important approach for reducing uncertainty is meta-learning, where a model learns across many datasets.

The following examples are some techniques and methods that are useful for small data:

Few-shot learning

Few-shot learning is a machine learning technique for learning a task or category given a small number of examples[121]. Humans are natural small data learners: given a few images of a car, children can generalise the concept and recognise similar objects and few-shot learning techniques aim to apply this idea to machine learning systems. Few-shot learning is an attractive tool for tackling small data challenges as it aims to optimise performance when data is scarce, as is often the case for disabled communities.

118 Hackenberg M *et al*. Small data explainer – The impact of small data methods in everyday life. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 15 April 2025).

119 This sections draws extensively on Hackenberg M *et al*. Small data explainer – The impact of small data methods in everyday life. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 15 April 2025).

120 *Ibid*.

121 Vinyals O, Blundell C, Lillicrap T, Wierstra D. 2016 Matching networks for one shot learning. Adv. Neural Inf. Process. Syst. 29.

Meta-learning

Meta-learning, or 'learning to learn', refers to a technique for training machine learning models using knowledge from several (potentially small) datasets. By training a model on several datasets, the aim is for the model to then be more readily adaptable to new tasks with few examples, which is especially useful for small data settings.

Neuro-symbolic AI

Neuro-symbolic AI combines two approaches to AI: neural networks based on data-driven modelling and symbolic AI which builds in explicit knowledge or rules into a system. This combines the strengths of neural networks, which can learn from large amounts of data but are difficult to interpret, with the strengths of symbolic AI techniques, which rely on knowledge and assumptions explicitly coded into a system, increasing explainability and efficiency. This approach can be useful for integrating small data with big data, where small data is explicit knowledge built into a larger neural network based on big data.

What is the potential of small data analytics for supporting disabled people?

Advancements in small data research and techniques could significantly improve analysis of disability data and create better DigAT.

Small data for research and policy

Small data approaches are a necessity when analysing small datasets, such as in rare disease research (diseases afflicting less than one in two thousand people). For example, a clinician may need to assess the right dose of a treatment for a new child patient with a rare genetic condition. Given the small number of previous patients with the condition, small data approaches could be used to match the new patient to the most similar subgroup of patients (eg patients under 10 years old) or draw on relevant information (eg age) to enable better predictions of the right dose[122]. Small data techniques could also be used to combine data from several different studies of individual patients to create a relatively larger dataset to be used for dose predictions[123].

122 Hackenberg M *et al*. Small data explainer – The impact of small data methods in everyday life. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 15 April 2025).

123 *Ibid*.

Analysis of small data can also be useful for evidence-informed policy-making. The use of big data analysis for policy-making prioritises the needs of the average individual, reinforcing the 'invisibility' of marginalised groups, such as disabled people, in decisions around spending priorities. Small data approaches could help ensure policy-making is more contextual and inclusive, leading to better outcomes for both individuals and society as a whole[124]. However, there are trade-offs involved since insights from small data will need to be balanced against other data to ensure small datasets are not skewed or biased.

Personalising DigAT

Small data approaches can also help personalise DigAT to better suit disabled peoples' unique needs. Few-shot learning, meta-learning and neuro-symbolic AI can enable systems to learn from smaller datasets creating opportunities for new adaptable DigATs.

Emerging research uses few-shot learning and meta-learning for automated sign language recognition systems[125, 126], personalisation of sound recognition systems used by D/deaf and hard-of-hearing users[127] and to design Augmentative and Alternative Communication (AAC) systems for people with complex speech and communication needs[128, 129].

For example, WESPER is a zero-shot AI tool converting whispers to normal speech, which can be useful for people with hearing loss[130]. FindMyThings, developed by Microsoft, is an AI object recognition tool designed to help people with vision loss find their personal items, which uses few-shot learning to reduce the number of examples required to complete the task with minimal effort from users[131]. Neuro-symbolic AI could be used to personalise devices, such as smartphones, by suggesting optimal accessibility settings on a phone based on data inputted by a disabled user[132].

124 Hackenberg M *et al*. Small data explainer – The impact of small data methods in everyday life. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 15 April 2025)..

125 Nihal R A, Broti N M. 2023 A Few-Shot Approach to Sign Language Recognition: Can Learning One Language Enable Understanding of All? In: Lu H, Blumenstein M, Cho S-B, Liu C-L, Yagi Y, Kamiya T (eds) Pattern Recognition, Springer Nature Switzerland. (doi:10.1007/978-3-031-47637-2_11)

126 Zhou H, Lu T, DeHaan K, Gowda M. 2024 ASLRing: American Sign Language Recognition with Meta-Learning on Wearables. 2024 IEEE/ACM Ninth International Conference on Internet-of-Things Design and Implementation (IoTDI), 203–214. (doi:10.1109/IoTDI61053.2024.00022)

127 Jain D *et al*. 2022 ProtoSound: A Personalized and Scalable Sound Recognition System for Deaf and Hard-of-Hearing Users. CHI Conference on Human Factors in Computing Systems, 1–16. (doi:10.1145/3491102.3502020)

128 Paola A D, Muraro S, Marinelli R, Pilato C. 2024 Foundation Models in Augmentative and Alternative Communication: Opportunities and Challenges. arXiv:2401.08866. (doi:10.48550/arXiv.2401.08866)

129 Pereira J A, Pereira J A, Zanchettin C, do Nascimento Fidalgo R. 2024 PrAACT: Predictive Augmentative and Alternative Communication with Transformers. Expert Systems with Applications 240. (doi:10.1016/j.eswa.2023.122417)

130 Rekimoto J. 2023 WESPER: Zero-shot and Realtime Whisper to Normal Voice Conversion for Whisper-based Speech Interactions. Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems, 1–12. (doi:10.1145/3544548.3580706)

131 Wen L Y, Morrison C, Grayson M, Marques R F, Massiceti D, Longden C, Cutrell E. 2024 Find My Things: Personalized Accessibility through Teachable AI for People who are Blind or Low Vision. Extended Abstracts of the CHI Conference on Human Factors in Computing Systems, 1–6. (doi:10.1145/3613905.3648641)

132 Wald, M. (2021). AI Data-Driven Personalisation and Disability Inclusion. Frontiers in Artificial Intelligence 3. (doi:10.3389/frai.2020.571955)

Analysing small data is also key to advancements in wearables and remote monitoring devices, such as those used in social care settings to detect falls. Fall detection is challenging due to significant variations in human bodies and how movement is recorded[133]. Small data approaches comparing small and large datasets can be used to personalise these devices by using an individual's collected data to understand how they normally move and improve accuracy[134].

What are the limitations of small data approaches?

Small data problems occur in a range of fields and hence, small data methodologies have been developed across many research areas. While this shows the relevance of small data research in many domains, it also means that research may be impeded due to a lack of interdisciplinary communication. This includes a lack of shared language for small data approaches.

One key limitation of small data approaches is the risk of overfitting, where the model learns patterns that are too closely aligned to the training data and fails to generalise to other datasets. While this is also a risk in big data approaches, the limited information available in small datasets means the data may not be diverse enough to cover a wide range of situations making it more likely a model will learn specific patterns that do not generalise[135]. This risk is heightened in cases where certain categories are overrepresented in a dataset leading to biased predictions or when a model relies on historical data, where the underlying pattern could change in the future[136].

Another limitation to small data approaches is the challenge of validating models trained on small data. To validate a model, there should be no overlap between the dataset used to train the model and the dataset used to test the model. When there is an overlap, a phenomenon known as data leakage, it leads to an overestimation of the model's accuracy and decreases the ability of a model to generalise to new data – an effect which is amplified for small datasets. External validation, where a model is tested on new similar datasets, is challenging in small data settings where there may be a scarcity of data available for training, let alone validation.

133 Igual R, Medrano C, Plaza I. 2013 Challenges, issues and trends in fall detection systems. Biomed. Eng. OnLine 12, 66. (doi: 10.1186/1475-925X-12-66)

134 Hackenberg M *et al*. Small data explainer – The impact of small data methods in everyday life. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 15 April 2025).

135 Pothuganti S. 2018 Review on over-fitting and under-fitting problems in Machine Learning and solutions. Int J Adv Res Electr Electron Instrum Eng 7, 3692–3695.

136 Vollmer S *et al*. 2020 Machine learning and artificial intelligence research for patient benefit: 20 critical questions on transparency, replicability, ethics, and effectiveness. bmj 368.

To address these challenges, assessment of similarity between datasets is crucial. Policies facilitating data exchange such as encouraging collaboration and providing data sharing infrastructure for researchers can help with addressing data scarcity[137]. The creation of datasets in accordance with the FAIR (Findable, Accessible, Interoperable, Reusable) principles enables easier comparisons for similarity assessments[138].

137 Champieux R *et al*. 2023 Ten simple rules for organizations to support research data sharing. PLOS Computational Biology 19, e1011136. (doi:10.1371/journal.pcbi.1011136)

138 Wilkinson M D *et al*. 2016 The FAIR guiding principles for scientific data management and stewardship. Sci. Data 3, 1–9.

CASE STUDY 3

DigAT for travel and tourism

For travel and tourism, DigAT can be used by disabled people to address challenges related to navigation, anxiety and communication. DigAT can improve how disabled travellers locate and interact with relevant information and create more opportunities for accessible experiences while travelling.

Opportunities

One key challenge disabled travellers face is navigation as it can be difficult to know in advance whether a route or location meets their accessibility needs. While mainstream travel search sites allow for filtering of search results for ‘accessibility’, these results are often unreliable due to lack of standardisation[139] and navigation apps often don’t include accessibility features[140]. Online platforms, such as accessibleGO[141] and wheelmap[142], include more specific information about facilities so travellers with mobility issues can accurately check whether a location meets their needs, for example, accessible bathrooms and showers. Companies, such as Ocean 3D, create virtual tours of airports, hotels and bars, which anxious people are able to view on their computer or on virtual reality headsets to explore a route and practice ahead of a trip[143].

While travelling or staying in novel environments, disabled travellers can face communication issues or barriers to essential information, which may only be communicated in one format such as audio announcements in a noisy environment. Audio-to-text systems can be useful, such as Spoke, a mobile app that integrates with public address systems to convert live announcements and sounds into written text for d/Deaf and hard of hearing people while travelling[144]. Navigation apps can increase the confidence of Blind and partially sighted people when travelling[145]. For example, WayMap uses location technologies that don’t require wi-fi or mobile signal to help users navigate locations such as train stations with audio instructions[146].

On reaching a destination, DigAT can be used to create more customised accessible experiences for disabled people. Through 3D printing and digital near field communication (NFC) technologies, PictureLive creates audio-tactile interactive experiences of visual information and artefacts for blind and partially sighted people who are often excluded from traditional “sight-seeing” when travelling[147]. Virtual reality headsets can also be used to provide tours of archaeological sites which are often inaccessible for wheelchair users[148].

139 Accessable. New AccessAble Survey highlights crucial insights on accessibility challenges and the need for action. See https://www.accessable.co.uk/articles/accessibility-and-you-survey-results-2023-2024 (accessed 15 April).

140 Warbox Creative. Leading the way in digital inclusion: Top apps for accessibility in 2024. See https://warboxcreative.co.uk/app-accessibility-2024/ (accessed 15 April 2025).

141 AccessibleGO. See https://accessiblego.com/ (accessed 15 April 2025).

142 Wheelmap. See https://wheelmap.org/ (accessed 15 April 2025).

143 Berti A. 2019 The digital twin: Creating virtual airport tours with Ocean3D. Airport Technology. 15 August 2019. See https://www.airport-technology.com/features/virtual-reality-at-airports/ (accessed 15 April 2025).

144 Spoke. See https://www.thespokeapp.com/ (accessed 15 April 2025).

145 Royal National Institute of Blind People (RNIB). 2023 Inclusive Journeys: Improving the accessibility of public transport for people with sight loss. See https://www.rnib.org.uk/professionals/health-social-care-education-professionals/knowledge-and-research-hub/reports-and-insight/inclusive-journeys-improving-the-accessibility-of-public-transport-for-people-with-sight-loss/ (accessed 15 April 2025).

146 Waymap. See https://www.waymapnav.com/ (accessed 15 April 2025).

147 PictureLive. See https://www.picturelive.org/ (accessed 15 April 2025).

148 Kyrlitsias C, Christofi M, Michael-Grigoriou D, Banakou D, Ioannou A. 2020 A Virtual Tour of a Hardly Accessible Archaeological Site: The Effect of Immersive Virtual Reality on User Experience, Learning and Attitude Change. Frontiers in Computer Science 2. (doi:10.3389/fcomp.2020.00023)

Challenges

One challenge for using DigAT for travel is a lack of consistent high-quality data across countries for navigation and about accessibility requirements. Data on specific accessibility requirements, such as sensory accommodations, are often not included in general datasets and there is a lack of standardisation of existing data meaning, for example, 'wheelchair accessible' doesn't guarantee standard measurements. Additionally, it is important that accessibility information is kept up-to-date to not foster a false sense of accessibility. International differences in how disability is defined and measured can also limit disabled travellers' ability to make well-informed decisions on whether their accessibility needs are met in different locations.

Developing robust DigAT that can be used in a wide range of contexts and locations is hindered by a lack of globally comprehensive datasets. For example, audio-to-text AI systems used to transcribe real-time information when travelling require datasets including audio and text data from multiple languages, which can be expensive to create or access. Inaccuracies can mislead disabled travellers causing frustrating or dangerous situations when a system is unable to recognise announcements or information in different languages. Using DigAT also requires reliable access to electricity and the internet, which often cannot be guaranteed while travelling, particularly in low-resource settings, reinforcing digital exclusion.

Example

Transport for London

Local public transportation authorities, such as Transport for London (TfL), can use and support DigAT to address navigation challenges when travelling. One recent TfL initiative has used Google Street View to visually map London's busiest stations so wheelchair users can virtually navigate and plan their travel routes[149]. In 2023, TfL also trialled NaviLens, an app that detects special QR codes while travelling to provide voice guidance for Blind and partially sighted people[150]. This is already used in several cities such as Barcelona and New York to provide access to real-time travel information in underground stations and bus stops[151].

Conclusion

There are significant opportunities to use DigAT for addressing challenges currently encountered by disabled travellers and tourists, such as for navigation and lack of accessible experiences. However, using DigAT in this context requires better collection and standardisation of accessibility data, access to relevant datasets for the creation of globally comprehensive DigAT and support for infrastructure so disabled travellers can reliably use DigAT.

149 Edwards T. 2024 Busiest London stations visually mapped by Google. BBC News. 5 December 2024. See https://www.bbc.co.uk/news/articles/c4g2d0x1098o (accessed 15 April 2025).

150 Transport for London. Transport for London and KeolisAmey Docklands trial new NaviLens technology at DLR stations. See https://tfl.gov.uk/info-for/media/press-releases/2023/july/transport-for-london-and-keolisamey-docklands-trial-new-navilens-technology-at-dlr-stations (accessed 15 April 2025).

151 Royal National Institute of Blind People (RNIB). NaviLens. See https://www.rnib.org.uk/living-with-sight-loss/assistive-aids-and-technology/navigation-and-communication/navilens/ (accessed 15 April 2025).

Chapter four
Inclusive design, sustainability and ethical concerns

Left
Recycling mobile phones.
© iStock / baranozdemir.

Inclusive design, sustainability and ethical concerns

> "[Often] people who make software don't have intuition about how to make it accessible. Putting a blindfold on does not give you intuition about what works for someone who is blind. [...] You really need to understand what does and doesn't work."
>
> Dr Vint Cerf ForMemRS speaking at the Royal Society's event marking the 50th anniversary of the Internet in 2024.

Developing DigAT which serves the needs of disabled people to a high standard will require the engagement of disabled people throughout the design process. This applies to both DigAT designed specifically for disability access as well as 'mainstream' technologies (eg smartphones, laptops, game consoles). These stages include the initial consideration of the minimum viable product, the development and testing stage, the business model and post-release. This need for meaningful engagement of disabled people was a theme which arose in many of the research activities conducted for this report.

Beyond engagement on the technical features of new digital technologies, there is a need to address challenges associated with the affordability and environmental sustainability of these products. A key challenge is the nature of digital technologies to quickly become obsolete as new innovations arise or as providers cease to exist. Another is the relationship between disability and income, with many disabled people experiencing lower levels of income compared with non-disabled people. According to an estimate by the World Health Organization, nearly 80% of disabled people live in low- and middle-income countries[152]. In the UK, it is estimated that disabled households make up 48% of all people living in relative poverty and that they are three times more likely than non-disabled households to use a foodbank[153].

The challenge on environmental sustainability is to address technology abandonment and ensure that the proliferation of DigAT products minimises the impact on electronic waste (e-waste). From 2010 to 2022, it is estimated that the amount of e-waste generated globally has increased from 34 billion kilograms to 62 billion kilograms, with the e-waste generation outpacing recycling by a factor of five[154]. E-waste can have health, as well as environmental, consequences and is defined as electrical and electronic devices which are discarded as products break or become obsolete[155].

Drawing on insights from workshops, roundtables and focus groups conducted for the report, this chapter outlines barriers to inclusive design, challenges related to technology transience and the potential of circular economy schemes for DigAT. Finally, it covers broad ethical concerns which cut across various aspects related to development of DigAT, including privacy concerns and informed consent.

152 World Health Organization. 2022 Global report on health equity for persons with disabilities. 2 December 2022. See https://www.who.int/publications/i/item/9789240063600 (accessed 20 January 2025).

153 House of Commons Library. 2024 UK disability statistics: Prevalence and life experiences. 2 October 2024. See https://researchbriefings.files.parliament.uk/documents/CBP-9602/CBP-9602.pdf (accessed 20 January 2025).

154 International Telecommunications Union. The Global E-waste Monitor 2024. See https://www.itu.int/en/ITU-D/Environment/Pages/Publications/The-Global-E-waste-Monitor-2024.aspx (accessed 20 January 2025).

155 World Health Organization. Electronic waste (e-waste). 1 October 2024. See https://www.who.int/news-room/fact-sheets/detail/electronic-waste-(e-waste) (accessed 20 January 2025).

Barriers to inclusive design and deployment of DigAT

The following ten key barriers to the effective and inclusive roll-out of DigAT have been identified:

1. **Data scarcity**
   The effective development of DigAT applications requires high quality data on the prevalence of different types of disability and the nature of people's functional challenges[156]. This is useful for both considering the products or applications which need to exist, as well as the potential business case for investment in their development. However, there are mixed views on whether data on the number of potential disabled customers should form part of a business case for a DigAT product, as an application developed for disabled people can be adopted by all users or customers (eg subtitling on television programmes)[157].

2. **Lack of standardisation**
   Standardisation of definitions, products and protocols is a challenge across digital technologies in general and applies for DigAT. There are different definitions and measurements of disability globally and the quality of data on disability varies greatly. This lack of consistent data on disability globally can impact investment decisions by companies and developers[158].

   Some products are not interoperable (eg accessible controllers for gaming do not work across all consoles) and are not labelled as accessible in a consistent way for users to be able to compare and contrast. A lack of open protocols means that existing DigAT products disabled people have may not be able to communicate with each other effectively or transfer a user's experiential data.

3. **Inclusivity as an afterthought**
   The development of DigAT applications which have high utility and do not reinforce existing challenges is hindered by a failure to meaningfully engage disabled people in the design of these applications at the outset[159]. A typical minimum viable product for a new technology application does not include requirements related to accessibility for disabled people. For example, digital interfaces in electric vehicles do not sufficiently consider the needs of disabled users[160]. It is often the case that design input from disabled people happens retrospectively leading to products not being fully optimised for their needs[161]. For example, research has argued for active involvement of physically disabled people in the development of immersive platforms to ensure inclusivity[162].

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156 Danemayer J, Holloway C. 2024 Disability and Assistive Technology in Population-Based Data. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

157 Royal Society and Sony PlayStation roundtable on DigAT for gaming, July 2024.

158 *Ibid*.

159 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

160 Mobability Foundation. 2023 EV design & disability inclusion. See https://www.motabilityfoundation.org.uk/media/dg0bgzyd/est0062-motability-report-v15.pdf (accessed 20 January 2025)

161 Royal Society and Policy Connect workshop on inclusive design and deployment of smart home devices for social care and independent living, April 2024.

162 Radanliev P, De Roure D, Novitsky P, Sluganovic I. 2023 Accessibility and inclusiveness of new information and communication technologies for disabled users and content creators in the Metaverse. Disability and Rehabilititation: Assistive Technology, 19(5), 1849-1863. (https://doi.org/10.1080/17483107.2023.2241882)

4. **Weak understanding of the economic value of accessible products**
The economic case for investing in accessible products can be challenging to make within technology companies[163]. Investing in accessible features can be seen to be appealing to a niche segment of a market rather than something which benefits the broad customer base. Where investment is made in accessibility, it can often be driven by disabled people themselves, working within the company rather than a decision led by those without lived experience of disability[164]. As such, many developers may fail to see an economic driver for investing in DigAT products.

5. **Disconnect between primary technology developers and assistive counterparts**
Where a failure on accessibility exists, some developers may create DigAT applications or products to work with another, potentially mainstream, product. An example is a third-party speech recognition app for a smartphone. The usability of these applications depends on the economic sustainability of the developer, which may be a small or medium sized enterprise, as well as continued synergy with the main product[165]. Poor synergy between third-party app developers and smartphone providers may mean applications lose utility or become unusable over time (eg after a software update)[166].

6. **Awareness and training**
Many DigAT tools are underutilised, in part, due to a lack of awareness amongst disabled people and carers about their existence or an understanding of how they work[167]. DigAT featured on mainstream devices may require set-up by someone else before they can be used by a disabled person. Furthermore, technology developers do not necessarily provide instructions in accessible formats, making their use cumbersome to achieve. There may also be a lack of awareness and training amongst organisations who provide services for disabled people such as libraries or care homes[168].

7. **Feature integration**
As disabled people are more likely to be in lower income households, integrating DigAT features into mainstream devices (eg smartphones, televisions) is likely to be the most cost-efficient method for DigAT adoption. The lack of integration means disabled people may rely on paying for expensive, standalone, DigAT devices or be unable to afford them altogether and be excluded from a service or activity[169, 170].

163 Royal Society and Sony PlayStation roundtable on DigAT for gaming, July 2024.

164 *Ibid*.

165 Royal Society and Policy Connect workshop on inclusive design and deployment of smart home devices for social care and independent living, April 2024.

166 Royal Society roundtable on technology transience and future-proofing assistive technologies against obsolescence and user abandonment, July 2024.

167 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

168 Royal Society and Policy Connect workshop on inclusive design and deployment of smart home devices for social care and independent living, April 2024.

169 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

170 Royal Society and YouGov survey, 2024.

8. **Cost**
   Beyond the cost of purchasing a DigAT device or application itself, disabled users face challenges related to the cost of broadband, mobile data, device repair and upgrades. If the costs are covered by a carer, it may lead to reduced expenditure on other important business or personal expenses[171]. Due to disabled people being more likely to fall in low-income brackets with little disposable income, this may further reinforce views among developers that catering for disabled people does not provide sufficient return on investment.

9. **Obsolescence and technology transience**
   Technology transience refers to the temporary nature of digital technologies due to products quickly becoming outdated or altogether obsolete. In the context of DigAT, obsolescence can cause disruption for disabled people as well as financial uncertainty for DigAT developers[172]. Disabled people may therefore be required to purchase different versions of the same product multiple times over the course of their life. The degrading utility, or total discontinuation, of products can act as a disincentive to adopting DigAT tools and foster ill feeling towards their use. Mechanisms for repairing DigAT applications need to be feasible, affordable, and come with accessible customer support in both digital and analogue formats[173].

10. **Breadth of data formats required**
    The design of some DigAT applications requires a breadth of multi-modal datasets (ie images, video, audio, location) which can be both expensive to collect, maintain and apply. An application which notifies a deaf person when a baby is crying, for example, would require audio datasets of babies crying in different settings, to be accurate and effective. If these types of training datasets do not already exist, they will need to be created, rendering potentially life-changing DigAT applications too expensive to develop or sustain. In recent years, this has become an area of active research for the development of immersive, metaverse platforms[174].

171 Royal Society and Policy Connect workshop on inclusive design and deployment of smart home devices for social care and independent living, April 2024.

172 Royal Society roundtable on technology transience and future-proofing assistive technologies against obsolescence and user abandonment, July 2024.

173 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

174 Radanliev P, De Roure D, Novitsky P, Sluganovic I. 2023 Accessibility and inclusiveness of new information and communication technologies for disabled users and content creators in the Metaverse. Disability and Rehabilititation: Assistive Technology, 19, 1849-1863. (https://doi.org/10.1080/17483107.2023.2241882)

Circular economy principles for DigAT

To ensure the longevity and affordability of DigAT, these products will need to be sustainable and easy to repair. In the context of a global rise in demand for digital technologies which is drawing on finite resources (eg rare earth metals), this may require consideration of circular economy principles in the production of new DigAT. The circular economy is a model which aims to extend the lifecycle of products through sharing; leasing; reusing; repairing; refurbishing; and recycling existing products as long as possible[175].

As these principles can extend to the entire supply chain of a product[176] (as demonstrated in figure 3), circular economy principles can be difficult to execute at scale. However, in the narrow context of DigAT, potential circular economy initiatives include universal accessibility standards; interoperability between DigAT and other digital technologies; lending libraries; digital technology repair schemes; and the integration of DigAT features into mainstream devices (eg smartphones).

Campaigns advocating for the 'right to repair' have led to some jurisdictions introducing or exploring specific right to repair legislation. These include the UK[177], the European Union[178] and the United States[179]. Critics argue, however, that independent repairs may introduce safety and security risks in devices[180]. Independent repairs can include individual or informal repair (via informal tradespeople), local initiatives (semi-formal services) and specialist workshops (eg by the technology provider)[181].

175 European Parliament. 2023 Circular economy: definition, importance, and benefits. 24 May 2023. See https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefits (accessed 20 January 2025).

176 Ellen MacArthur Foundation. 2023 Building a circular supply chain: Achieving resilient operations with the circular economy. 15 November 2023. See https://www.ellenmacarthurfoundation.org/circular-supply-chains (accessed 20 January 2025).

177 House of Commons Library. 2021 Right to Repair Regulations. 24 September 2021. See https://commonslibrary.parliament.uk/research-briefings/cbp-9302/ (accessed 20 January 2025).

178 European Commission. Directive on repair of goods. See https://commission.europa.eu/law/law-topic/consumer-protection-law/directive-repair-goods_en (accessed 20 January 2025).

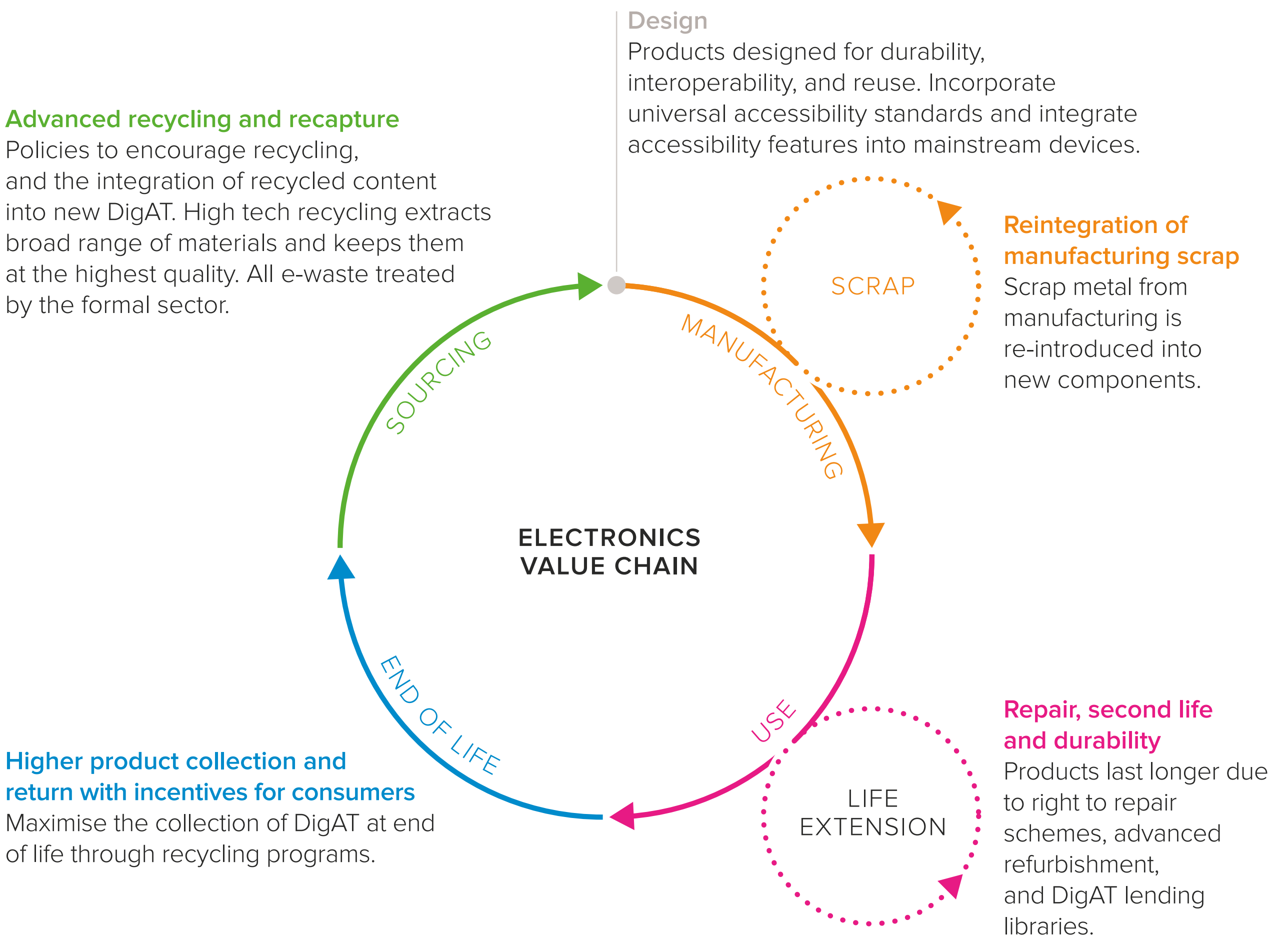
179 Godwin C. 2021 Right to repair movement gains power in US and Europe. BBC News. 7 July 2021. See https://www.bbc.co.uk/news/technology-57744091 (accessed 20 January 2025).

180 *Ibid*.

181 Oldfrey B *et al*. 2023 Repair strategies for assistive technology in low resource settings. Disability and Rehabilitation: Assistive Technology, 19, 1945–1955 (https://doi.org/10.1080/17483107.2023.2236142)

FIGURE 3

Circular economy model for DigAT[182]



182 Adapted from source: World Economic Forum. 2019. A New Circular Vision for Electronics, Time for a Global Reboot. 24 January 2019. See https://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf (accessed 4 June 2025).

Cross-cutting ethical considerations

The design and deployment of DigAT present various ethical considerations. The following challenges were identified throughout the activities undertaken for this report and cut across diverse applications of DigAT. In particular, this section draws on insights developed from a PESTEL (political; economic; social; technological; environmental; and legal) analysis of DigAT[183]. Some of these challenges may require new policies or legislation, while others may require trade-offs to be made by DigAT consumers.

Privacy and surveillance

Applications of DigAT which collect personal data on individuals present privacy risks. Examples include applications or devices which track health statistics or smart home devices which monitor home environments. The collection of this data could lead to personally identifiable information or personal health information being used to identify an individual. Beyond potential security breaches, there is also the risk that companies collecting the data may claim the right to freely use or sell such data without users' consent. These risks exist across a wide range of digital applications beyond DigAT and require considerations on data protection legislation and enforcement, especially when applications or devices may be developed or storing data in other jurisdictions.

Data bias

DigAT which rely on machine learning techniques risk reproducing biases within the training data. The reproduction of these could lead to the misrepresentation of disabled people's experiences and inaccurate or, even, harmful solutions being proposed. The nature of this challenge will depend on the application and the data used to train models. In this context, the challenge is likely to be greater than normal due to existing limitations of disability data. Examples of risks may include emotion recognition technology which operates on ableist assumptions about emotional expressions[184] or weak translations of text into accessible languages.

Digital exclusion

DigAT will not be a solution for all people and many will prefer to retain more analogue and interpersonal methods of accessing essential services. Furthermore, levels of digital literacy are likely to vary significantly across demographics and regions which could lead to some disabled people being unable to use applications being developed on their behalf. For example, on age, a survey of the British public conducted for this report found that 76% of 18- to 24-year-olds feel confident in their ability to adapt to future technological changes as they age compared with 56% of those aged 55 and over. Exclusion is likely to also be a risk across income levels with disabled people often being disproportionately represented in lower income households.

183 Baskerville J, Pan Y, Pham T, Sutton D. 2024 Towards the adoption of digital assistive technologies in the UK: An international comparison of policy factors. See https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

184 Ryan-Mosley T. 2023 AI isn't great at decoding human emotions. So why are regulators targeting the tech? MIT Technology Review. 14 August 2023. See https://www.technologyreview.com/2023/08/14/1077788/ai-decoding-human-emotions-target-for-regulators/ (accessed 15 April 2025).

Access-washing

The concept of access-washing refers to organisations adopting assistive technologies without addressing deeper ethical or infrastructural issues. For example, technologies such as automated captioning might provide greater accessibility for some hearing-impaired users but risk excluding others who prefer or require human captioners. Furthermore, in a social care setting, DigAT may have negative implications for care workers as well as affecting the quality of care provided to individuals. DigAT could also have negative consequences for disabled people if their needs (including needs related to complex or intellectual disabilities) are not sufficiently accounted for in the design of these products. In addition, the environments or contexts in which DigAT products may be deployed is not always fully considered. For example, in Pittsburgh, the roll-out of food delivery robots was paused after wheelchair users complained that the robots were blocking ramps and narrow roads[185].

Informed consent

For the execution of inclusive design practices, it is necessary to integrate the perspectives of potential end-users for a product. However, to collect this information while abiding by ethical research norms will require gaining informed consent. This challenge particularly applies to people with intellectual disabilities who may be perceived as being unable to provide informed consent. Due to this perception, they may be excluded entirely from research. Considering how to include people with intellectual disabilities will be essential to ensuring DigAT can serve people across a range of disabilities. As this challenge applies to research generally, there will be lessons to be learned from experiences in fields beyond DigAT development (eg educational and clinical psychology).

Copyright

The use of generative AI in DigAT (eg to lower barriers to accessibility in game design) poses ethical challenges associated with the use of platforms which may have been built upon copyrighted material without permission[186]. This can often be the case with applications which have been trained on data scraped from the internet. This data can include original artwork, film and written materials, amongst others. The risk of plagiarism may lead to disabled content creators not wanting to use DigAT built upon opaque generative AI platforms which lack clarity about the training data used.

Ecosystem misalignment

Differences in the worldviews held by the developers of digital technologies and disabled communities can pose challenges for those who align more closely with the social, rather than medical, model of disability. This difference is particularly challenging when the views of developers may be considered eugenicist, viewing DigAT as optimising humans or ‘fixing’ disability instead of aiding disabled people to live more independently in their social environments. Ensuring DigAT exist to serve the needs of disabled people instead of a notion of how humans should be will require meaningful engagement and discussion with disabled people in the development of new DigAT.

185 Ackerman E. 2019 My fight with a sidewalk robot. Bloomberg. 19 November 2019. See https://www.bloomberg.com/news/articles/2019-11-19/why-tech-needs-more-designers-with-disabilities (accessed 20 January 2025).

186 Royal Society and Sony PlayStation roundtable on DigAT for gaming, July 2024

CASE STUDY 4

DigAT for playing and composing music

Music is a fundamental part of human expression, offering social benefits, such as promoting cohesion and individual benefits, such as improving wellbeing. While the capacity to create and enjoy music is not limited to non-disabled people, barriers due to inaccessible instruments and music venues limit disabled people's access to music.

Opportunities

Advancements in DigAT, such as wearable technologies, software and mobile apps, offer opportunities to increase music inclusion for disabled individuals, from beginner to professional levels. Specialised tools created for gaming, such as eye-trackers and joysticks, can be adopted for musical creation and enjoyment. EyeHarp is a digital instrument using eye-tracking systems to allow people with severe mobility issues, such as locked-in syndrome, to learn and play music with several instrument sounds through eye movements[187]. The CMPSR music controller, built with gaming hardware, can be connected to any Musical Instrument Digital Interface (MIDI)-enabled software or hardware to play musical notes and chords using the joystick and buttons[188]. The free music notation app MuseScore supports screen readers and live Braille translation of music scores supporting Blind and low vision musicians to create and explore music scores[189].

DigAT can also help create more inclusive and accessible environments for enjoying music. SightPlus, an augmented reality headset which provides real-time magnification, has been piloted at a music festival to provide a better experience for people with low vision[190]. Haptic suits, which are wearable technologies providing tactile feedback in response to music, can be used by D/deaf and hard of hearing people to feel live music vibrations at concerts and clubs[191]. Lack of accessibility information for venues and difficulty booking access online leads to disabled people having to share personal health information multiple times to confirm whether a venue meets their needs. The use of online booking systems which integrate with disability and access requirements data, such as through the Access Card, could provide a simple way for disabled customers to only share this information once[192].

Challenges

While DigAT in music show great promise, significant barriers hinder their widespread adoption, particularly for disabled artists. Many technologies, including advanced wearables, remain expensive to develop, costly for individual users and similar to traditional instruments, often require extensive training. Sustainable financial support is essential for developing new DigAT and preventing technology abandonment.

187 EyeHarp – Playing music with eyes. See https://eyeharp.org/ (accessed 13 January 2025).

188 Digit Music. CMPSR MIDI Instrument. See https://www.digitmusic.co.uk/cmpsr/ (accessed 15 April 2025).

189 Muse Group. Compose in Braille with MuseScore 4: An Accessibility Breakthrough. See https://www.mu.se/post/704tef5v71-accessibility-breakthrough-compose-in-br (accessed 13 January 2025).

190 Bullock C, Howard A. 2023 Forward Festival trails headset to aid visually impaired. BBC News. 3 September 2023. See https://www.bbc.co.uk/news/uk-england-bristol-66700805 (accessed 13 January 2025).

191 Vanasco J. 2023 Vibrating haptic suits give deaf people a new way to feel live music. NPR. 17 July 2023. See https://www.nprillinois.org/2023-07-17/vibrating-haptic-suits-give-deaf-people-a-new-way-to-feel-live-music (accessed 13 January 2025).

192 Attitude is everything. 2018 State of Access Report 2018: Ticketing Without Barriers. April 2018. See https://attitudeiseverything.org.uk/wp-content/uploads/2022/08/State-of-Access-Report-2018.pdf (accessed 13 January 2025).

Initiatives like Drake Music's DMLab[193] and Abbey Road's REDD incubator[194] can drive innovation in accessible music technologies. However, scaling these efforts requires ongoing investment, skills development, infrastructure and community-building. Collaboration between developers and disabled artists through co-design processes is also essential for ensuring technologies are effective and meet users' needs.

Affordability is a major obstacle, especially for artists in low-resource settings. In a recent survey, 67% of disabled music makers considered financial barriers to be a significant obstacle to creating music[195]. Overcoming financial barriers is key to making these innovations accessible. Programs like the UK's Music Opportunities Pilot for disadvantaged and Special Educational Needs and Disabilities (SEND) students could help ensure equitable access to music education, fostering future generations of skilled disabled musicians by connecting SEND programs with assistive music technologies[196].

Lack of awareness of accessible music instruments amongst disabled people, music retailers and educators also contributes to lack of adoption[197]. Promoting education and options to try accessible music instruments can help raise awareness about digital instruments.

Example

Soundbeam 6

Soundbeam 6 is a gesture-controlled music tool designed to allow disabled individuals with physical, sensory or intellectual disabilities to express themselves musically[198]. The device uses sensors to translate movements into sounds with a library of sounds that can be programmed for personalisation. In England, Soundbeam 6 is a government-approved assistive music technology made available to young disabled people under the UK government's 2022 National Plan for Music Education[199].

Conclusion

Several examples of innovative DigAT are already used by disabled artists creating music and by disabled people enjoying music at home or at music venues. More widespread DigAT adoption requires addressing barriers related to affordability, lack of awareness and creating a scalable and sustainable ecosystem to develop DigAT that works for all disabled users.

193 Drake Music. DM Lab Community. See https://www.drakemusic.org/technology/dmlab-community/ (accessed 13 March 2025).

194 Abbey Road. Abbey Road REDD. See https://www.abbeyroad.com/redd?ref=heysummit (accessed 13 March 2025).

195 Youth Music. 2020 Reshape Music: A report exploring the lived experience of Disabled musicians in education and beyond. October 2020. See https://www.youthmusic.org.uk/resources/reshape-music (accessed 20 January 2025).

196 GOV.UK. 2024 Music pilot launched to help break down barriers to opportunity. 13 September 2024. See https://www.gov.uk/government/news/music-pilot-launched-to-help-break-down-barriers-to-opportunity (accessed 13 January 2025).

197 Youth Music. 2020 Reshape Music: A report exploring the lived experience of Disabled musicians in education and beyond. October 2020. See https://www.youthmusic.org.uk/resources/reshape-music (accessed 20 January 2025).

198 Soundbeam. See https://www.soundbeam.co.uk/ (accessed 13 January 2025).

199 GOV.UK. 2022 The power of music to change lives: a national plan for music education. 25 June 2022. See https://www.gov.uk/government/publications/the-power-of-music-to-change-lives-a-national-plan-for-music-education (accessed 20 January 2025)

Chapter five
Imagined futures for DigAT

Left
Using sign language on a video call.

Imagined futures for DigAT

As part of focus groups with UK-based disabled people conducted for this report, participants were asked to come up with new ideas for transformative DigAT and inspire innovative thinking in this space[199]. These ideas were focused on applications which have the capacity to interpret their experience of the world or to complete tasks that would otherwise be difficult or impossible for them to complete independently. A selection of these ideas is presented below.

Body language interpretation glasses

"Body language is such an important part of language and quite often I don't understand from looking at someone if they are angry or joking and some kind of body translator for people with autism would be incredibly helpful… some kind of smart glasses."

Participant with a cognitive impairment.

British Sign Language (BSL) and closed-captions hologram

"My dream would be to have a sort of hologram both in BSL interpreters and captions that was 100% accurate and it would just be available everywhere at any time of day. It would change my life."

Participant with a sensory impairment.

Robot assistant

"For me it would have to be a robot that could do all of my personal care. I just wish there was a robot I could say help me go to the loo or help me to get in the shower – that's all I'd like to see."

Participant with a mobility and cognitive impairment.

Texting support tool

"If you're sending a text to someone, it can be so easily misconstrued. It's so easy to want to put something into writing and the other person at the other end takes it the wrong way. If there was something to interfere and say you put so and so which could be misconstrued – that would be a very good help."

Participant with a cognitive, mobility and dexterity impairment.

Incorporating information about accessibility into wayfinding apps

"For the Google Street view to expand… if there was a little robot that would go into the entrance of every single business you go to on the high street that would take 360 degree images of the ramps, access, what it's like inside…you can view the accessibility whenever you are planning a trip."

Participant with a cognitive, hearing, visual and mobility impairment.

Improved connectivity between devices and systems

"I have multiple carers each day, somebody different and when you've got anxiety and you're quite vulnerable anyway, having this constant stream of strangers coming into your house that you don't know. It ends up being more stressful than helpful so having that permanent fixture in your house that could do all of those things and connect to all your devices, call for assistance if needed."

Participant with a cognitive and physical impairment.

199 Research Institute for Disabled Consumers. 2024 Research report: Disability data and assistive technologies. See: https://royalsociety.org/news-resources/projects/disability-data-assistive-technology/ (accessed 18 December 2024).

CASE STUDY 5

DigAT for social care and independent living

Many disabled and older adults report needing support with everyday tasks and issues accessing social care[200]. DigAT in adult social care can support people to live independently in their own homes for longer. This case study draws on a workshop jointly organised with Policy Connect conducted for this report in April 2024.

Opportunities

The use of DigAT has the potential to provide disabled and older adults with tools to independently control their home environments to better meet their needs. Mainstream smart home devices, such as Amazon Alexa and Google Home, can give people with mobility issues new ways to control lights and heating, ask for information, set reminders, access entertainment and keep in touch with friends and family using voice commands or a smartphone[201]. Other forms of home automation, such as robot vacuum cleaners and voice-operated doorbell intercom systems, are used by Blind or partially-sighted people to perform everyday tasks[202]. These technologies could reduce the cost of in-home care and the workload of carers[203].

Many local authorities and social care providers have been experimenting with digital sensors and AI systems aiming to support monitoring for care and wellbeing[204]. For example, local authorities have piloted remote monitoring technology systems, where sensors installed in homes or wearable devices collect and analyse information on daily routines, such as sleep patterns and meal preparation and notify carers if there is concerning activity deviating from normal routines[205]. This could lead to health benefits and allow earlier interventions in emergencies[206]. Workshop participants suggested AI systems could be a potential tool to reduce the administrative burden on caregivers, allowing them to focus more on direct care[207]. ‘Social robots’, such as the robotic baby seal PARO developed in Japan, have been used to reduce agitation and increase social engagement for people with advanced dementia[208].

200 Age UK. 2019 Later Life in the United Kingdom. May 2019. See https://www.ageuk.org.uk/siteassets/documents/reports-and-publications/later_life_uk_factsheet.pdf (accessed 15 April 2025).

201 Duffy O, Synnott J, McNaney R, Zambrano P B, Kernohan W G. 2021 Attitudes Toward the Use of Voice-Assisted Technologies Among People With Parkinson Disease: Findings From a Web-Based Survey. JMIR Rehabilitation and Assistive Technologies 8, e23006. (doi:10.2196/23006)

202 Policy Connect. 2022 Smarter Homes for Independent Living. 28 April 2022. See https://www.policyconnect.org.uk/research/smarter-homes-independent-living (accessed 15 April 2025).

203 Cleland J, Hutchinson C, Williams P A H, Manuel K, Laver K. 2024 A scoping review to explore the health, social and economic outcomes of home automation for people with disability. Disability and Rehabilitation: Assistive Technology 19, 1446–1453. (doi:10.1080/17483107.2023.2196308)

204 The Health Foundation. Tech for Better Care. See https://www.health.org.uk/funding-and-partnerships/programmes/tech-for-better-care (accessed 15 April 2025).

205 Glasby J, Litchfield I, Parkinson S, Hocking L, Tanner D, Roe, B, Bousfield J. 2023 New and emerging technology for adult social care—The example of home sensors with artificial intelligence (AI) technology. Health and Social Care Delivery Research 11, 1–64. (doi:10.3310/HRYW4281)

206 Rostill H, Nilforooshan R, Morgan A, Barnaghi P, Ream E, Chrysanthaki T. 2018 Technology integrated health management for dementia. British Journal of Community Nursing 23, 502–508. (doi:10.12968/bjcn.2018.23.10.502)

207 Royal Society and Policy Connect workshop on inclusive design and deployment of smart home devices for social care and independent living, April 2024.

208 Hung L, Liu C, Woldum E, Au-Yeung A, Berndt A, Wallsworth C, Horne N, Gregorio M, Mann J, Chaudhury H. 2019 The benefits of and barriers to using a social robot PARO in care settings: A scoping review. BMC Geriatrics 19, 232. (doi:10.1186/s12877-019-1244-6)

CASE STUDY 5 (CONTINUED)

Challenges

Privacy is a significant concern for users of DigAT in social care. Open-source technologies, such as Home Assistant, offer better privacy controls but require significant technical knowledge. Data minimisation, on-device processing and the use of zero-knowledge proofs which allow systems to confirm a user meets certain criteria without revealing additional personal information, can offer privacy-preserving alternatives. However, social challenges remain, such as users feeling coerced into accepting technologies presented as the only option for receiving care, diminishing disabled and older users of their agency and right to privacy[209].

One of the key challenges with the use of DigAT for social care is the difficulty of integrating technologies into the social care system. Local authorities responsible for social care struggle with the high costs and time needed to implement new systems, especially in resource-poor settings or areas with poor digital infrastructure. Integrating digital costs into overall care costs when providing funding could ensure smart home technologies are more widely accessible. There are also challenges with the lack of training for users and the social care workforce, where there is a recognised digital skills gap[210].

Ensuring uniform training is difficult due to the mix of providers in the social care sector and varying levels of digital literacy. Smaller providers, already lacking in resources, often struggle to see the value in investing in digital training. Knowledge-sharing resources could assist organisations struggling with how to proceed with decisions to deploy new technologies[211]. Effective onboarding processes and tailored training for DigAT is important, especially for initial setup with new technologies, where users may be less confident.

Despite high interest in DigAT, its efficacy in social care is unclear, exacerbating challenges in securing funding. Research has found mixed results on the efficacy of DigAT for improving health and quality of life for disabled people and challenged claims DigAT reduce care costs with some evidence that DigAT, such as social robots, increase carer workload[212, 213]. Concerns around how DigAT impact jobs could lead to resistance from both caregivers and care recipients. Many social care providers approach technology deployment through the lens of efficiency and savings rather than focusing on user needs, which could compound social isolation[214].

209 Shew A. 2020 Ableism, Technoableism, and Future AI. IEEE Technology and Society Magazine 39, 40–85. (doi: 10.1109/MTS.2020.2967492)

210 Ipsos MORI. 2021 NHSX Adult social care technology and digital skills reviews. November 2021. See https://www.ipsos.com/sites/default/files/ct/publication/documents/2021-12/NHSX_Technology_and_Digital_Skills_Review_Main_Report_November_2021.pdf (accessed 15 April 2025).

211 Glasby J, Litchfield I, Parkinson S, Hocking L, Tanner D. 2023 'If I knew then what I know now…': a short guide to introducing new technology in adult social care. BRACE Rapid Evaluation Centre. See https://preview-uob.cloud.contensis.com/documents/college-social-sciences/social-policy/brace/ai-and-social-care-booklet-final-digital-accessible.pdf (accessed 15 April 2025).

212 Wright J. 2023 Inside Japan's long experiment in automating elder care. MIT Technology Review. 9 January 2023. See https://www.technologyreview.com/2023/01/09/1065135/japan-automating-eldercare-robots/ (accessed 15 April 2025).

213 London Office of Technology and Innovation (LOTI). 2021 LOTI Research – Assistive Technology in Social Care. See https://loti.london/wp-content/uploads/2020/12/LOTI-Assistive-Technology-Research.pdf (accessed 15 April 2025).

214 National Institute for Health and Care Research (NIHR) School for Social Care Research. Assistive technology in adult social care. See https://www.sscr.nihr.ac.uk/potential-of-assistive-technology-in-adult-social-care/ (accessed 15 April 2025).

Technical challenges in inclusive design hinder the use of mainstream devices, such as smart home technologies, for specialised needs. For example, mainstream speech recognition technologies struggle with speech disfluencies. Ensuring thorough user research before product development and incorporating feedback throughout the process can help create DigAT that are both functional and responsive to the diverse needs of users.

Example

Smart home devices for independent living

In Scotland, the Blackwood group, a specialist housing and care provider for disabled people, has introduced the CleverCogs™ digital system into its housing facilities. CleverCogs™ is accessed through a touchscreen tablet and provides simplified internet access for those typically digitally excluded for home automation, social interaction and health planning[215].

Conclusion

DigAT, especially mainstream smart home devices, are already used to support independent living for disabled people and older adults. However, there are several challenges hindering wider integration into social care systems due to issues with funding, demonstrating efficacy of technologies, privacy concerns and the need for digital skills and training.

215 Carnegie UK Trust. 2018 Living Digitally – An Evaluation of the CleverCogs™ Digital Care and Support System. See https://www.housinglin.org.uk/_assets/Resources/Housing/OtherOrganisation/Living-Digitally-Clever-Cogs-Report1.pdf (accessed 15 April 2025).

Conclusion

Left
A visually impaired woman using smartphone and earphones during a business meeting.

Conclusion

The potential of digital assistive technologies (DigAT) to enable people to live more independent, fulfilled lives, is significant. As demonstrated throughout this report, they are technologies which can help improve access to work, play, rest and care – four fundamental aspects of life. Their development encapsulates the Royal Society's guiding mission of science benefiting humanity. However, due to the disparate and inherently diverse customer base for DigAT, there are equally significant challenges in incentivising sufficient investment and adoption. Furthermore, for some people, DigAT will be a hindrance or provide no help at all.

These challenges include a need to improve the quality of disability data, to embed inclusive design practices across the development lifecycle and to ensure DigAT are affordable.

On data, a robust understanding of the global landscape of disability will require a greater focus on measuring people's functional challenges. Current approaches to data collection on disability are non-standardised with different definitions across regions and nations. Approaches which prioritise self-identification are not always useful and risk omitting people who may be living with a disability but do not consider themselves as disabled. A focus on functional challenges, instead, will offer richer insights into people's precise needs and help guide decision-makers on resource allocation and DigAT development.

Inclusive design practices will require the meaningful participation of disabled people from the initial product concept and throughout its lifecycle. Inclusivity is often seen as an afterthought in the development of new technologies and is not seen as part of the minimum viable product. This will need to change if the potential of DigAT is to be realised. This principle applies to the development of mainstream technologies as well as technologies specifically designed for disabled people. With the capability to host many different accessibility applications in one place, for many people, their smartphone is their DigAT. They are no less an assistive technology than a wheelchair or a cane.

Progress on DigAT will also require an understanding of the reality disabled people face. With many disabled people, globally, experiencing lower levels of income compared with non-disabled people, DigAT will need to be affordable if they are to be useful. The cost associated with DigAT is not limited to the initial purchase price of a product but to maintenance. Furthermore, technology obsolescence – where technology becomes outdated and in need of replacement – presents a further affordability challenge.

With an estimated 1.3 billion disabled people globally, there is already a pressing need to incentivise the development of DigAT. As generations of digital natives emerge and experience disability in future, the demand for DigAT is likely to be much greater. Meeting this demand will require careful consideration and, most importantly, action from researchers, funders, government, industry and civil society.

Appendices

Left
A blind person using a computer
with refreshable braille display.
© iStock / Chansom Pantip.

APPENDIX 1

Glossary

Augmentative and Alternative Communication (AAC)
Systems, tools and devices that support people with communication challenges. This includes digital tools such as text-to-speech computer systems.

Artificial Intelligence (AI)
Computational systems capable of tasks that conventionally required human cognitive abilities. This includes tasks such as object recognition, text generation and problem-solving. AI systems are used widely in mainstream technologies such as search engines, navigation systems and virtual assistants.

Augmented reality devices or headsets
Devices (often worn on the head such as smart glasses) that 'augment' a user's perception of the physical world (eg a user being able to magnify their surroundings).

Circular economy
A model aiming to extend the lifecycle of products through sharing, leasing, reusing, repairing, refurbishing and recycling existing products as long as possible. This can support more sustainable and affordable digital products.

Closed captioning
A process which displays audio information (such as speech or sounds) as text on a visual display (such as on a smartphone), where a user can choose whether the text is displayed.

Data linking
The process of joining together information from different datasets to gain a more comprehensive understanding. This can include combining information about the same individual whose data may be held in separate datasets.

Data minimisation
A principle that limits the collection and storage of data to what is strictly necessary for the purpose the data is being used for. For example, data minimisation could involve not collecting demographic information about a person if it's not needed for a process (eg making an online purchase).

Digital assistive technology (DigAT)
A digital technology that processes information to help make people's lives easier, such as screen-readers, speech-to-text software and smartphone apps. This definition was co-formulated with disabled people as part of focus groups conducted by the Research Institute for Disabled Consumers (RiDC) for this project.

Digital exclusion
The lack of access to digital technologies and tools. This includes barriers such as unreliable internet connections, unaffordable digital devices or lacking the skills to use digital technologies.

Digital literacy
The ability to use digital technologies to find, evaluate, share and create information and content.

Disability
A significant and long-term impairment which negatively impacts a person's ability to perform personal daily activities and their participation in society. Two common ways of understanding disability are medical models, where disability is understood primarily as a health condition to be avoided and social models, where disability is due to societal barriers in the environment. Some models of disability (eg biopsychosocial) combine aspects of the medical and social models. Refer to the 'Background' section in the Introduction for more detail.

Disability data
Information regarding an individual's disability, a disabled person's other personal data and national or international information on disability prevalence within a population. Refer to chapter 2 for more detail.

Few-shot learning
A type of small data technique used in machine learning where models are trained to perform tasks using only a small number of examples (eg recognising images of cars based on a few images).

Generative AI
AI systems generating new text, images, audio, or video in response to user input using machine learning techniques.

Haptic suits
A type of wearable technology which provides tactile sensory feedback to the user (eg vibrations in response to live music or while playing a video game).

Interoperability
The ability of different data, devices or systems to communicate and work together with minimal effort.

Machine learning
A type of artificial intelligence (AI) involving algorithms that learn patterns from data and apply these findings to make predictions or generate content.

Meta-learning
A type of machine learning technique where models are trained to adapt to new tasks using prior knowledge from multiple datasets. This can be especially useful in small data contexts where several small datasets can be used to improve model performance.

Neuro-symbolic AI
A hybrid approach to developing AI systems that combines the pattern recognition capabilities of machine learning models with the structured reasoning approach of symbolic AI. This aims to combine the strengths of these two AI approaches and can be useful in small data contexts.

Obsolescence
In the context of technology, this refers to the process of technologies becoming no longer useful or obsolete due to the availability of newer technologies or lack of support for an older technology. Compare to 'technology transience' glossary entry.

Screen-readers

A type of digital assistive technology (DigAT) which supports blind or low vision users to read text by converting it into audio or Braille format.

Small data analysis/techniques
The use of tools and techniques for data analysis in settings where there are small datasets (ie limited amounts of data and information available). Examples of techniques useful in small data contexts include few-shot learning, meta-learning and neuro-symbolic AI. Refer to chapter 3 for more detail.

Smart home devices
Interconnected household devices that are controlled automatically or remotely by a user through a smartphone or computer (eg app controlled smart lighting and switches).

Technology transience
The temporary nature of digital technologies due to products quickly becoming outdated or obsolete. Also refer to ‘obsolescence’ glossary entry.

Text-to-speech
Software systems converting text information into speech, which can be useful for disabled people who need text read aloud (eg Blind or low vision people).

Virtual reality devices or headsets
Devices (often worn on the head) where users perceive and interact with a computer-generated 3D virtual environment (eg for people to explore a route and practice ahead of travelling or for site tours).

Voice assistant/voice-controlled assistant
Software systems (typically using AI) which respond to user’s voice commands (eg Amazon Alexa, Siri).

Voice-to-text
Software systems converting audio speech information into text, which can also be used by disabled people to control devices through voice (eg people with mobility issues).

Wearable technologies
Devices that are designed to be worn on a user’s body such as smart watches or sensors on prosthetics. These can be used to collect or monitor data from a user.

APPENDIX 2

Index of figures

APPENDIX 3

Details on methodology

Summary of research activities

This report draws on several research and evidence-gathering activities as described below.

- Five commissioned research and evidence-gathering projects including a policy analysis report on factors affecting digital assistive technology (DigAT) adoption, a YouGov survey exploring general public attitudes towards technology accessibility, a mixed-methods study on disabled people's opinions and experiences of assistive technologies, a literature review on small data research methods and a literature review on disability data metrics and gaps.
- 35+ semi-structured interviews with experts in digital assistive technologies.
- Four roundtables and workshops on the topics of inclusive design of DigAT, technical and ethical challenges with DigAT for social care, DigAT in gaming and technology transience and obsolescence of DigAT.

Commissioned evidence-gathering and reviews

Hackenberg M, Nolde S, Kabus F, Backofen R, Köttgen A, Rohde A, Binder N, Brawner J, Markham E, Hardalupas M, Chowdhury A and Binder H, 2024. *Small data explainer – The impact of small data methods in everyday life*.

Danemayer J, Holloway C, 2024. *Disability and Assistive Technology in Population-Based Data*.

YouGov survey
Where figures are from YouGov Plc., the total sample size was 2076 adults. Fieldwork was undertaken between 14th – 15th March 2024. The survey was carried out online. The figures have been weighted and are representative of all UK adults (aged 18+).

Cashman C, Chessell D, 2024. *Disability, data and digital assistive technologies (DigAT).*

Baskerville J, Pan Y, Pham T and Sutton D, 2024. *Towards the Adoption of Digital Assistive Technologies in the UK: An International Comparison of Policy Factors*.

Event and research activities

The Royal Society would like to thank all those who contributed to this project, through participation in the following events.

***35+ interviews*, October 2022 – July 2024**

Royal Society staff interviewed scientists, researchers, industry professionals and civil society representatives on digital assistive technologies.

Roundtable on inclusive design of Digital Assistive Technologies (DigAT), June 2023

The Royal Society hosted a roundtable in Edinburgh as part of its *Creating Connections* event series, which hosts regional meetings addressing the scientific opportunities and challenges faced by the UK. The roundtable convened industry leaders, academics and civil society representatives in Edinburgh to discuss the potential and challenges of inclusive design of DigAT. The roundtable was chaired by Professor Jacques Fleuriot, Chair of Artificial Intelligence in the School of Informatics at the University of Edinburgh and Head of the AI Modelling Lab. The key topics discussed were barriers to industry development, co-design methodologies and ethical challenges.

Name	Organisation
Professor Jacques Fleuriot	University of Edinburgh
Dr Mauro Dragone	Heriot-Watt University
Professor Oliver Lemon	Heriot-Watt University
Professor Keith Bowen FREng FRS	Adaptix
James Duncan	Disability Information Scotland
Dr Oliver King-Smith	SmartR.ai
Amy White	Health and Social Care Alliance Scotland
Dr Maria Wolters	University of Edinburgh
Dr Nadin Kokciyan	University of Edinburgh
Dr Matthew Aylett	CereProc Ltd.
Dr Sophie Meekings	University of York
Dr Aurora Constantin	University of Edinburgh
Dr Chris Lu	University of Edinburgh
Dr Maurits van Tol	Johnson Matthey

Workshop on DigAT for social care, April 2024

The Royal Society and Policy Connect jointly organised a workshop on the inclusive design and deployment of smart home devices for social care and independent living. The workshop convened an interdisciplinary group of UK experts in data ethics, disability, social care and assistive technology development from both public and private sectors. Presentations from Clive Gilbert, Senior Policy and Research Manager at Policy Connect and Professor Lee-Ann Fenge, Professor of Social Care at Bournemouth University, framed the discussion around the opportunities and challenges of DigAT for social care. The workshop was chaired by Sir Bernard Silverman FRS, Emeritus Professor of Statistics at the University of Oxford. The key topics discussed were technical challenges, user design and co-production challenges, privacy and surveillance concerns and challenges to affordability of devices.

Name	Organisation
David George Williams	Cynthia Systems
Dr Kate Mesh	Open Inclusion
Louis Holmes	Care England
Marc Goblot	Tech for Disability & Cabinet Office Disability Unit Greater London Network
Dr Meghna Asthana	Alan Turing Institute
Ben Hardman	GDI Hub
Christine Hemphill	Open Inclusion
Clive Gilbert	Policy Connect
Professor Lee-Ann Fenge	Bournemouth University
Rohan Slaughter	University of Dundee
Dr Mahi Hardalupas	Ada Lovelace Institute
Dr Mike Katell	Alan Turing Institute
Sam Nutt	London Office of Technology and Innovation
Sarah Darrall	Responsible Technology Adoption Unit, DSIT
Dr Tom Griffiths	University of Dundee
Dr William Seymour	King's College London
Andrew Whelan	Future Care Capital
Dr Kush Kanodia	AbilityNet
Stuart Moore	National Association of Disabled Staff Networks
Carolyn Gilbert	Policy Connect
Debbie Chessell	Research Institute for Disabled Consumers
Jerry Overton	appliedAIstudio
Dr Jide Edu	Strathclyde University
LaVonne Roberts	Scott-Morgan Foundation

Name	Organisation
Professor Mark Hawley	University of Sheffield
Matt Gopsill	Independent
Matthew Crocker	Kent County Council
Sean Gilroy	BBC
Victoria Boelman	Royal National Institute for Deaf People
Zoë Clarke	Barnsley Assistive Technology Team, NHS
Zoe Ota	Department of Health and Social Care
Andrew Morgan	The Scott-Morgan Foundation
Professor Oliver Lemon	Heriot-Watt University

Roundtable on DigAT in gaming, July 2024

The Royal Society and PlayStation jointly organised a roundtable on DigAT in gaming to understand how DigAT can enhance accessibility and how insights from gaming DigAT could be adopted for daily life. The roundtable convened industry representatives developing DigAT for gaming and included remarks and case studies shared by Katy Minshall, Public Policy Director at PlayStation and Dr Kieren Mayers, Senior Director of Environment, Social and Governance at Sony Interactive Entertainment. The roundtable was chaired by Areeq Chowdhury, Head of Policy (Data and Digital Technologies) at the Royal Society. The key topics discussed included best practices for DigAT in gaming, challenges and limitations in developing and implementing DigAT and future trends for advancing DigAT in gaming and other sectors.

Name	Organisation
Katy Minshall	PlayStation
Dr Kieren Mayers	Sony Interactive Entertainment
Adam Ingle	The LEGO Group
Cait Goodale	Glowmade
Caroline Hurst	The LEGO Group
Christopher Patnoe	Google
Craig Donovan	Lucid Games Ltd
Dom Shaw	UKIE
Ian Hamilton	Ubisoft
Jess Hider	Rare Ltd
Jess Molloy	Stellar Entertainment Software
Rodrigo Sanchez	Square Enix
Theo Lomas	Epic Games
Tim Scott	Roblox
Anna-Sophie (Ash) Harling	Epic Games

Roundtable on technology transience and obsolescence of DigAT, July 2024

The Royal Society organised a virtual roundtable on technology transience, obsolescence and user abandonment of DigAT. The roundtable convened an interdisciplinary and international group of experts to explore the drivers of technology transience and propose actionable solutions. These topics were introduced through invited presentations by Professor Tim Denison from the University of Oxford, Fernando Botelho representing UNICEF, Margaret Noonan from AT Suppliers' Association and Professor John Naughton from the Minderoo Centre for Technology & Democracy at the University of Cambridge. The roundtable was chaired by Professor Michael Okun, Director of the Norman Fixel Institute for Neurological Diseases at the University of Florida. The key topics discussed were structural and policy changes for sustainable innovation in DigAT and opportunities and challenges with existing and alternative business models for development.

Name	Organisation
Professor Michael Okun	University of Florida
Professor Tim Denison	University of Oxford
Dr Luke Bashford	University of Newcastle
Professor Tara Brabazon	Charles Darwin University
Fernando Botelho	UNICEF
Liam Drew	Independent
Professor Jean D.Hallewell Haslwanter	TU Wien
Pranay Arun Kumar	RMIT University
Professor Aisling McMahon	Maynooth University
Dr Kayleen Manwaring	University of New South Wales
Dr Gabriel Lázaro-Muñoz	Harvard Medical School
Professor John Naughton	University of Cambridge
Ben Oldfrey	Global Disability Innovation Hub
Alexandros Pino	University of Athens (Greece)
Theresa Vaughan	Neuroabilities advisory council, NCAN
Dr Rachel Wurzman	Dana Foundation

APPENDIX 4

Acknowledgements

Steering Committee members

The members of the Steering Committee involved in this report are listed below. Members acted in an individual and not a representative capacity and declared any potential conflicts of interest. Members contributed to the project based on their own expertise and good judgement.

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This report has been reviewed by a panel of experts, who provided feedback on the report. The review panel members were not asked to endorse the conclusions or recommendations of the report, but to act as independent referees of its technical content and presentation. Panel members acted in a personal and not a representative capacity. The Royal Society gratefully acknowledges the contribution of the following reviewers.

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