The King's Fund

Ideas that change health and care

Shaping the future of digital technology in health and social care

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Executive summary

- The potential of digital technology to transform the health and social care system has still not been realised, though the Covid-19 pandemic has caused a rapid shift towards the remote delivery of care through online technologies.
- We conducted a review of high-quality evidence for how emerging technologies such as artificial intelligence (AI), smartphones, wearable devices and the internet of things are being used within care settings around the world, supported by a series of expert interviews.
- This research was mostly conducted pre-pandemic and is supplemented by our own evidence-gathering on how digital technology has been used during the pandemic, in England in particular.
- Although there is evidence that these tools have potential and can be used to support staff and patients with specific tasks (such as the use of AI in diagnostic testing or wearables in behaviour change), there are large gaps in the evidence base.
- For the health and social care sector to make the most of emerging technologies, there need to be fundamental changes in how new tools are evaluated and supported during implementation.
- More evidence is needed on a range of factors, including the cost-effectiveness of such tools, the groups best suited to using these interventions, the effects of digital inequalities on access, and the impact of tools that use digital technologies on outcomes.
- The public must also become a key stakeholder and partner with the health and social care sector as people's data becomes a source of potential financial gain to the sector and private partners through the development of products built using patient data, in addition to helping the sector understand the impact of digital inequalities.
- Staff in the system and third-party suppliers need to be supported to improve implementation and design while building up the level of analytical skills throughout the health and care workforce.

- National leadership in this area is often reshuffled, with a lack of clear responsibility in many aspects of implementation or strategy-setting compounding issues with delivery of funding to the front line.
- Local leaders need support to develop change management and analytical skills as well as how best to support to around how best to leverage the opportunities provided by digital technology to improve care for their populations.
- We outline three potential future scenarios for the health and care sector with regard to digital technology: a 'techlash' against new tools resulting from a loss of trust in how patient data is used; a continuation of the uneven spread of digital technology across the health and social care sector, with low-quality evidence stifling uptake of new tools; and a more optimistic view, where the support and quality of evidence we outline throughout this report develops within the sector and change happens at scale and speed.
- The decisions taken in the next few years will have a huge effect on how the health and social care system is transformed. The Covid-19 pandemic has created a huge set of pressures on the system while it is undergoing a significant transformation – with the establishment of integrated care systems (ICSs) as statutory bodies over the next 12 months marking a fundamental change to how health and care organisations make decisions and exchange information. We hope this report will help leaders within the sector to meet those new challenges and transform the care they provide.

1 Introduction

Background

This is possibly the most challenging period in the history of the NHS. The impact of the Covid-19 pandemic on both the health sector and the economy will compound issues with workforce supply, waiting times, unmet need and staff welfare that have been troubling the sector for several years. These are not problems that will be solved in a matter of months, but rather years, requiring long-term planning to address.

At the same time, the pandemic has had a transformative knock-on effect on how digital technology is used within the NHS and society. There has been an unprecedented shift towards the provision of care and information through digital means within health care, with millions of GP appointments taking place over telephone and video calls, text messages providing updates and information to service users, and back office functions moving to programmes like Microsoft Teams.

Decisions taken now will influence the way health and care systems adopt tools to adapt to the needs of their populations. With digital technology playing a larger role in the provision of care every day in the NHS now and in the future, we were commissioned by the Health Foundation to produce this report to help provide insights and support strategic thinking about the role of digital technology in health and care systems in the future.

It is undeniable that digital technologies have played an important role in social change over recent years. The first smartphones were released around 2007, and 10 years later, 80 per cent of the United Kingdom (UK) population were using them for hours each day. Artificial intelligence had a renaissance in the 2010s, with increases in research and hype alike. During the Covid-19 pandemic, billions of people are finding ways to connect with others remotely while living with social distancing guidelines in both their personal and work lives, transforming their habits to wrap around digital technology where they have the capability to do so. For others, this period of time has compounded existing digital inequalities, leaving them even further behind.

This report provides a summary of evidence and analysis to support leaders in health and care to engage in long-term thinking about the role of digital technology in their sector. It looks back at recent developments in digital technology in the health and care system, and looks forward, to a set of potential futures, to distil factors driving change and what this means for leaders now.

What do we mean by digital technology?

There is no universal definition of 'digital technology' across health and social care. Some draw a distinction between 'digital technologies' and 'data-driven technologies', though many will use these terms interchangeably, as we will in this report for simplicity.

The use case of some digital technologies is already proven, and well embedded in the health and care sector, such as email or electronic record keeping. These technologies will continue to underpin the work of the sector in future, so we have focused this report around four key technologies that have both significant potential to shape the future of care and a robust evidence base in the existing literature, and which are currently not widely used across the health and care sector. There is additional detail on how we formed this list in the Appendix.

Artificial intelligence

Artificial intelligence (AI) is an umbrella term encompassing a number of different approaches (such as machine learning) where software replicates functions that have, until recently, been synonymous with human intelligence. This includes a wide spectrum of abilities such as visually identifying and classifying objects, converting speech to text and text to speech, etc (Mistry 2020).

Mobile computing

Mobile computing is the field of wireless communication and carry-around computers, such as tablets or smartphones (Mistry 2020). More computing power than ever is in the hands and pockets of consumers and service users, supported by an ever-growing network of broadband provision that presents entirely new ways of providing access to care and information. In this review, we focus on the use of smartphone technology.

Personal and wearable devices

Separate to smartphones, personal and wearable devices – generally in direct contact with the wearer for long durations – generate large quantities of data on specific biometrics or behaviours (Mistry 2020). These devices include smartwatches, fitness trackers, implants or patches with the ability to connect to other devices.

Internet of things

Technically, anything that connects to the internet can be considered part of the 'internet of things' – the use of everyday objects as connected devices that provide an additional function through digital technology. Where the previous category focused on technology that came into direct contact with the end user, the internet of things covers things like smart home technology, such as smart thermostats or other connected devices.

2 Approach and methodology

What will we address in this report?

This research was originally commissioned by the Health Foundation in 2019 to answer the following four questions.

- What are the key developments to date in digital technology relevant to health and social care in the UK?
- What is the evidence on the impact of digital technologies on health and social care services and outcomes?
- How could digital technologies for health and social care develop in the future in the UK, and what factors are driving these changes?
- What are the implications for health and social care?

The first two questions deal with the recent history of digital technologies, with a view to providing a shared understanding of their impact on the health and social care system. Section 3 addresses these two questions.

The second two questions look forward, sketching out possible scenarios, features and likelihoods, their implications for the health and social care system and the ways that senior decision-makers can help shape these futures. These are mainly answered in sections 4 and 5.

Our approach

We began by undertaking a literature review about the impact of digital technology on health and social care. Given that we were looking for high-quality evidence about recent developments within the technologies outlined in the previous section and their impact on outcomes, we thought that an approach that focused on key technologies rather than higher-level trends would help us find the most significant reviews of how that technology is being applied to care.

We conducted literature searches in health and care and social science databases (a full longlist of terms is available in the Appendix), and have subsequently supplemented these results with our own handsearches of relevant journals and government policy documents, as well as papers recommended by our expert interviewees or shared by other experts on social media.

To help us understand the practical implications of using new technologies and tools in health and social care, as well as how their use could develop in the future, we conducted semi-structured interviews with 10 experts selected for their expertise and experience in applying the technologies – either in a particular category of technologies, or in applying some combination of them to the health and social care system.

Given that digital technology is a fast-developing field, some of our evidence may not be completely up to date with current trends, as the original literature review was conducted in 2019 to support the Health Foundation's work internally. This means that the initial literature review is now limited by the fact that it does not cover the pandemic period and the rapid changes that have accompanied it, though we have continued to gather evidence through our regular monitoring of events and publications as part of our knowledge-gathering within The King's Fund.

We created the possible scenarios presented in Section 4, and the factors driving them, through combining insight from the literature review and expert interviews. We provide a short description of our interviewees' relevant roles in the Appendix, and would like to thank them for their contributions.

In Section 5, we use the factors that are driving development of digital technology to outline the implications for health and care, and draw on The King's Fund's understanding of the health and social care system and digital health and care ecosystem to form recommendations for policy-makers about how they might shape the future.

3 What are the key developments in each category of technology?

Overview of key developments across digital technologies

Our review focused on two priorities: the key developments to date within the use of each technology within health and social care; and the evidence of the impact of these technologies on health and social care. The key findings from our evidence-gathering are summarised in Table 1, with additional detail through the rest of this section. For each type of technology, we present some brief background, the key developments to date and impacts on the health and care system, and areas for further study.

Table 1 Key developments across digital technologies

Key developments so far	
Artificial intelligence	Advancements in computing and investment from a range of sources have resulted in an expansion of the capabilities of AI technology, but there are few examples of use in healthcare, with a focus on diagnostic testing.
Mobile computing	Smartphone use has continued to rise over the past 10 years, though use is unevenly spread across age and socio-economic groups. The Covid-19 pandemic has sped up the implementation of video and other digital technologies to replace back-office and traditional functions.
Personal and wearable technologies	Advances in the size and styling of wearable technologies have encouraged growth in the use of smartwatches and fitness trackers. Few examples in UK health services, some integration into insurance plans in the United States.
Internet of things	As computing technology gets smaller, more and more ‘smart’ devices are reaching the consumer market, most notably smart

	speakers, though there are few examples in the health and social care sector beyond a handful of trials.
Overall impact	
Artificial intelligence	No evidence of large-scale impact to date, though some evidence of efficacy in performing diagnostic imaging tasks, which could support staff in these roles in the future.
Mobile computing	Rapid expansion of remote access tools, especially in primary care, has transformed the use of smartphone technology in the health and care sector; however, other apps and smartphone-based tools are used much less within the health and care system.
Personal and wearable technologies	Little evidence of overall system impact, though some impact for individuals where a need or motivation to change health status exists.
Internet of things	No large-scale trials or project evaluations exist within the literature, though there are studies that prove the technology functions and could be promising for monitoring health in the future.
Opportunities for further research	
Artificial intelligence	More information is needed about the overall impact of AI tools on quality, efficiency and equity, the role of regulators in maintaining these and the ability of the health and care sector to create representative, high-quality data to inform the development of new AI tools. There needs to be more engagement and clear communication with service users about how their data will be used in financial agreements with third-party organisations.
Mobile computing	The health and social care system needs to build better insight into the overall impact of smartphone use for health purposes, as well as the nature of digital exclusion.
Personal and wearable technologies	Large scale studies could be conducted using consumer devices already in the possession of a large number of customers (eg, Apple Watch study) to investigate the opportunities for the prevention and management of long-term conditions.

Internet of things	Further evidence of impact on overall pathways where 'smart' technology is used will be needed to increase use throughout health and care. Service users and providers will need to establish a mutual understanding of data usage and collection, given the privacy concerns around this technology.

Artificial intelligence

Background

Though the field of artificial intelligence (AI) dates back to the mid-20th century, recent developments have increased our capabilities. This has been enabled by major investment by large technology companies and state actors, the growth in the amount of data generated by a more connected world, and the development of machine learning. Most of the applications in health and care that we have found involved the use of AI tools to improve performance on tasks like making predictions compared to traditional processes.

Key developments

A helpful review written by Fenech *et al* (2018) identified five areas for AI use: preclinical research, clinical pathways, operational efficiencies (referred to as 'process optimisation'), patient-facing applications, and population-level applications. Our present review excludes developments in applying AI techniques to preclinical research such as drug discovery and genomic science. However, we do cover the remaining four areas.

The most prominent developments have been in research seeking to develop algorithms that perform useful functions in tasks in clinical pathways. But there have been few reviews looking at overall impact on pathways.

Far fewer reviews compare algorithm performance to human performance in meaningful ways. The first systematic review of studies that compared algorithm performance against health care professionals across a number of diseases (eye disease, breast cancer, trauma and orthopaedics, dermatological cancer, lung cancer, and respiratory disease, among others) found that the accuracy of each was about the same (Liu *et al* 2019a).

The results of the first prospective trial of an autonomous AI system for a diagnostic assessment were published in 2018 (Abràmoff *et al* 2018). Beyond diagnostics, there have also been early applications of similar techniques to planning treatments, such as the use of segmentation techniques for planning therapy (Nikolov *et al* 2018). The NHS has been gathering together chest imaging scans into the NHS Chest Imaging Database (NHSX 2020b) through the pandemic as part of an effort to use AI to improve diagnosis and treatment of Covid-19. This project is still in its early stages, and was rolled out in January 2021 to NHS providers.

AI techniques built on deep learning and other modern techniques are effective in the narrow tasks they are set up and tested for, but what the studies do not tell us is whether a tool's adoption and implementation in the health system is safe, effective, and provides value for money.

To generate evidence of this kind of impact, we expect to see the introduction of more sophisticated service evaluation, with the intended outcomes from an intervention tracked from the outset of a project, including economic outcomes. Whether these systems are effective will depend on a series of factors such as data quality, the technical capabilities of staff and service users, and pathway and service configuration.

Moving beyond imaging data, analysis of electronic patient record data can also use combinations of machine learning techniques alongside standard checks by humans to detect diseases not yet diagnosed or predict future health care needs. Machine learning has been reported to be useful in some of these tasks (Rajkomar *et al* 2018), but whereas it is particularly useful in image analysis, the mix of structured and unstructured (such as free text) data in electronic health records (EHRs) means that other kinds of analysis are often applied (Christodoulou *et al* 2019). Again, in the reviews that we found, these have been limited to proofs of concepts rather than evaluating systems that routinely rely on these techniques to supply these predictions in real-world settings. A key review of this area notes that complexity and potential for changes over time in the generation and use of EHR data are likely to make this field a particularly complex area for future research and development (Xiao *et al* 2018).

During the pandemic, NHSX launched the Covid-19 Data Store (NHS England 2020), bringing together data from several sources within the health and social care system as part of a project to use AI to build a predictive model to inform the government's response to Covid-19. There has been controversy about how the agreements with the private companies providing these tools were made, with some groups accusing the government of a lack of transparency (Downey 2020b).

Applications to other data that individuals generate outside the health and care system have been used to infer health status. For example, the data generated by social media users has been analysed using machine learning to make predictions about users' health – particularly mental health (Yin *et al* 2019). But research in this area is at an early stage and seems likely to be particularly vulnerable to changes in technology use and habits over time. In our research on the topic we have found similar conclusions, though questions remain around ethical processes and there are other issues that have yet to be addressed (Buck *et al* 2017).

While we found no systematic reviews of applications of AI to the planning and management of health and care services, we are aware of some examples of exploratory research in this area. One example is the development of models that predict the likelihood that individuals attend appointments (Nelson *et al* 2019) that have been offered as part of EHR platforms (Murray *et al* 2020).

Areas for further study

We would expect to see regulators try to find ways to keep pace with developments in AI – for example, developing processes that ensure that developers test new systems on sufficiently representative datasets, developing more realistic comparisons of the performance of AI tools versus human performance.

There remain questions about where accountability sits if an algorithm causes errors; if the data informing the process is incomplete, is it the fault of the data supplier or the organisation creating the algorithm if biases emerge? What is the role of the regulator? Finally, more complete evaluation of systems in action in clinical settings will start to bring real evidence of the impact of AI in the near future (Joshi and Morley 2019). At the moment, however, there is divergence between the AI developments in the peer-reviewed evidence base (mainly limited to research settings) and the systems that are in the market. At least 30 systems that incorporate some kind of algorithm that play a role in interpreting images (many using deep learning) have been approved by the U.S. Food and Drug Administration (FDA) but not all of these systems' developers have published peer-reviewed studies (Topol 2019) on their efficacy in improving decision-making. Further evidence on this would be desirable for system leaders making decisions about which tools to invest in for the future.

AI applications like these require attention to the fairness of decisions made using these predictions. For example, using AI to predict risk among populations also has the potential for similar ethical harms through perpetuating existing health inequalities if the data used does not accurately represent the population at risk (Obermeyer *et al* 2019). Possible options to account for and avoid unfair outcomes include using impact assessments when new tools make important allocative decisions (Reisman *et al* 2018).

The challenge of interpreting algorithmic decision-making using AI is frequently commented on in the literature. AI development involves building complex systems, which rely on analytical techniques that perform well but are hard to explain (Ordish *et al* 2019).

Finally, the boom of interest in AI in recent years has raised questions about how to govern partnerships with industry so that a fair exchange of value occurs between patients, health providers and the manufacturers that develop products using NHS data. Estimates of the value of NHS data have been made (Wayman and Hunderlach 2019), along with suggested models for the future governance and sale of NHS data (Fontana *et al.*, 2020). NHSX has established the Centre for Improving Data Collaboration to support the establishment of these partnerships (NHSX 2020c).

Mobile computing

Background

As of 2018, four out of five people in the UK owned a smartphone (Ofcom 2019). They bring together in a single, portable and ever-cheaper device high levels of computing power, simple touchscreens, high-quality cameras and microphones, short- and long-range wireless connections, cellular voice and text messaging services, and – most importantly – high speed connections to the internet.

There is an age gradient to smartphone use: 95 per cent of people aged 16–24 own one, with rates dropping through older age groups to 51 per cent for people aged 55 and over. There is also an association between socio-economic status and reduced smartphone ownership (Ofcom 2019). For many, the smartphone is the only or main device used to access the internet: around 20 per cent of adults aged 16–64 working in semi-skilled and unskilled manual occupations or who are unemployed use smartphones as their exclusive means to get online (Ofcom 2019).

Key developments

As with other aspects of the digital revolution, health and care is perceived to have lagged behind other sectors in its adoption and impactful use of mobile computing and smartphones. However, in our search of the evidence base, we found many reviews of interventions and organisational approaches that apply smartphones and apps installed on them to health and care problems.

Some of these apps have been shown to have potential to help people manage aspects of their own health – ranging from maintaining their health by supporting fitness, all the way through to managing complex conditions. The evidence about their impact on health outcomes overall is extremely limited, despite many patients using and engaging with them extensively (Chib and Lin 2018).

However, the downsides of the extensive quantity of apps purporting to support health is explored in a review of 'consumer-facing' apps. This covers apps that provide health information or tools for self-management and symptom-checking. We found numerous safety risks, including incorrect information, incomplete information, faulty alarms or reminders, lack of validation of data, and health apps using out-of-date evidence with no input from clinical experts (Akbar *et al* 2019). A review focusing on applications in mental health found similar concerns about quality and little evidence of impact (Wang *et al* 2018).

We found many systematic reviews of system-level interventions that used smartphones and apps (sometimes in combination with wearable devices) to support healthy behaviours, like preventing ill health or living with existing conditions. The latest key systematic review that we found assessed app-based interventions to help people with long-term conditions with weight management. Studies showed more consistently positive outcomes regarding weight management (Dounavi and Tsoumani 2019). This change over time suggests that good practice in app design and overall intervention design might be emerging and spreading. However, the same authors caution that the overall quality of the evidence base for impact on health behaviours is low.

The NHS has had two major national apps launch in the past three years: the NHS app and the NHS Covid-19 app. The NHS app has gone through several redesigns, with some of the potential ambitions around digital care provision and record access through the app as a single point of call being dropped as local areas and providers choose their own systems. A picture is beginning to emerge of multiple apps being deployed across the country for different aspects of care, with primary care having developed a series of local online access offers during the course of the pandemic (Baird and Maguire 2021).

The role of NHS smartphone apps and the internet to provide information has changed significantly during the course of the pandemic. The need to communicate guidance about social distancing, the use of the health service for non-coronavirus issues, as well as what to do if experiencing Covid-19 symptoms meant that the NHS website played a central role in the response. NHS Digital created an online NHS 111 symptom checker that became the advised destination for everyone with coronavirus symptoms, hitting over 30 million views by August 2020 (NHS Digital 2020b). With the additional pressures on accident and emergency (A&E) services created by the winter period, NHS 111 has become the official entry point for all urgent care (excluding cancer) where not an emergency.

The NHS Covid-19 app had a troubled development, including a fundamental redesign when the original app struggled to perform adequately in a trial on the Isle of Wight (Downey 2020a). Issues pertaining to how data generated by the app is shared with local public health teams have constrained the app's potential, in addition to ongoing technical issues, such as false isolation notifications (Manthorpe 2020), and concerns have been raised around the data-sharing terms of the app. National projects like this have the potential to act as an exemplar for the public on how the NHS can provide care and information digitally, building or eroding confidence that the NHS can be trusted with sensitive data and the quality of care provided online.

Much of the evidence we found can be gathered under two main themes, which we explore in detail below: 'digital-first' models of care, and staff-facing apps.

Digital-first models

Widespread use of remote access to care did not emerge until the pandemic forced the NHS into a systemic shift towards digital access, particularly through patients' phones. We have seen a rapid expansion of online triage and remote access to care through digital technologies in primary care in particular, with a smaller shift towards digital provision in outpatient care (Eccles 2020). In primary care, this shift has been towards text messaging and telephone contacts, rather than video, even where video consultations are available (Baird and Maguire 2021).

Pre-pandemic, the most well-known provider of digital-first primary care services in England was GP at hand, based on the Babylon Health platform launched in 2013. The company originally provided a small private fee-for-service model that matched clinicians to patients. The firm began to deliver NHS services in the winter of 2017 (by registering as a practice based in West London), taking advantage of the out-of-area patient scheme, which lets patients register with practices beyond a geographic catchment area. The firm offered their GP at hand service to Londoners at first before subsequently being deployed in Birmingham, with tens of thousands of patients registering with the practice.

The highest-quality evidence we have for digital-first models comes from the GP at hand evaluation conducted over its first year (Ipsos MORI Social Research Institute and York Health Economics Consortium 2019). This found that the app and video consultation-based model was bringing high levels of satisfaction in terms of patient experience for those who opted in to the service, while possibly both meeting unmet need and triggering supply-induced demand. The review was unable to conclude whether or not the digital-first service model was sustainable for a whole health system, as the evaluators were not able to access data on outcomes, and the numbers of staff required appeared to be much higher than 'traditional' models of primary care. For these reasons, the evidence must be read with appropriate caution. Future evaluations of digital-first or digital-only access tools would benefit from more complete access to data.

Digital-first service models are also embedded in the context of a wider system struggling to meet demand for primary care in general (Baird *et al* 2016) and a series of estate and hardware concerns. At the onset of the introduction of social distancing measures, there was a rapid deployment of information technology (IT) equipment to GPs, but there are ongoing issues around broadband and workstation quality for many GPs (Baird and Maguire 2021).

The evidence about the quality of these remote consultations is relatively positive, suggesting that while there are elements of good practice to learn and technical challenges in set-up, they can be a good option for some patients (Shaw *et al* 2018) and compared favourably with telephone appointments (Rush *et al* 2018). It should be noted that most of this evidence is from studies of remote consultations for particular patient cohorts rather than all of primary care.

There are standing commitments in the NHS Long Term Plan to offer remote consultations as an option beyond primary care, but during the course of the pandemic, this has been restricted to outpatient care. NHS England offered providers the Attend Anywhere platform, previously deployed in Scotland as a video service for online outpatient services, as well as funding for alternative platforms (Eccles 2020). However, uptake has been restricted both by technical issues with the Attend Anywhere platform (Campbell 2020) and a reduction in demand for outpatient care (as of November 2020, referrals from GPs into outpatient services were a quarter of their typical amount by that stage of the year) (NHS Digital 2020c).

Staff-facing applications

As with patients and citizens, most staff in health and care now have access to and regularly use smartphone technology in their day-to-day lives. They are also increasingly using smartphone apps to support their work, using either personal or dedicated work devices.

In the hospital sector, there is the potential to replace ageing communication technologies, such as pagers, with smartphone-based apps for activities like messaging and task management once the NHS has overcome basic infrastructure issues including a lack of wi-fi (Wenzel and Evans 2019).

The authors of the key systematic reviews we found argued that these kinds of technologies can improve efficiency and safety, but overall there is as yet little in the way of best practice (Martin *et al* 2019; Pourmand *et al* 2018). There is also a set of implementation and technical challenges to overcome in integrating these technologies into existing clinical workflows (Martin *et al* 2019).

Communication tools were procured for staff to connect to each other remotely during the pandemic with a national rollout of Microsoft Teams as a virtual meeting and chat solution, allowing back-office functions to continue remotely across the NHS. Longer-term questions remain about the continued use of these tools once the conditions around their use change. Will clinicians continue to use these tools or switch back to traditional methods of care provision? Which approach will patients prefer? Can GPs and secondary care organisations afford to continue to use these tools once the discounts or free access currently being offered end?

We found no reviews of applications in social care, though we heard through our interviews that provider-supplied smartphones and tablets are increasingly being used in social care to support record-keeping. Tablets were offered to a number of care homes during the pandemic to allow residents to keep in touch with loved ones (NHSX 2020a); however, this was not a universal offer.

Areas for further study

With the rapid shift towards remote consultations (particularly in primary care) and the longer-term ambition to provide other aspects of care digitally in the future, health and care providers need more complete information on the effectiveness of smartphone technology apps and other online consultation and information provision technology for their populations. It is not clear what effect these interventions and access points have on patient outcomes. There is significant potential for the NHS to reach many more people in a more flexible way through these technologies, but there is little data on managing digital inequalities while making these changes, and on which interventions have the greatest impact.

Personal and wearable devices

Background

Personal and wearable devices integrate sensors that gather data about a person's activity or health into a device designed to be carried or worn on the body. Some display data for that person on the device or send it elsewhere for later analysis, often by health care professionals. This category of technology partly overlaps with 'mobile computing' as we have defined it, given that some personal and wearable devices link wirelessly to smartphones, and many have standalone capabilities.

Readers are most likely to be familiar with activity trackers and smartwatches like those marketed by Fitbit and Apple. These devices are most commonly marketed as devices that support fitness, health and wellbeing – most often, through increased physical activity.

The devices bring together a host of technologies that have been miniaturised in recent years, including sensor, battery, display, processing and wireless technologies. They have become more compact and have been designed into various forms, including wrist-worn, waist-worn or pocket devices. Key sensors include accelerometers (motion sensors), Global Positioning System (GPS) sensors, and light sensors (used to infer heart rate). Of particular importance in this category is the development of the products' design; for many, these are designed to function as clothing and accessories as much as data-gathering machines.

Key developments

In the United States, the integration of wearables into health plans is reasonably common, particularly when combined with employer schemes. In 2015, 35 per cent of corporate wellness programmes offered wearable devices to members in some way (Jo *et al* 2019). In the UK, this appears to be less common, with some private health insurers incorporating these products into some part of their plans. To our knowledge, there are no NHS services that currently integrate or prescribe consumer-grade wearable devices to affect activity or monitor other health metrics.

The vast majority of the evidence base on wearable devices seeks to understand their usefulness in: measuring and displaying health data accurately; encouraging changes in behaviour (most of the evidence we found fell into this category, specifically for physical activity); or predicting or detecting adverse events.

Early work tested the validity and reliability of data reported by such devices in step counting, energy expenditure and sleep metrics. They found them more reliable for steps than for energy and sleep (Reeder and David 2016; Evenson *et al* 2015).

Another application of personal and wearable devices is in population health research, such as comparing activity levels in employment, where passive monitoring using wearable devices outperforms self-reporting (Prince *et al* 2019). Features such as energy spend and sleep measurement remain less reliable and should be treated with caution in this kind of research (Feehan *et al* 2018).

Early reviews found by our literature search in this category seemed to be generally focused on studies of healthy, able-bodied adults (Evenson *et al* 2015), to the exclusion of groups like people with disabilities, young people and, in some areas of research, women (Marin *et al* 2019).

Two systematic reviews found that use of these devices needed to be combined with other interventions (eg, motivational feedback or coaching) to increase the likelihood of impact on important health outcome measures (rather than activity alone). This suggests that the key questions for this kind of technology are how to integrate them into interventions and service models most effectively, rather than hoping they will improve outcomes on their own (Jo *et al* 2019; Abedtash and Holden 2017).

Over time, they have been used as part of broadly successful interventions for specific groups, such as cancer patients, for whom it was known that exercise can improve outcomes (Schaffer *et al* 2019), and for older people, though the evidence base is not yet mature enough to determine whether this group sees positive or negative impacts (Cooper *et al* 2018).

Market research firms have attempted to estimate the continued usage of products with activity tracking. Studies suggest that wearable devices are frequently discarded within months, though this probably masks significant variation between different kinds of product (one would expect smartwatches to be retained for longer than activity-focused devices) and may not properly account for cases where individuals are using devices for specific health interventions.

It is intuitive that wearable devices would be more widely used the more they fit in with users' preferences about clothes or jewellery. For example, one review noted that interventions for young people and children that used early consumer wearables were often limited by poor physical fit and undesirable visual design for those groups, with a need for longer-term understanding of the impact of the use of such devices through the stages of youth (Ridgers *et al* 2016). Similarly, for clinical applications, authors have noted that more research is needed for people who have disabilities as a result of medical conditions like stroke (Lynch E.A. *et al.*, 2018), and there may be socially stigmatising effects from wearing more obviously clinical devices (Johansson *et al* 2018).

More recent evidence suggests that for some patients who have chronic diseases, or a perception of risk of a chronic disease, there may be a motivation effect, meaning that interventions using these technologies are more successful in increasing physical activity than for the general population (Kirk *et al* 2019).

Work is ongoing to determine how best to use data captured by wearable sensors (much of this work overlaps with the AI techniques covered in that section). For measuring fall risk in older people, an array of sensors on the body are in use, but this seems to be in the early stages of research

(Montesinos *et al* 2018). One function of the Apple Watch seeks to detect whether a wearer has fallen and to contact emergency services in that event.

One notable development in recent evidence worth treating separately from our review of reviews is the 400,000-participant Apple Watch study (Perez *et al* 2019). This sought to test the capability of the consumer watch in a clinical screening application to detect atrial fibrillation (AF). This was an opt-in study for Apple Watch owners, so the cohort was not particularly high risk for AF (as evidenced by the very low probability of participants being notified of an irregular pulse and invited for further AF investigation).

The evidence base on use of these kinds of consumer devices to identify cases of disease within the population is small, and remains far from establishing any kind of clinical effectiveness or cost-effectiveness. The Apple Watch Series 6 received regulatory 'clearance' by the FDA for offering electrocardiogram readings on the device to determine if the wearer has AF.

Devices that support remote monitoring have been used in some examples of interventions for particular conditions. Overall, the evidence base could be described as low quality and still developing.

One such example of use of these devices for those with particular conditions is chronic obstructive pulmonary disease (COPD). A Cochrane review found some evidence of a positive impact from using monitoring technology on quality-of-life measures and reduced care activity for these groups, but the evidence base was not yet mature enough to establish whether these improvements were sustained over time (McCabe *et al* 2017). In relation to heart failure, (Bashi *et al.*, 2017) showed some overall positive effect from the use of telemonitoring for patients in terms of mortality, but found limited evidence regarding other outcomes, such as quality of life or service use.

Neurological conditions seem particularly amenable to clinical measurement and intervention using wearable devices, but were likewise too early in development and too broadly defined to be declared effective (Johansson *et al* 2018).

There is some initial research which suggests that wearable devices could be capable of detecting Covid-19 before a person becomes symptomatic (Mishra *et al* 2020), though this study uses technology not yet available to the public and is indicative at best, with much more data required to act as part of a set of detection tools within the population.

Areas for further study

There is a need for the research community to develop improved, more consistent practice in terms of how the quality of data is managed in studies examining the impact of these technologies (Abdolkhani *et al* 2018). Strategic leaders will need more information on how to build wearable devices into pathways while making the best use of investment, particularly concerning the direct provision of information from patient to clinician. There are also clear gaps in the evidence base regarding research affecting people who are not able-bodied adults, and the long-term impact on outcomes.

Internet of things

Background

Sensor, networking and computing technologies have been sufficiently miniaturised and reduced in cost to make it viable to connect objects and devices to networks. These developments are closely related to those covered in the mobile computing section, yet here we focus on how environments, buildings and objects are becoming part of the network of digital technologies.

Ten years ago, laptops and desktop personal computers (PCs) would be the only devices with computing and network capabilities in use in health and care settings. It is now possible to fit devices and objects with low-cost, low-power components that enable them to capture data about things like their use or their location over time and to transmit this information. As *The Economist* (2019) put it, these developments mean we can have 'chips with everything'.

Certain technologies are fundamental to this change. A mix of private and public infrastructure, services and datasets play important roles. For example, GPS and sensors like radio-frequency identification (RFID) readers and motion sensors allow devices and their owners to be located in outdoor and indoor spaces (Loveday *et al* 2015), and maps help to pinpoint where those devices are. There are other applications where information about a device's location can be used in relation to one another – for example, in virtual reality headsets.

Key developments

Some studies have explored the feasibility of inferring people's health status and their need for care using data from sensors. At the more sophisticated end of the scale (in terms of data analysis), researchers are exploring the use of home monitoring systems to pick up early signs of cognitive decline and other changes in health status, though these have not yet moved from proofof-concept in the lab setting into real-world home settings (Piau *et al* 2019; Ray *et al* 2019).

At the other end, some care homes in the UK use acoustic monitoring, where staff are able to listen in to audio feeds from residents' rooms, with alerts triggered for louder sounds (WCS Care 2017). Whether sensing technologies are acceptable to users depends on the kind of surveillance involved, the analysis method, and who is using the information gathered. The mode of data collected appears important too, with one review reporting that video and microphones are considered more intrusive than things like infrared, RFID or door sensors (Piau *et al* 2019).

The capability to control or operate devices in response to analysis of data or user input is another important feature of this category. In the UK and other countries, millions of people have adopted connected smart speakers and other devices to automate tasks like turning on lights and playing music. There are four major platforms that offer these services provided by the large technology companies, with their access to the huge infrastructures of computation, data and people needed to sustain such services (Crawford and Joler 2018). One in five people in the UK are estimated to use devices like these, with their 'always-on recording' sustaining debate about how users' data is being processed (Centre for Data Ethics and Innovation 2019). We found no reviews in the literature of the impact of deploying smart speaker technology within consultation rooms on the health system.

Augmented reality combines sensing technology with display technologies including smartphone screens or virtual reality. Most of the literature to date has explored applications in medical and surgical training, with several firms and projects seeking to build applications intended to embed the technology in clinical training programmes. The thinking behind this is that increasing the realism of stressful training scenarios or providing more visual guidance during them will eventually improve knowledge and skill retention. As this field has matured slightly, authors found tentative positive indications about the benefits of training using these tools (Ayoub and Pulijala 2019; Munzer *et al* 2019; Barsom *et al* 2016).

The other application of augmented reality that we picked up in our search is for surgical planning, with researchers experimenting (mainly on models, with no trials covered by our reviews) with displaying visual information in real time on a visor in combination with touch-based feedback (for example, vibrations through a touchscreen) during surgery to help surgeons operate safely. These tools introduce extra set-up costs as additional systems are added between surgeon and patient (Ayoub and Pulijala 2019; Bosc *et al* 2019).

Areas for further study

Even more than the other areas of technology examined in this review, the applications reviewed in this category were mainly limited to a series of pilots, feasibility studies, or examples of systems applied on the operational side of health and care. Overall, we found very little evidence of their impact on the health system to date, or benefits such as cost-effectiveness.

With surveillance of some form inherent in their design, major issues like security, privacy and acceptability were frequently discussed by review authors (Piau *et al* 2019; Talal *et al* 2019), though none treated these essentially social questions as the primary areas of enquiry. We explore these issues in greater detail in the next section on scenarios, starting on page 44.

4 What could the future look like?

Leaders in the health and care system should recognise that, in addition to making best use of existing devices and services developed in the technology industry, they have opportunities and power to shape how those devices and services develop in the long run. It is important to recognise that they can have impact not only on the health and care system, but also on big debates about the role of technology in people's lives, about automation replacing jobs in the labour market, about privacy and surveillance, and about fair distribution of the benefits of data and technology.

This section aims to support leaders in thinking about the role they should play by setting out some of the factors that have shaped developments to date, based around three main themes: helping the public to make the most of their data; supporting staff to maximise digital technology; and developing local and national leadership (*see* Table 2).

Table 2 Key factors in the future of digital technology in health and social care

Helping the public to make the most of data and digital technology	Supporting staff to maximise digital technology	Developing local and national leadership
• Trust in how the health and care system uses data • Sharing benefits from the value of data fairly • The nature and scale of digital exclusion	• Implementation, adaptation and redesign of everyday work • Building the skills to work with data and analytics • Capacity for evaluation of digital interventions and services	• The NHS–social care gap • Funding environment • Regulatory environment • Political leadership on digital health and care • Strategic and policy decisions

After this, we construct three possible scenarios for the long-term future of digital and data-driven technology in the health and social care system. These are designed to provoke discussion and support leaders to explore which scenario or which features of each they would like to steer the system towards. They are neither predictions nor complete in their coverage of possible futures.

Which scenario we arrive at will depend on a range of complex and interrelated factors. To understand this, we used thematic analysis of the data generated in our expert interviews and linked this to our understanding of what drove the developments detailed in the previous section. In this section we present these themes.

Helping the public to make the most of their data

Trust in how the health and care system uses data

At numerous points in our literature review, we found studies that identified issues with the way that patients were being involved (or not involved) in decisions around how their data is used, both by their care provider, but also third parties. With more and more private firms providing the tools used within the health and care system, it is becoming increasingly important that people feel confident that their data is being used appropriately.

The NHS has already had several controversies around how it shares and stores patient information. The care.data project (an initiative intended to bring together patient information into a central store for research and planning purposes) generated significant concerns about how data might be shared with third parties for secondary use (Triggle 2014). In another case, NHS Digital entered into a data-sharing arrangement with the Home Office, sharing patient data to assist in immigration investigations – an arrangement that was ended soon after it came to public attention (Crouch 2018).

During the initial phase of the pandemic, the NHS Covid-19 app was subject to changes in the terms for which it collected and stored data (Healthwatch England 2020), with concerns about the length of retention and sharing of data across public and private organisations. Separately to this, the Secretary of State for Health and Social Care made emergency amendments to the data protection regulations to allow more flexibility and easier sharing of data for health and social care providers and their partners during the pandemic (Department of Health and Social Care 2020). Public attitudes to data use for pandemic response purposes have not been tested to our knowledge.

The number of opt-outs from secondary use of personal health data held by the NHS has remained largely steady overall (NHS Digital 2020a). Only a few of our interviewees expressed the view that trust in organisations like the NHS to protect data would be lost, but all mentioned trust as an important influence on the trajectory of the technologies explored in this report and the future of the health and care system in the coming years.

Understanding Patient Data (UPD) (2020) summarises evidence generated in this area through academic and market research. It explains that spontaneous understanding of how patient data is used within the health and care sector is low, but people support the sharing of their data for individual care and for research with public benefit. For UPD, to ensure that public trust is retained into the future requires constructing a trustworthy system.

In our work with Ipsos MORI assisting with the public engagement activities of the OneLondon project (Ipsos MORI and The King's Fund 2020), we found that engaging with the public in a genuine and informed discussion helped to build practical, meaningful recommendations for data use and a mutual understanding of how the public's data would be used.

This is not to say that the NHS cannot establish a clear agreement with the people it serves around data-sharing. In fact, in some areas (such as Berkshire), coming together with the public to form a mutual understanding of how data will be used within their local area has formed the foundation of how an integrated care system (ICS) will bring organisations together (Maguire *et al* 2018).

Several companies provide products and services that create and store information that *could* be used to learn about millions of people's health-related behaviours. This includes location and activity information. If personal and wearable technology will be key to the development of digital technology in care, these private companies will also have to be seen by users and care providers as trustworthy.

Trustworthy systems require transparency and meaningful dialogue with public and patients centred on real, concrete examples (Understanding Patient Data 2019). They also require a system of robust data protection, currently provided for by the General Data Protection Regulation (GDPR) and Data Protection Act 2018. Retention of trust will also depend on the continuous, meaningful involvement of patients in major data-related decisions (Ghafur *et al* 2020).

Sharing benefits from the value of data fairly

As a result of the ongoing digitisation of many aspects of health and care, large amounts of data have been created. This data resides in the digital systems implemented in the health and care system, and in those used by patients on their own devices. In many settings, this information is now in digital form as opposed to paper for the first time. As we explained in the previous section, questions remain about how the health and care system and patients can most fairly benefit from the creation of new tools based on patient data, which are then used possibly globally by private companies.

A former NHS England board member summarised this opportunity in new avenues for building data-driven technology:

> *The other big thing going on is the digitisation of content. The US has now almost entirely digitised its provider sector with electronic patient records. The UK is now making significant strides in that space and it can make even bigger strides.*

If patients and service users feel they are being used as commercial assets without permission or that they are not seeing a fair benefit from such use of their data (for example, through improved care), then they may request that their data be removed from the systems creating new tools.

How the system and patients might take advantage of this surge of digitally stored health and care data is a hot topic; some have used the metaphor of a gold or oil rush, imagining data as a kind of natural resource that can be extracted and refined through cleaning and analysis, and commodified by sharing copies of datasets or their analyses (Steventon 2019).

One recent estimate put the financial returns the NHS could realise through commodification of patient data in the range of £5 billion to £10 billion annually over the next 5–10 years (Wayman and Hunderlach 2019). Benefits extend well beyond financial returns, with potential improvements to research and development, including the prospects of efficiency and quality improvements through tools developed using such data.

Whether this can be fairly achieved through partnership with industry will be influenced by whether the public are engaged and understand how their data is being used, and whether the controllers of data in the system at national and local levels have the incentives and access to strategic, legal and commercial skills to negotiate in the interests of the public at large.

The nature and scale of digital exclusion

Digital exclusion is understood as a deprivation of access and of the skills and capabilities needed to engage with devices or digital services that help people participate in society. It often overlaps with other forms of social exclusion and disadvantage (Honeyman *et al* 2020) and can act as a barrier where digital tools are used as a point of access to resources. There can also be a significant overlap with an individual’s health literacy.

For example, where communication happens digitally, information is often presented in a standard way without being tailored to the individual, though evidence would suggest that adapting how information is presented helps people to do more with what is presented to them (Honeyman *et al* 2020). There is unfortunately little evidence on the cost-effectiveness of adapting for specific digital inequalities compared to a generic offer across a whole population in public health, for example (Honeyman *et al* 2020).

Variations in use of different technologies are common and mean that there are opportunities to reach populations as well as barriers. The variations in digital technology use can be harnessed if we seek to understand them.

> *On the other hand, young people who have historically been hard to reach for certain things use it more. Use among very different ethnic groups varies but quite often use is high, or even higher than averages in certain groups. So, it gives you certain routes in.*
> Clinical senior lecturer and public health doctor

As digital technology has been used by more and more of the population, the gap in digital capability between older and younger age groups has closed. The reduction in this gap may not continue though – for example, it is unclear how the rapid shifts we have seen in the use of technology during the pandemic have played out across different age groups. According to one of our interviewees, ‘Digital access is a dynamic thing, it's changing all the time, and so is the population using it.’

Supporting staff to maximise digital technology

Implementation, adaptation and redesign of everyday work

In his book, *The digital doctor*, Bob Wachter describes the challenge of moving into the second phase of embedding digital technology, beyond the first generation of tools that were adopted across health systems in the

United States, including EHRs and e-prescribing (Wachter, 2015). He discusses how the tools deployed had unintended consequences as new technology collided with the social and human factors that underpin health care organisations; new tools introduced sources of error that changed interactions between staff and patients, increasing the time it took to perform regular tasks.

Atul Gawande updated Wachter's complaint in a popular article written in 2018, entitled 'Why doctors hate their computers' (Gawande, 2018). In it, he describes clinician burnout from intensifying workloads as a result of the way many US providers implemented their electronic systems. To address these issues, Wachter talks about the imperative to redesign organisational processes, now that substantial parts of the workflow have been digitised, to 'recreate (or reimagine) the parts of the exchanges that remain crucial to the work'.

Designing new tools around the workflow and processes that staff and organisations work with is most critical for the development of AI in health and care: where in the system will automation replace or support manual tasks and to what purposes? The capacity of the system to not only meet the technical challenges of building better-performing algorithms with better data, but also the social and organisational challenges of how to deploy them, will determine their impact.

> *In health care settings… information has to be very good, it has to be trusted, and so having systems where things are shifting and changing without making it apparent to people who rely on that information… I think is a key kind of question that we're going to face in these kinds of information settings.*
> Professor of technology and society

The capacity of organisations in the health and care sector to adjust new tools to the working patterns and preferences of staff and organisations will play a key role in determining how digital technology will be used in the future. This may be particularly challenging in the midst of the pressures created by the Covid-19 pandemic, both as capacity is strained by demands on intensive care services and with the need to reduce non-Covid activity during the pandemic, but also by the size of the backlog of other care that is not being provided now, which may take years to address.

These organisational factors are only one concern regarding adoption and implementation of digital tools. In England, there is often significant pressure to produce productivity gains or cost savings quickly, despite evidence showing that the return on investment of digital technology in health care is often delayed. Responsibility for distribution of funding and setting of priorities for investment has also shifted several times in recent years, leaving a confused picture.

The realignment of the health and care system around ICSs in the future may help bridge some of the organisational divides that contribute to these issues by providing strategic oversight at the local level from ICS leadership. However, local partners will probably need the time and space to address some of the difficulties of implementing new ways of working to do so (Charles *et al* 2018).

Building the skills to work with data and analytics

In many of the studies we found, there was an implicit assumption that health and care systems would have access to the kind of analytical capacity the researchers involved had access to when replicating their work. In our expert interviews, however, this capacity was identified as a key issue that the health and social care system in England has struggled to develop.

Analytical skills cover a range of capabilities, from analysis and presentation of data about organisational performance, through to modelling techniques that providers might want to utilise in understanding their local populations. They also include the skills developed by clinicians (as advocated by the Topol review) and managers to understand and act on this analysis, and the size and spread of an analytical workforce dedicated to conducting and communicating data analysis (Bardsley *et al* 2019).

One concern is that over time, these analytical skills will exist but will not be accessible within the health system's own workforce. The Nuffield Trust recently articulated concern that the technical skills required in future digital change could be impeded by current NHS pay structures, for example (Castle-Clarke and Hutchings 2019). One of our interviewees also had concerns that without the ability to attract the best analysts, the health and care system will not be able to develop systems of its own:

> *All of the best analysts might be working for one of five companies, whether it's Facebook, Amazon. Your actual… ability to change some of*

> *these [systems], both with people with higher levels of skills or literacy in your workforce, is a bit limited because a lot of it is done for us… People aren't necessarily having to go about this the hard way because a lot of it's handed to them.*
> Chief clinical information officer

A key principle here is that the move towards data-driven improvements in care is not the responsibility of specialised analysis staff alone. Many others play a role in ensuring that data analysis is able to translate into improvements in care.

> *In this [non-UK] context, the medical secretaries really play an enormous role in both how they were transitioning to an electronic health record, but also in a whole host of picking up small tasks that no one really had thought to assign. So, for example, errors in the national database: in one hospital, the medical secretaries corrected 40,000 errors alone. This was work that they put in their off-time when things weren't busy, they just kind of filled in extra work, but it's work absolutely that needs to be done in order to ensure that records could be used for research, for discovery, for other things… It's these kinds of tasks that we often forget, slip through the cracks when we're trying to do the translations from data from one area to another.*
> Professor of technology and society

This also extends to the use of analysed data in helping people to manage their health, whether collected with personal wearable devices or as part of data collected within the health system. A key skill for staff in the future will be to help individuals understand and respond to their data – for example, through behavioural change techniques like coaching or other interventions.

The health and care system must help its workforce to develop its ability to leverage data. How well staff are able to do so will determine whether the value of data can be realised in improvements to quality and efficiency.

Capacity for evaluation of digital interventions and services

Change involving digital technologies is hard to evaluate. One major reason is the dynamic, adaptive nature of the developments involved. Products and services, especially the software they depend on, can be changed very quickly, posing a set of challenges for evaluators.

In the field of AI, often systems would automatically update the models they are built upon to take account of new data, changing their responses to new cases accordingly. Sometimes this is easier to keep track of than others; the performance of a diagnostic test, for example, may be appropriately evaluated through methods like randomised controlled trials. Where an entire care pathway would be transformed, however, this requires a full suite of quantitative and qualitative information to understand the consequences for patients and systems.

As well as the adaptive nature of change, there is a risk that systems – again, particularly those involving AI – can be built that have stellar performance in controlled settings or test datasets, but do not translate to real-world impacts when they are tested. Without capacity to conduct research that assesses this, and a system that can use this evidence to act as a savvy commissioner of technology, there is a risk of failing to realise the benefits of such technologies.

As the AI field increasingly moves to the prospective clinical trial phase of research, efforts have begun to develop a clinical and technical consensus on standards for how clinical AI research is reported (Liu *et al* 2019b). The international nature of digital health means that influencing standardisation of evaluation to take into account the goals of each particular health system will be important too. Several efforts are described in NHSX's AI policy paper, *Artificial intelligence: how to get it right* (Joshi and Morley 2019).

The rapid deployment of new, digital means of access (such as remote access to primary care) in response to the pandemic has occurred without the typical preparation that would precede the implementation of a new tool within the NHS. Commissioners and providers will broadly be relying on retrospective evaluation of these tools when they have the time and space to examine their effectiveness and value for money. Capturing some metrics, such as the overall change in the number of consultations provided in primary care, will be more straightforward than capturing live information on the satisfaction of patients with these services or the impact on health outcomes (for example), as the data captured by these tools might not include these metrics by default.

The capacity of the health and care system to generate and then utilise this kind of holistic evidence will determine whether technologies like AI or mobile computing have an impact at scale on clinical outcomes, as well as the spread of such technology when business cases are built by local leaders.

Local and national leadership issues

The NHS–social care gap

Throughout much of this report, we have referred to issues for the health and social care system without much of the evidence in the literature referring to specific interventions in social care. Unfortunately, there is a clear deficit in the amount of evidence on how digital technology is being used within social care settings compared to health care.

The gap between NHS providers' digital maturity and that of the social care system appears large, even accounting for the substantial difference in technology use between NHS providers.

We heard several examples of digital technology deployment in social care from our expert interviewees, including acoustic monitoring, smartphone record-keeping, and the use of digital assistants in home care. However, these were cited as isolated examples and our literature review found little evidence relating to the impact of digital technologies in the social care sector.

The need to move to remote delivery of care in response to Covid-19 has accelerated the use of tablets in care homes to provide video consultations with clinicians, though how this trend will continue once face-to-face contact becomes safer is unclear. There remain issues with the development of digital skills within the social care workforce, as well as the infrastructure within care facilities, with a GP describing care homes as 'like Faraday cages' in our research into the primary care response to the pandemic (Baird and Maguire 2021).

Several government initiatives have focused on generating ideas and pilots within the social care sector, but explicit investment and support for scaling and spreading approaches through the sector may well be necessary, beyond the efforts of the Local Government Association's Digital Transformation programme. Social care is being left behind health care with regards to the quality and level of evidence available to support the spread and implementation of new digital tools within the sector. Without more support, it is likely to be left even further behind.

Funding environment

Whether the health and social care system puts a sufficient amount of investment towards digital services and infrastructure has long been a topic of debate. There are substantial questions on the horizon for the health and social care sector once the free or discounted deals provided by several tech companies during the pandemic expire and long-term decisions need to be made. Transitioning to a fair and sustainable model will be an important challenge, particularly for platforms that have become embedded in people's practice and workflows.

There have been few published, reliable estimates of the total spend on digital technology across central bodies, local providers and commissioners. The National Audit Office (NAO) concluded in early 2020 that previous targets for spending on digital technology were missed as 'recent investment in digital transformation has not been sufficient to deliver the national ambitions' (NAO 2020).

Looking forward over the next 10 years, the NAO reports that NHS England and NHS Improvement's own estimate of the required funding to achieve a core level of digitisation in every provider would be at least £8.1 billion, comprising £5.1 billion from central bodies before 2023/24 and a further £3 billion from local providers to 2028/29. They judged there to be a significant risk that local providers would be 'unwilling or unable' to meet the £3 billion funding expected from them in the current spending plans to 2028/29 (NAO 2020).

As mentioned earlier, funding for digital technologies can often be tied to expected efficiency gains or productivity improvements, often over a shorter time period than the available evidence on the return on investment for digital technologies in health care would suggest is possible. This pushes the incentives for digital technology adoption away from innovation and towards products with established evidence bases for cost saving – for example, replacing letters for patients with digital communication.

Such changes would be positive, but could become more limited in scope. Even the move towards the use of digital-first services in primary care is a mostly like-for-like change, with telephone contacts replacing face-to-face ones. This transformation is substitutional, not transformational, with regards to long-term condition management, for example (Baird and Maguire 2021).

It should also be noted that on capital investment, the Health Foundation (Kraindler *et al* 2019) concluded that the low overall capital investment over many years had left the IT infrastructure inadequate and ageing – an issue also identified in our examination of the changes in digital primary care during the pandemic (Baird and Maguire 2021).

Regulatory environment

Two related areas of regulation will have a major impact on the development of digital technologies over the coming years, but there are many overlapping areas that will impact on this.

First, there is the regime of rules and governance over what can be done with people's health and care data. A central part of this framework seems particularly likely to be subject to change in the next decade, with the UK's departure from the European Union (EU) leaving the status of the GDPR uncertain beyond the end of 2021. Any change in the framework introduces uncertainty as a new regime is agreed and must be assessed on the substance and likely impact on overall health and wellbeing. Understanding the likely impact on the level of public trust in the system will be particularly important, whether for reducing existing regulations or introducing new ones.

Second, there are the regulations on medical devices and, in particular, software as a medical device. The expansion of investment and development of the various kinds of software turning generic hardware (like the smartphone) into medical devices has posed challenges for regulators. These challenges have included the quantity of new devices, new (often smaller) industry players who find it hard to understand where their device fits, and a set of challenges about how to regulate the application of more techniques like AI. The PHG Foundation review (Ordish *et al* 2019), *Algorithms as medical devices,* found that more should be done to clarify this picture for industry.

The plethora of regulators in these spaces finally poses a co-ordinating and communications challenge. The Information Commissioner's Office enforces much of the data protection framework, along with the Health Research Authority. The Medicines and Healthcare products Regulatory Agency (MHRA) is tasked with enforcing the medical device regulations and any new role carved out for it in the current Medicines and Medical Devices Act that was passed in February 2021. There is no formal role for the National Institute for Health and Care Excellence (NICE) in assessing the cost-effectiveness of new health and care technologies in the same way as it does for pharmaceutical advances, though it has produced guidance on evidence standards (NICE 2019). The Care Quality Commission (CQC) and NHS England and NHS

Improvement monitor the quality and financial governance of providers, while the Office of the National Data Guardian advises and challenges information governance within the sector.

There is a need for clarity on what is expected of industry and providers using digital products and services, and the different parts of the development, deployment and monitoring pathway. This complex picture requires boundaries to be agreed and rules to be articulated and clearly understood – something that NHSX had recognised and pledged to act on in early 2020 (NHSX 2020c).

Political leadership on digital health and care

Eye-catching commitments to improve health and care technology are common, with the past two decades seeing two multi-billion pound major national IT modernisation programmes in the National Programme for IT (in the 2000s) and the paperless NHS initiative (in the 2010s). Commitments like these will continue to exist; several are already embedded in the NHS Long Term Plan (NHS England 2019), including a reduction in face-to-face outpatient attendances by one-third. However, there is currently a notable absence of commitments in social care to match.

The Secretary of State's technology vision (Department of Health and Social Care 2018) outlines a number of principles and values that could support the health and social care system to implement technology more consistently, such as open standards for record-keeping, commitments to providing high-quality tools and infrastructure to staff, and supporting productive and fair partnerships between the NHS and private companies. The ambitions in this strategy have not been met by consistent leadership across the national NHS bodies, with responsibilities shifting; more changes have been proposed to how NHSX and NHS England split responsibilities (Carding 2021) and new funding for all of these areas has not yet been forthcoming.

The wider political context will influence things like the state of digital public services across government, levels of digital inclusion, the regulatory environment, and the overall funding envelope for investment in digital technology.

Strategic and policy decisions

The ability of leaders within the health system to create digital transformation projects that have an impact on outcomes will determine what we see in the future. This can be summarised at two levels: leadership from the centre, creating the strategic environment for adoption to be spread widely; and local organisational and system leadership, in which effective technologies and practices are utilised.

> *Just technology doesn't do the transformation that health care needs. It is a people process and technology issue, which is why the health service is going to be redesigned to optimise these technologies.*
> Former NHS England board member

The kind of digital leadership required to navigate this complexity is an ability to see technological implementations as adaptive change – change which requires regular re-examination and auditing of existing systems and processes (Greenhalgh *et al* 2017), while implementation must be part of organisations' wider strategic directions. This is true for both national and local leaders.

The diversity of decisions national leaders should expect to take around the development of digital technology was striking in our interviews, bringing together overarching policy in every sector from primary care through to social care. There are also open questions about how the influence of national stakeholders feeds into the local level as ICSs develop. Which bodies will be responsible for supporting implementation and evaluation? What is the future of the Academic Health Science Networks (AHSN)? How will funding models be structured to provide flexibility to local areas? To drive adoption of technologies in the health and care system, incentives need to be provided to the organisations operating within it. It is well documented that to get incentives for care to be aligned with improved population health outcomes is challenging (Buck *et al* 2018), but will require additional expertise to support digital change.

Take primary care, for example. Our interviewees discussed how the technology eventually used by patients and staff would interact with high-level policy decisions such as changes to the primary care payment system, the impact of digital exclusion on achieving policy goals, and the likely legal decisions or negotiations about whether every location requires a physical GP surgery.

Other experts discussed national policy decisions and speculated about future ones across a large range, covering the following issues.

- The need for prompt and robust approval of multi-million pound investment business cases for providers in the NHS secondary care sector to implement or continue developing digital infrastructure – something that happened rapidly in primary and outpatient care in the first phase of the pandemic.
- How to respond to Health Education England's Topol review in professionalising digital leadership routes (such as chief clinical information officers), and making support available to boards on digital leadership.
- Where to strike the balance between priorities at the local, regional and national levels when building datasets, and maximising the value realised in using them.
- How to support a social care sector that has far less digital maturity in terms of the network and device infrastructure in place, and less historical development of the digital skills of its workforce.
- How the health system's use of national datasets responds to changes in the data protection regulatory environment that may arise from EU trade negotiations or other domestic policy developments.
- Aligning the regulatory arrangements for AI systems across several bodies that have competence for care quality, medical devices, data use and protection, and health providers.

Factors beyond the health and care system

Major long-term changes that develop in politics, economics, technology, the environment and wider society will also have an impact. In the labour market, analytical work of the kind described here for the health and social care system will be pivotal in other sectors too. Automation using AI will reshape other industries, perhaps more so than health and care. A climate emergency is currently under way and so the shift to remote contact and monitoring may be part of greater attention to the environmental footprint of the health service, reducing journeys – although additional demands for energy and materials for digital technologies might offset this. There is obviously much more to be explored in all of these factors, which we do not have time to fully explore in this report.

Three scenarios

We have constructed three possible scenarios for the future trajectory of digital technologies in the health and care system over a rough time period of the next 5–10 years. The time period is less important than the features we describe in each scenario and the different factors driving these. We hope that these scenarios can act as an illustration of how the future may unfold and help leaders in the system to think about the implications of the outcomes we describe.

There are two key dimensions along which the scenarios differ. The first we characterise as **trust** in the system's use of data. The second is the **capacity** within the health and care system to utilise digital technologies effectively. Our analysis of the literature and our interviews indicate that both will have major impacts on the products and services that are developed for and with the health and care system, and those that become available to it. They are the basis on which individual decisions are made and influence the impact of major policy decisions.

The scenarios and how they differ are set out below. It is very unlikely that any trajectory starting in 2021 will play out in exactly the ways we have described as scenarios here. We do not intend these to act as predictions but also because of remaining questions about the long-term impact of the pandemic on the needs of the populations that the system serves and the priorities for that system going forward. In reality, we will likely see a composite of features from all three and other features that are not covered here.

We have also assumed that the health and social care system will have adapted more significantly to, or moved on from, the Covid-19 pandemic by the end of this decade. As we have highlighted in the previous section, there may be differences in how trust or capacity within the sector is affected by how the system responds to Covid-19. There is potential for both aspects to be affected by how the system uses personal data in response to the pandemic, as well as the resources given to staff to adapt to change.

Table 3 Levels of public trust and capacity and capability in our three scenarios for the future trajectory of digital technologies in health and care

	Scenario 1: a health 'techlash'[1]	Scenario 2: a willing system with uneven spread	Scenario 3: spread and scale at pace
Public trust	Low	High	High
Capacity and capability	Low	Mixed	High

Scenario 1: A health 'techlash'

The first scenario is one in which the benefits that the health and care system can realise from digital technologies are limited by two related factors: a decline in public trust, and a lack of capability to take advantage of digital technology.

In this scenario, the UK health and care system fails to retain the trust of its patients and staff in the way their data is used and shared to develop digital technology (resulting in a backlash against technology, or a 'techlash'). The inverse can also be true, where the public's trust in how their data is used by health and care providers is maintained, but the public holds low trust in the technology itself; however, we do not believe this to be likely, given the increasing rate of personal technology use outlined in Section 3. Instead, we focus on a potential loss of trust in how data is used.

History serves as a lesson. Before the care.data project was cancelled, examples came to light of data being shared and handled against national and local rules (NHS Information Centre 2014). This contributed to the political decision to delay and cancel the project.

Looking forward 5–10 years and the proliferation of data-sharing arrangements, in this future scenario, despite noble intentions to support the

[1] 'Techlash' is term defined by the Financial Times in 2018 as the 'growing public animosity towards large Silicon Valley platform technology companies' which has resulted in lower public sentiment towards these companies, if not lower profits or share prices.

development of better data-driven tools for patients and staff using AI, history is repeated.

A proliferation of data-sharing arrangements with third parties, often created rapidly under the relaxed data-sharing rules in place during the pandemic, puts the capacity for governing these under strain, resulting in similar issues. A move away from the more robust data protection regime stipulated by the EU's GDPR as a result of post-Brexit international trade talks relaxes restrictions on the use of data for purposes beyond those for which it was originally collected and reduces the fines applied for misuse. A series of media stories emerge about deals with big international technology firms that built the first wave of automated clinical AI decision systems. A theme is clear: NHS providers involved in these deals are perceived to have gotten a poor deal or breached the perceptions patients held about their privacy.

The result is like importing the 'techlash' to health and care. Patient representative groups lose confidence, attack central policy and withdraw their support for data use in the NHS, having previously advocated for it with appropriate public engagement. The public lose confidence and think these kinds of technologies are exploitative of patients, the NHS and its staff, since fair exchange for the value in data was not assured. Campaigns for patients to exercise their national opt-out for secondary uses of data are successful, reducing the utility of many datasets for both the NHS and its partners, creating future risks from AI tools based on unrepresentative data. Public support to expand the current ban on sharing data beyond marketing and insurance purposes increases.

The collapse in trust damages and slows the capacity of the health system and technology sector to develop new products and services, and the capacity to evaluate their use. There is a cycle of lower investment across both private and state actors in capacity building, in terms of products and services and the infrastructure on which they run. Providers are left without the devices and services they would otherwise have implemented. Leaders and staff continue to believe that the digital tools they have in health care are always going to be difficult to use or implement. The promise of using technologies to give clinicians 'the gift of time', in the words of the Topol review, is not realised as they are not spread widely around the system.

One area that depends less on public trust and more on the decisions made by providers and commissioners is operational efficiency – where operational and logistics data is used to inform managerial decisions about how the NHS is run. As this use of data is much less tightly regulated or subject to the same kind of public scrutiny, technology supporting operational efficiency is the focus.

For example, organisations are able to use operational data to link predicted demand to staffing rotas or long-term hiring decisions more efficiently through recommendations to managers. Other opportunities for operational improvements within providers are taken with the use of pervasive sensing devices that help to track the utilisation and location of resources like beds (and perhaps staff) and support marginal gains in patient flow, allowing systems to run closer to capacity, safely, more often. The incentive to adopt operational technology depends on the system incentives, so whether these kinds of technology have an impact on the whole system's use of resources depends on the extent of wider system reform.

Scenario 2: A willing system, with uneven spread

In this scenario, public trust ends up being retained or reinforced through the construction of a trustworthy system governing data use for health care, able to meet the expansion of demand for data-sharing arrangements so that digital services can support care, as well as supporting longer-term research and development. This scenario is the one that most resembles the current state of the use of digital technology in health and social care.

Tools that automate clinical decision-making in a small set of screening and diagnostic tasks are evaluated to improve efficiency and quality of services overall after trials commenced in the early 2020s. Online triage systems put into place during the pandemic in primary and urgent care become an expected part of accessing these services, directing patients towards appropriate services. A diverse range of tools are built for staff in many different settings, dependent on a digital infrastructure of electronic records and networks across the system that meet centrally set standards. Some of these tools support clinical decision-making but most are pieces of software that automate repetitive tasks for professionals, helping to improve efficiency and bringing marginal improvements in health outcomes in the providers who can adopt them.

However, the capacity to take advantage of the digital technologies involved is not spread widely throughout the providers in the health and care system. Nor is it spread evenly through the population at large.

As is the case now, there remains extreme variation between providers in terms of the tools and capabilities available to staff. Policy decisions concentrate funding in leading providers and sectors rather than spreading the investment more evenly. In secondary care, digital infrastructure and maturity is built up in larger specialist centres serving urban areas while smaller regional units fall further behind, missing out on safety and efficiency improvements. Organisational development capabilities are similarly concentrated, with digital leadership capability for clinical leaders and boards concentrated in these providers. Tools implemented in primary care continue to be typically proprietary, without open standards that allow information exchange with other sectors.

On the patient-facing side of technology developments, there is an automatic preference for so-called digital-first service models of prevention programmes, primary care and outpatient care. But there is little effort to understand whether the allocation of resources to these models of care is equitable or efficient. Providers who might engage in better digital communication with their patients are hampered by continued underinvestment and lack of digital maturity; they tend to match up with areas where patients are already disadvantaged. Most importantly, the barriers to evaluation of interventions based on digital technology persist and there is little investment in efforts to overcome these to deliver better evaluations of such interventions.

The resulting picture is one of variation. Digitally delivered prevention programmes are rolled out with little understanding of their cost-effectiveness. Remote outpatient services are harder or impossible to deliver in less digitally mature providers, exacerbating inequalities in access. The demand-driven segmentation of the primary care population continues, as generally healthier populations opt in to digital-first providers, while the remaining ‘traditional’ GP practices meet the needs of patients who are more likely to be both digitally excluded and experiencing higher burdens of ill health at the same time. It is very hard for the centre to ensure that financial incentives are aligned so that providers are reimbursed in proportion to their populations’ care needs.

There is a failure to create an environment for digital health technology development that respond to NHS user needs. Despite declarations of intent to move the NHS and social care to a more open and competitive health technology market, it proves a tough policy challenge. Efforts to introduce competition are hampered by the continued stickiness of procurement processes and frameworks. Moves to open standards for digital services are limited by a lack of central investment to support their development and a tendency to grant local exceptions or delays in meeting them requested by dominant suppliers.

One result of this variation is that the expertise and capacity to develop technologies remains small and, in turn, system and user needs are not translated into better-designed and better-performing products and services. A range of factors, including restrictive salary policy, means that analytic and technology expertise is concentrated in 'digital-first' providers who can compete for that workforce. Software development companies focused on partnership and supply to the NHS are limited in their opportunities to expand and grow, as the varied picture limits them to more digitally mature trusts.

Developments in AI, mobile computing, and personal and wearable devices continue to improve tools that support people's own health and care; the retained trust in the system of personal data collection required for this plays a big part in people's willingness to adopt tools and accept that data will be analysed to improve this knowledge and evidence base. Digital exclusion has a big impact on the technologies used in prevention and in primary care. Little is done to address continued inequality in access and capability to use these tools.

Those with the means to do so use these tools and services to monitor their health, and spot problems sooner using the data they gather. They either gather and interpret data themselves, or they can access digital services that offer to help them act on these insights. Those living with long-term conditions served by the more digitally mature parts of the health system are equipped to provide the data to their supporting professionals through remote monitoring to help them interpret and act on new information. Those without the means – who are also more likely to be served by less digitally mature providers – are further excluded from these possible benefits, with little dividend in terms of reallocated resources to support them.

Scenario 3: Spread and scale at pace

In the most optimistic of the three scenarios constructed here, the health and care system in the UK overcomes the considerable challenges it faces in supporting the development and use of digital technology.

Attitudes among the public and among health and care professionals remain positive as a trustworthy system for the use of their data is created.

Investment continues to be directed towards research and development to build digital technologies and to evaluate them as their use expands and improves. There are benefits beyond the digital sector as a trustworthy and fair system is necessary to maximise the benefits of medical and pharmaceutical technologies.

Data breaches are rare and dealt with promptly, transparently, and through extensive use of regulators' powers. Arrangements made by the NHS for sharing proceeds from research and development enable the NHS to profit from tools that live up to the ambitious projections we see now about the future of AI. This creates financial returns for the health system, the benefits of which are shared equitably through the system (and are perceived to have been so).

Capability and capacity to use technology is spread across the system evenly, through a mixture of exemplar systems sharing and spreading good practice in well-networked provider sectors, and a move to sufficient investment from central bodies and providers in infrastructure as well as products and services.

In particular, the benefits of AI in staff-facing technology are spread to a greater extent across the system than in the second scenario. This is because the platforms and digital infrastructure on which they are deployed are adopted by a sector that has more digitally mature providers. Demand for parts of the workforce in shortage are reduced by effective and safe use of automation. For example, in screening programmes that depend on imaging (such as breast cancer screening), robust machine learning systems are deployed as part of redesigned services that result in a substantial reduction in the amount of clinician time spent reviewing.

The capacity to holistically evaluate these kinds of technology-enabled service changes is in place, meaning that safety and cost-effectiveness can be assessed through prospective trials of these redesigned services; these evaluations go well beyond the evaluation of the algorithms alone to the cost-effectiveness of services that use them. AI systems that support clinicians' decisions and care planning in hospital settings are in place.

A host of different systems are available through EHR platforms' app-store-style arrangements, using standard automated extraction processes to interact with the data held within. Regulators of these systems have taken key decisions. Where appropriate, staff are generally trained anew when deployed to a particular provider site, taking into account the distribution of the data in that population. The risks to safety that might be posed through automation bias are addressed through substantial investment in clinical safety and quality improvement programmes.

A larger and responsive health technology ecosystem helps to speed up the cycle of identifying staff user needs, expressing them to health technologists, and responding in the form of products and services that can be provided and adopted. This goes for tools for patients but especially clinicians. Systems like electronic records, e-prescribing, automated observations and clinical communication apps are developed, adapted and adopted by providers in most settings across the country. Together, they help clinicians treat people more safely and efficiently, with a low administrative burden.

One result of this robust health tech ecosystem is that the ‘traditional’ provider sector has access to tools that they demand. Clinicians have access to the necessary infrastructure and technology that allows them to offer their entire pool of patients all options. In primary care, GPs can see a patient face-to-face for a physical examination and turn to their PC or own smartphone to see a patient who has used an app to connect from elsewhere. Staff are supported to address digital exclusion among patients – for example, through social prescribing routes to schemes that promote digital skills or linking to family, friends or staff who can help support a patient’s use of technology to monitor their health or stay in touch with health services.

The analytical work necessary to create, maintain, analyse and act on data captured by the array of devices now available to patients and staff in the health system is sufficiently resourced. This enables provider management to support existing efficiency and quality improvement methods. Patients are able to manage their long-term conditions with insights about their likely course and trajectory, spotting some kinds of deterioration sooner with the remote monitoring facilitated by personal and wearable devices. Where possible, some are supported to do this through a mixture of automated data analysis that offers them nudges and structured behavioural interventions. Where automation is not possible or effective, health professionals have the capacity to interpret data and offer support that is tailored to that person’s context.

5 How can the future be shaped?

Implications and recommendations

This final section takes each factor driving the future of technology in health and care and makes recommendations for leaders within the health and social care sector who are looking to make sure the decisions they take now shape the future. These will not be the only actions available. However, they should serve as a useful stimulus and present some important ideas about how to preserve the factors that are working well, and change course or avoid some of the more troubling outcomes presented in the scenarios section.

Table 4 Key factors in the future of digital technology in health and social care

Factors	Recommendations
Trust in how the health and care system uses data	Build trustworthy systems of data based on an active understanding of public expectations for the use of their data with clear communication of potential use.
Sharing benefits from the value of data fairly	Set out principles and reform governance arrangements to ensure the fair exchange of value for NHS data, with meaningful citizen involvement in their development.
The nature and scale of digital exclusion	Invest in tools and programmes to answer some of the outstanding questions regarding the effect of digital exclusion on health, address exclusion in local populations and monitor the changing nature of digital exclusion.
Implementation, adaptation and redesign of everyday work	Build capability for continuous adaptation and improvement, using technology in practice by embedding change management processes in digital leadership development schemes and supporting the enhancement of digital skills as part of continuing

	professional development throughout the health and care system.
Building the skills to work with data and analytics	Ensure the people strategy (and workforce planning numbers) are aligned with the long-term digital and data strategy; ensure appropriate technical skillsets can be attracted to sector.
Capacity for evaluation of digital interventions and services	Support methodological development to overcome the challenges of evaluation and help generate data to support this while being realistic about the likelihood of cost savings as opposed to productivity increases.
The NHS–social care gap	Dramatically increase investment in spread and scale of best practice in social care digital technology use and into research for opportunities to support better outcomes using digital technology.
Funding environment	Funding must be aligned with expectations set from the centre, must be sufficient, will need to address historic under-investment and once committed should be delivered to the front line with pace across all forms of care, not just the hospital sector.
Regulatory environment	Ensure that regulatory bodies have clarity on how accountability around algorithm-based tools will be designated. Coordinate and sign up to clear explanations of regulatory pathways and build adaptability to future technologies.
Political leadership on digital health and care	Priority messaging must be matched with investment of time, attention to detail and delivered funding commitments.
Strategic and policy decisions	Decisions affecting digital technology should become part of the role of every policymaker. Steps must be taken to build up digital competencies across all delivery/policy staff. Avoid placing expectations on technology to achieve things that the wider system isn't incentivised to achieve and create incentives to encourage providers away from traditional forms of care delivery. Be explicit with industry about the capacity to respond to demands from the health and

	care sector that is needed, incentivise its growth and be clear about technical standards and standards for commercial behaviour.
Other major futures trends	Build an understanding of societal level long term trends in digital technology and respond to emerging changes.

As stated at the outset of this report, the health and social care system is at a crucial point in determining how the next decade will look. Following years of underinvestment in health care and cuts to social care funding, the system was already struggling to cope with an increasingly complex and ageing population when the Covid-19 pandemic created a whole new source of pressure in the short term and built-up demand in the long term.

As a result, creating the ideal environment for the development of the health and care system's capability to use digital technology will feel far more important to some in the health and care workforce than others. These pressures are not a reason to avoid the effort required to harness the potential of digital technology to improve people's lives; in fact, they are a reminder of why this agenda is so important.

The pandemic has accelerated some aspects of progress outlined in our third scenario, but there remain significant unanswered questions about how these tools will be supported and paid for when free and subsidised agreements end and how digital inequalities will affect the continued use of the tools we have seen deployed over the past 12 months. There will also be significant pressures resulting from a backlog of demand for care that need to be addressed while continuing to support the implementation of the technologies we have examined in this report.

The move towards population-based care marks the beginning of a journey for the health and care system to move away from a paternalistic model of providing care at the point of need in clinical settings and moving the intervention point towards the preventive, empowering individuals and communities to look after their own wellbeing better.

The tools highlighted in our research represent the first wave of technology that the health and care system will develop to make this happen, and the factors we have outlined in Section 4 will determine the future we face. We hope that this report has helped to highlight the key issues in what can be a fast-moving topic. With leadership, foresight and the resources to make it happen, the health and social care sector can reap the benefits from a rapid spread and uptake of digital technology, but this work needs to begin now.

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Appendices

Appendix A1: Detailed methodology

To compile our research, we undertook a literature review about digital technology to understand how others define and map the field. Some key reviews have divided their evidence by categories of technology, others mix broad fields and trends (Topol 2019), while others have focused on summarising what has happened in different health and care sectors (World Health Organization 2019) or by types of task or user within the health and care system (Baird and Maguire 2021).

Given that we were looking for high-quality evidence about recent developments and their impact on outcomes, we thought that an approach that focused on key technologies rather than higher-level trends would help us find key reviews of how that technology is being applied to care.

This research was commissioned in late 2019 and the evidence review and fieldwork with expert interviews were conducted over the winter of 2019–20. This means a large portion of the research was completed before the novel coronavirus pandemic. We have updated the initial research with publications and studies that have been released since, based on our knowledge of the system.

We developed a longlist of terms that centred around the four technologies we are focusing on in this review, outlined in the next section of this Appendix.

We excluded the following categories because our initial search gave us the impression they had not had a major impact on the UK health and care system to date, or were not distinct enough from the other categories:

- robotics – an initial literature search after sifting yielded a handful of low-quality papers
- virtual and augmented reality – augmented reality merged with internet of things as it depends on those technologies
- blockchain and similar technologies – applications in data security and sharing health data were not distinct or widespread enough to have generated a solid evidence base

- wireless networking technologies – not distinct enough from mobile computing.

We conducted literature searches in health and care and social science databases, and supplemented these results with our own handsearches of relevant journals and government policy documents, as well as papers recommended by our expert interviewees or shared by other experts on social media.

We took a 'review of reviews' approach, limiting the results to systematic and narrative reviews. This means that we have prioritised the quality of evidence ahead of how recent it is. Given that digital technology is a fast-developing field, some of our evidence may not be completely up to date with current trends.

The following exclusion criteria were applied upon a review of the titles and abstracts: irrelevance, excluding items that were not about the technology or its application in health and care; over-specialised, excluding papers from narrow fields of clinical specialties or sub-specialties; quality, excluding papers that had important limitations, meaning that their findings would not generalise; and context, excluding international evidence limited to systems with similar resources to the UK.

The original searches were somewhat useful. However, we excluded over 95 per cent of the papers returned. The literature that we added through handsearching, snowballing through references in papers and our own wider and prior reading in the areas was substantial.

We created the possible scenarios presented in Section 4 and the factors driving them through a combination of the literature review and expert interviews. We conducted semi-structured interviews with 10 experts selected for their expertise and experience in applying the technologies – either in a particular category of technologies, or in applying some combination of them to the health and social care system (*see* Table A1). We would like to thank them for their contributions to this report.

Table A1 Interviewee's role and organisation

Chief clinical information officer, and co-author of *BMJ* paper on AI safety

Clinical senior lecturer in primary care and public health and a public health doctor
Professor of technology and society
Consultant in digital technology, former doctor
Public sector expert, telecare consultancy
Former care home chain chief executive
Independent strategy consultant, former NHS England board member
Senior consultant, clinical digital consultancy
Consulting manager and command centre operations manager, digital technology supplier and consultancy
Head of digital, telehealth and online triage supplier

The interviews were semi-structured to guide participants through discussions about the key developments in applying technology in the health and care system, the factors driving them, and the possible scenarios that might see the adoption of technologies in the future. The final part of the interviews invited participants to consider what kinds of major strategic decisions policy-makers, the technology industry and patients/citizens should be thinking about now to affect those future scenarios. The interview guide is included in Section A2 of this Appendix.

We conducted a thematic analysis of these interview transcripts to construct a basic set of factors driving the developments summarised in Section 3. Using these factors, along with the outcomes of the literature review and our experience in digital health and social care research and policy to date, we grouped the factors and constructed a set of three scenarios about the developments of digital technologies in the health and care system, as well as the factors that would affect the development of each scenario.

Appendix A2: Search strategy

AI search terms

1. PubMed – 2015–20 title/abstract search

Title/abstract: (deep learning OR machine learning OR artificial intelligence OR neural network OR algorithm* OR supervised machine learning OR unsupervised machine learning) AND publication type: systematic reviews

2. PubMed – 2015–20 MeSH major topic search

MeSH major topic: (artificial intelligence OR machine learning OR deep learning OR neural networks OR algorithms OR supervised machine learning OR unsupervised machine learning) AND publication type: systematic reviews

1. Embase – 2015–20 title/abstract search

Title/abstract: (deep learning OR machine learning OR artificial intelligence OR neural network OR algorithm* OR supervised machine learning OR unsupervised machine learning) AND title/abstract: systematic review*

2. Embase – 2015–20 Emtree major topic search

Emtree major topic: (artificial intelligence OR deep learning OR machine learning OR artificial neural network OR algorithm) AND Emtree topic: (systematic review or systematic review (topic)

1. The King's Fund library database – 2015 title/abstract search

Title/abstract: (deep learning OR machine learning OR artificial intelligence OR neural network OR algorithm* OR supervised machine learning OR unsupervised machine learning) AND title/abstract: systematic review)

2. The King's Fund library database –2015–20 subject headings search

su: artificial intelligence and su: systematic reviews

Mobile computing search terms

1. PubMed – 2015–20 title/abstract search

Title/abstract: (remote consultation* OR virtual consultation* OR smartphone apps OR mobile apps OR smartphone OR digital primary care OR digital secondary care) AND publication type: systematic reviews

2. PubMed – 2015–20 MeSH major topic search

MeSH major topic: (smartphone OR computers, handheld OR mobile applications OR remote consultations) AND publication type: systematic reviews

1. Embase – 2015–20 title/abstract search

Title/abstract: (remote consultation* OR virtual consultation* OR smartphone apps OR mobile apps OR smartphone OR digital primary care OR digital secondary care) AND Emtree major topic: (systematic review or systematic review (topic)

2. Embase – 2015–20 Emtree major topic search

Emtree major topic: (teleconsultation or mobile application or smartphone) and Emtree major topic: (systematic review or systematic review (topic)

1. The King's Fund library database – 2015 title/abstract search

Title/abstract: (remote consultation* OR virtual consultation* OR smartphone apps OR mobile apps OR smartphone OR digital primary care OR digital secondary care) AND title/abstract: (systematic reviews)

2. The King's Fund library database – 2015–20 subject headings search

su: (mobile applications or mobile devices OR mobile communication systems) AND su: systematic reviews

Personal and wearable devices search terms

1. PubMed – 2015–20 title/abstract search

Title/abstract: (Wearables OR Fitness tracker* OR Activity tracker* OR Self tracking OR Quantified self OR Fitbit* OR Apple Watch* OR Apple Health OR Google Fit OR Smartphone tracking OR Step count*) AND publication type: systematic reviews

2. PubMed – 2015–20 MeSH major topic search

MeSH major topic: (wearable electronic devices OR fitness trackers OR mobile applications) AND publication type: systematic reviews

1. Embase – 2015–20 title/abstract search

Title/abstract: (Wearables OR Fitness tracker* OR Activity tracker* OR Self tracking OR Quantified self OR Fitbit* OR Apple Watch* OR Apple Health OR Google fit OR Smartphone tracking OR Step count*) AND title/abstract: systematic review*

2. Embase – 2015–20 Emtree major topic search

Emtree major topic: (activity tracker OR actimetry OR wearable electronic drug delivery patch OR wearable computer OR **wearable electronic devices**) AND Emtree topic: (systematic review or systematic review (topic)

1. The King's Fund library database – 2015–20 title/abstract search

Title/abstract: (Wearables OR Fitness tracker* OR Activity tracker* OR Self tracking OR Quantified self OR Fitbit* OR Apple Watch* OR Apple Health OR Google fit OR Smartphone tracking OR Step count*) AND title/abstract: (systematic reviews)

2. The King's Fund library database – 2015–20 subject headings search

su: (mobile devices or mobile applications) AND su: systematic reviews

Internet of things search terms

1. PubMed – 2015–20 title/abstract search

Title/abstract: (internet of things OR IoT* OR passive sens* or RFID tag* OR RFID camera* OR object tracking OR embedded computer* OR embedded system* OR augmented reality) AND publication type: systematic reviews

2. PubMed – 2015–20 MeSH major topic search

MeSH major topic: (Radio Frequency Identification Device) AND publication type: systematic reviews

1. Embase – 2015–20 title/abstract search

Title/abstract: (internet of things OR IoT* OR passive sens* or RFID tag* OR RFID camera* OR object tracking OR embedded computer* OR embedded system* OR augmented reality) AND title/abstract: systematic review*

2. Embase – 2015–20 Emtree major topic search

Emtree major topic: (internet of things OR radiofrequency identification) AND Emtree topic: (systematic review or systematic review (topic)

1. The King's Fund library database – 2015 title/abstract search

Title/abstract: (internet of things OR IoT OR passive sens* or RFID tag* OR RFID camera* OR object tracking OR embedded computer* OR embedded system* OR augmented reality) AND title/abstract: systematic review

Science Direct https://www.sciencedirect.com/search/advanced

The free, simplified version
[Title/abstract/keywords] (Internet of things OR passive sensors OR passive sensing OR RFID tags OR RFID cameras OR object tracing OR embedded computers OR embedded systems) and systematic review and healthcare

Google Scholar

"systematic review" NHS OR healthcare OR health "internet of things"
Also: passive sensors OR passive sensing OR RFID tag OR RFID camera* OR object tracking OR embedded systems OR embedded computers OR augmented reality
Robotics search terms – attempted

PubMed

1 [MeSH major topic]: robotic surgical procedures AND publication type: systematic reviews) NOT title/abstract: (robot-assisted OR robotic-assisted)

2 (Title/abstract: robot* AND title/abstract: surgery AND publication type: systematic reviews) NOT title/abstract: (robot-assisted OR robotic-assisted)

3 (Title/abstract: (robot* OR drone*) AND publication type: systematic reviews)

Embase

1 (Emtree major topic: (robotics OR robotized exoskeleton)
AND Emtree topic: surgery AND Emtree topic: (systematic review or systematic review (topic)) NOT title/abstract: (robot-assisted OR robotic-assisted)

2 (Title/abstract: robot* AND title/abstract: surgery AND (Title/Abstract: systematic review OR Emtree topic: (systematic review OR systematic review (topic)) NOT title/abstract: (robot-assisted OR robotic-assisted)

3 Title/abstract: (robot* OR drone*) AND (title/abstract: systematic review OR Emtree topic: (systematic review OR systematic review (topic))

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Kw: (robot* or drone*)

Appendix A3: Interview guide

Section title [suggested time allocation for one-hour interview]

Introduction to the project [5 minutes]

- The King's Fund commissioned by the Health Foundation.
- Recap objectives of the interviews: (1) to understand the changes in digital and data-driven technology and their impacts on health and care; (2) to explore how these could develop in the future; (3) to consider some of the implications for policy.
- Remind them of scope and definition of digital and data-driven technology and that we are asking them to speak in their capacity as an expert in XXX area, but are interested in their thoughts more broadly around system-wide implications.
- [Optional] review the key points of information sheet:
    - How we'll use the transcript
        - Identifiable quotes, list experts
        - Initial audience: The King's Fund, Health Foundation and the Health Foundation Strategy Group
        - Possible public-facing report/materials
        - Chance for them to ask questions.
- Turn on recorder.
- Ask them to confirm who they are and verbally restate their consent.
- Ask them to provide brief overview of their current role and experience.

Part 1: Key developments to date [20 minutes]

1. If you were talking to people outside your field of expertise and they were to ask you to look back five years and identify the key changes in the way technology has changed in your [specialist area], what would they be?
    a. [If international] is there anything specific or different about the UK health and care system's recent development?
2. What do you think the impact has been on health and/or social care?
    a. Why/ in what circumstances?
    [Probe on specific examples, and what evidence they are drawing on eg, anecdote/research, what circumstances]

[Use the prompts below if necessary – no need to cover all]

- safety of care using these technologies
- effectiveness of care using these technologies
- patient experience of care
- timeliness of care
- efficiency of care
- equity of care
- staff experience.

3. What are the factors that drove these changes?
    a. inside the health system
    b. outside it.

    [Use prompts if necessary: regulation, policy, financing, scientific/ technological discovery]

Part 2: Possible scenario for future impact, covering near-term then further ahead [25 minutes]

Let's mainly think now about the future, and where health systems like that in the UK could be heading with digital and data-driven technology. We're interested in the key developments we're likely to see in the technology in your field – and the way it gets implemented in health and care in the next **five years**.

Probe about:

4. What is it about the technologies and devices themselves that is likely to change in this period?
    a. Is there anything in other sectors that may be relevant to health and social care?

5. What about the ways in which they are applied in health and social care (UK and elsewhere)
    a. We're thinking here about the business and care models that use them.

6. What will be the impact on the health and care system? Why/what circumstances?

[Use prompts for examples of different areas they could have impact on:] safety; effectiveness; patient experience; timeliness; efficiency; equity – will some groups benefit more than others?; staff experience.

7. Why do you think this is the likely scenario?
   a. What assumptions do you have about the future that underpin this scenario?
   b. Where are the key uncertainties in these assumptions?
   c. How preferable is this future scenario?

8. IF NEGATIVE: What is a more preferable scenario?

9. What about looking further ahead 10 years? Where are the key uncertainties?

Ending: Key opportunities to shape development and impact [10 minutes]

Our key audience for this project are quite senior decisionmakers with national responsibilities for planning, regulating, delivering, etc. The organisations involved influence the health and care of millions of people across England. We're interested in helping them understand how decisions taken today will shape the impact of digital and data-driven technology on the system in future.

10. What are the factors and drivers shaping the future in your field, and how can these kinds of decision-makers affect them?
    a. Are they factors amenable to:
       i. governments, regulators, providers?
       ii. citizens and collective action?
       iii. technology companies and their leadership / employees?

11. And given the purpose of this project, is there anything we haven't covered today that you are surprised that we should be considering?

12. [Optional] Are there any authors or specific papers that you think an evidence review like this should definitely cover?
    - narrative/systematic reviews particularly

Appendix A4: Interview transcript analysis framework

Key developments to date (for capturing interviewees' accounts of the trends in digital and data-driven technology in recent past)

- Mobile computing
  - description of technology
  - impact on system.
- Personal and wearable devices
  - description of technology
  - impact on system.
- Artificial intelligence
  - description of technology
  - impact on system.
- Internet of things / pervasive sensing
  - description of technology
  - impact on system.
- Robotics
  - description of technology
  - impact on system.
- Virtual and augmented reality
  - description of technology
  - impact on system.
- Digital and data-driven tech from other categories
  - description of technology
  - impact on system.

Predictions about the future

- Description of key technology trends
  - mobile computing
  - personal and wearable devices

  - artificial intelligence
  - internet of things / pervasive sensing
  - robotics
  - virtual and augmented reality
  - digital and data-driven tech from other categories.
- Impacts on the health and care system
- Judgements about likelihood
- Opportunities to shape
  - policy-makers
  - industry
  - citizens/collective action.

Key themes (a set that is developed as the transcripts are analysed)

- Public trust and engagement

About the authors

David Maguire is a senior analyst in the policy team at The King's Fund and is responsible for the analysis of quantitative data, using a range of methods, across topics including workforce, primary care, inequalities, productivity and social care.

Before joining The King's Fund, David worked at the South Eastern Health and Social Care Trust in Northern Ireland where he supported managers to make their services more financially sustainable. He has an MA in health economics from the University of York and previous experience in the commissioning sector in Northern Ireland.

Matt Honeyman worked in The King's Fund's Policy team between 2013 and 2020, during which time he worked on projects across the full breadth of the Fund's Policy and research work. He specialised in and led work on the use of digital technology in the health and care system, having studied for an MSc at the Oxford Internet Institute in 2017. Matt now works as the Policy and Information Governance Lead at accuRx, a company that builds software to facilitate communication in the health and care system.

Deborah Fenney works in the policy team At The King's Fund. Before joining the Fund in 2018, Deborah worked for two years as a senior analyst at the Care Quality Commission (CQC). While at CQC she worked on various projects including reviews of health and social care systems in local authority areas and a review of how NHS trusts investigate deaths of patients.

Deborah has a PhD in sociology and social policy from the University of Leeds, which explored disabled people's access to sustainable lifestyles

Joni Jabbal is a researcher in the Policy team and contributes to the Fund's research and analysis on health and social care policy and practice. Joni is responsible for work tracking the performance of the health and social care system through the Fund's Quarterly Monitoring Report.

Joni has a particular interest in incentives and behavioural outcomes in health care settings. Before joining the Fund in 2013 Joni worked at the Royal College of Physicians, focusing on the impact of the NHS reforms, developing new models of urgent and emergency care services, and leading the college's public health work. She has an MSc in comparative social policy from the University of Oxford.