Digital Health & Care
Innovation Centre

Emerging Trends in Digital Health and Care:
A Refresh post-COVID

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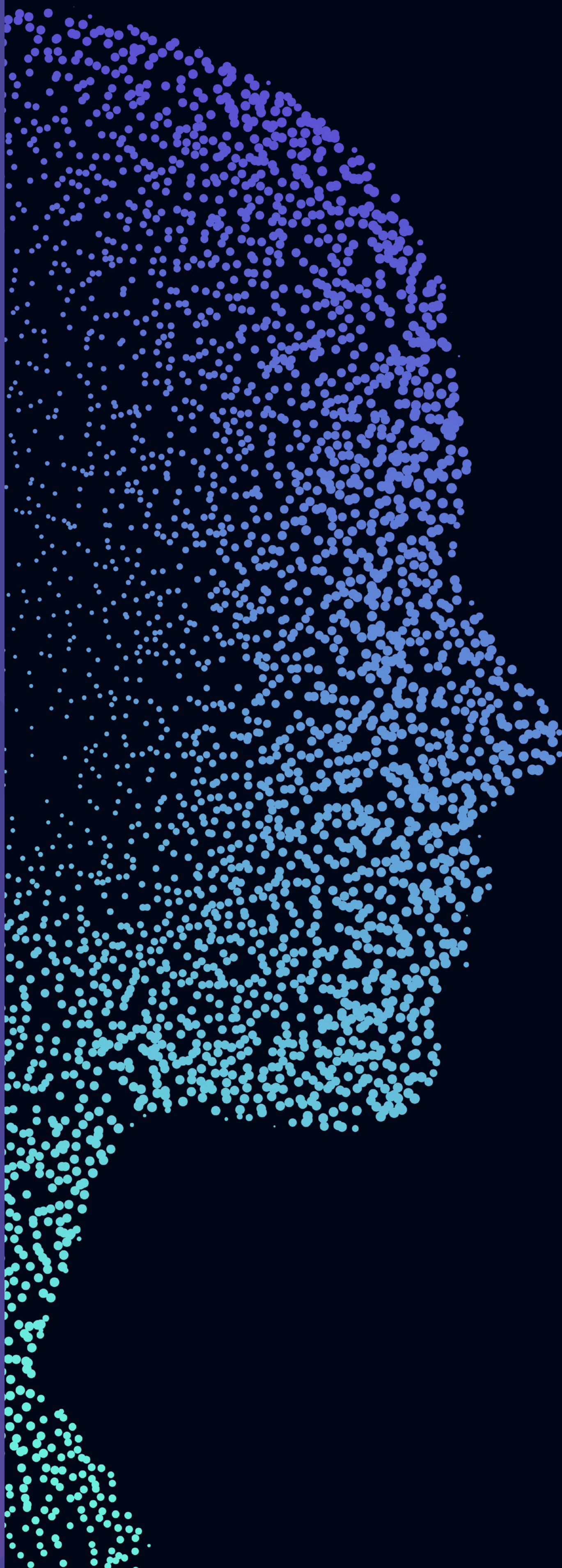

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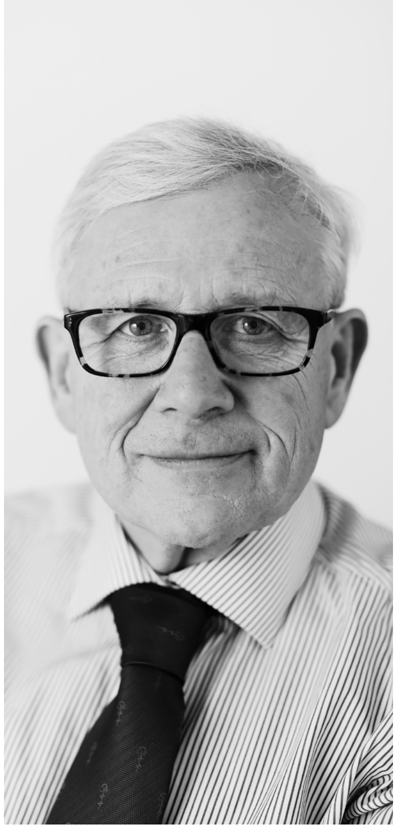

John Galsworthy, the Nobel laureate said, “if you don’t think about the future, you cannot have one”. This is as true today as when he said it a 100 years ago.

Building on previous global research carried out by DHI, this report reviews the digital health and care landscape in the aftermath of the global COVID-19 pandemic, and helps pinpoint areas where digital health and care are finding traction and beginning to add value in the planning, organisation and delivery of health and care services around the world. The role that technology can - and may - play in the future delivery of health and care is only limited by our imagination. If we do not understand the art of the possible, we may miss significant opportunities created by digital tools and services that are available today. By focussing our attention in areas that are beginning to develop traction elsewhere, and by taking learning from others’ experience in scaling up innovations, we have the opportunity to de-risk future investments in time, effort and funding.

Professor George Crooks OBE - Chief Executive Officer

Glossary

Analogue Systems - process analogue signals, which can take any value within a range, for example, the output from a microphone (e.g., an audio amplifier) (Electronics Club n.d.). Many telehealth technologies rely on analogue telephone lines to work. These are being switched off in Scotland in 2025.

Artificial Intelligence – refers to "the science and engineering of making intelligent machines" (McCarthy, 2007). Artificial intelligence is a broad term, describing various systems which perform cognitive processes like those performed by humans (D'Alfonso, 2020).

Big Data – a dataset which is too extensive in volume, variety, velocity, and/or variability to be effectively managed through traditional software or approaches (National Institute of Standards and Technology, 2015).

Big Data Analytics – refers to the use of advanced analytic techniques against very large, diverse data sets, and that include structured, semi-structured and unstructured data pertaining to different sources (IBM, 2022a).

Blockchain – a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a network. Widely identified as the most appropriate technology for the healthcare system to provide secure management and analysis of big health data (IBM, 2022b; Qadri et al., 2020; Kashani et al., 2021).

Body Area Networks – sensors which are worn or implanted under the skin, used for measuring vital signs and detecting emotions (Negra et al., 2016).

Clinical Decision Support (CDS) – digital tools, including computerized alerts/reminders, focused patient information, and diagnostic support, used to enhance decision making in clinical settings (Office of the National Coordinator for Health Information Technology, n.d.).

Cloud Computing - on-demand access, over the internet, to hosted services, such as data storage, servers, databases, networking, and software (Patil et al., 2022).

Digestible – Digital Pill (DP) relates to digital pharmaceuticals. DP involves medication ingredients combined with digestible sensors to monitor medication ingestion, aiming to decrease medication non-adherence and collect various personal data (e.g., behaviours) (Peters-Strickland et al., 2018).

Digital Biomarkers – quantifiable physiological and behavioural data that are collected and measured via digital devices, including mobile devices, wearables, implants or digestibles (Karger, 2022).

Digital Phenotyping – refers to the "moment-by-moment quantification of the individual-level phenotype in-situ using data from smartphones and other personal digital devices" (Torous et al., 2016).

Digital Systems - process digital signals, which can take only a limited number of values (discrete steps), usually just two values are used: the positive supply voltage (+Vs) and zero volts (0V) (Electronics Club, n.d.). Computers are all based on digital systems.

Digital Therapeutics – refers to any patient facing evidence-based therapeutic interventions that are driven by software to prevent, manage or treat a medical condition with proven clinical benefit (Patel and Butte, 2020).

Electronic Health Records (EHRs) – electronic/digital versions of a patient's medical history kept by their healthcare provider, which include all administrative clinical patient data (Keshta and Odeh, 2021).

Electronic Medical Records (EMRs) – contain patient-related health data and are made up of legal and administrative records composed in a hospital environment, allowing staff to optimise tracking patient's medical/treatment history (Keshta and Odeh, 2021).

ePrescribing or electronic prescribing - technology framework that allows physicians and other medical practitioners to write and send prescriptions to a participating pharmacy electronically instead of using handwritten or faxed notes or calling in prescriptions (TechTarget, 2010).

Genomics – the study of all a person's genes (the genome), including interactions of those genes with each other and with the person's environment. (National Human Genome Research Institute, n.d.).

Haemodynamic - the branch of physiology that studies the circulation of the blood and the forces involved (Wordnik, n.d.).

Healthcare Analytics – focuses on technologies that support the analysis of health and care data, including clinical, pharmaceutical, cost, and patient behavioural data.

Internet of Things (IoT) – a network of hardware that connect and communicate to each other via the Internet.

Machine Learning (ML) – is a "sub-category of artificial intelligence that refers to the process by which computers develop pattern recognition, or the ability to continuously learn from and make predictions based on data, then make adjustments without being specifically programmed to do so" (Hewlett Packard Enterprise, 2020).

mHealth – relies on mobile communication devices for the delivery of health and care services and information. Often overlaps with telehealth solutions.

Natural Language Processing – a branch of computer science which focuses on allowing computers to understand text and spoken words in the same way as humans. A subfield of artificial intelligence (IBM, 2022c).

Personal Health and Care Record (PHR) - an application or online platform through which patients are able to maintain and manage both their own health information, but also when authorised the information of others, in a private and secure space (NHS, 2022; Nazi, 2021).

Predictive Analytics – an aspect of advanced analytics that makes predictions about future outcomes using multiple statistical techniques including machine learning, predictive modelling, and data mining (IBM, 2022a).

Remote Patient Monitoring/Telemonitoring – "refers to the recording and transmission of patient biometrics, vital signs and/or disease-related data to a healthcare provider using information and communications technology" (Taylor et al., 2021).

Telehealth (also known as virtual health) – involves the use of telecommunication technologies to deliver care-related services, information supporting patient care, administrative activities, and health education. It includes a broad spectrum of services including patient/clinician contact as well as patient education, advice, health interventions, and monitoring.

Telecare – refers to assistive technologies which support individuals to live independently in their own home (Croner-i, 2012).

Digital Health & Care Innovation Centre

Executive Summary

Executive Summary

In November 2019, the DHI released a 'Review of Emerging Trends in Digital Health and Care ' to try and understand the future direction of the field. In the aftermath of the COVID-19 pandemic, the landscape of the digital health and care sector has been forever changed. The DHI have performed this review of emerging trends in digital health and care in the post-COVID era to understand how the pandemic impacted the sector and how it may shape its immediate future.

In the lead up to the pandemic, the implementation and use of digital health solutions and awareness of the field were steadily on the rise. However, the onset of the COVID-19 pandemic saw an unprecedented hike in the provision and the use of digital health and care solutions.

This was a direct response of the health and care services globally to the various national lockdown measures implemented at the time. While such high levels of use of digital tech in health and care delivery are expected to fall post pandemic, the levels will remain much higher than those observed before the pandemic.

This pandemic-accelerated proliferation of digital health and care solutions predictably pushed the sector onto the world stage, as the underlying infrastructures, legislation and guidance for these solutions needed to be realised.

This report has been informed by large-scale desk research of academic and grey literature, drawing information on post-COVID developments in digital health and care from international sources and across all levels of government, academia, business, and industry. The report begins with looking at the enablers and drivers affecting the digitalisation of health and care, followed by a digital health and care market overview.

After this, the report is organised into two parts: Part 1 reviews the various technical developments and Part 2 examines softer developments in digital health and care post-COVID. These developments are presented under overarching themes of the transformation of health and care services, migration from analogue and legacy systems to modern digital approaches, the acceleration of digital innovation in health and care, and the acceptance of digital in health and care.

Within these themes and across the various subsectors in digital health and care, the following overarching trends were identified, which are discussed in the conclusions:

1. Greater personalisation of health and care.
2. More efficient, effective, and precise use of health care data.
3. Growing health data autonomy for citizens.
4. Overall emphasis on wellbeing and prevention of ill health.
5. Care moving away from hospitals into community setting.
6. Transformation in skills needs and workforce requirements in health and care.

The primary takeaway from this review is that there is now an established acceptance for digital health and care solutions as part of health and care service delivery. The pandemic has acted as a catalyst for change in the sector, with citizens expecting digital technology to play a part in the delivery of their health and care (Figure 1).

Figure 1. Emerging trends in digital health and care (1).

1 - Introduction

This report has been written by the Digital Health & Care Innovation Centre (DHI) as an update on our 2019 "Review of Emerging Trends in Digital Health and Care" (Rooney et al., 2019).

This report seeks to provide a broad overview of the emerging trends in digital health and care in the post COVID-19 era but does not claim to be exhaustive in its overview of the sector's future. This document is based on rigorous desktop research that has been thoroughly reviewed by digital health and care peers but has not been subjected to an academic peer-review process.

The digital health and care sector has become more established and better known in the years following the release of our 2019 review. Despite this, the very definition of the sector is still somewhat in flux. The context this report discusses digital health and care arises from the intersection of health and care services, information technology, mobile technology, and other novel digital technologies, for the purposes of advancing and improving health and wellbeing for the individual and overall population (Deloitte, 2015).

The digital health and care solutions within this context comprise certain essential elements, including wireless devices, hardware and software sensors, the Internet of Things (IoT), mobile and body area networks, health IT, and genomics or personal genetic information. The varied nature of these elements means that the term digital health forms an umbrella term for the various sub-sectors used throughout this report.

1.1 - Impact of COVID-19 on Digital Health and Care

The COVID-19 pandemic has had, and will likely continue to have, a significant impact across global health, economics, and society. Healthcare specifically has faced massive disruptions both directly as a result of the immediate effect of the virus itself, and indirectly due to the public health measures put in place to combat the virus. These developments will likely have a negative effect on health outcomes in the immediate aftermath of the pandemic and beyond (Scottish Government, 2021a).

Prior to the pandemic, digital solutions were gradually being introduced in health and care services. We witnessed, for example, an increased use of online platforms, such as NHS Inform, that provide reliable and accessible information on healthcare conditions, instructions for self-care, and when to contact clinicians.

Similarly, secure messaging applications for healthcare providers were becoming more and more popular. Meanwhile, other technologies for virtual care and remote monitoring were rarely being used in standard practice, a trend reflected within the clinical literature at the time (Van Hattem et al., 2021).

Multiple common measures were observed across the world in response to the pandemic. These include health services being forced to reorganise care for existing patients to reduce the number of face-to-face clinical appointments; having to find ways to remotely triage cases requiring urgent consultations; postponing non-urgent appointments (including elective procedures); and establishing new infection control measures (Gunasekeran et al., 2021). The methods used to enable these measures, and to work around their negative impacts, propelled the digital health and care sector onto the global stage as the need for digital alternatives to standard health and care skyrocketed. This, in combination with the advancement of digital transformation of health and care services leading up to the pandemic, resulted in unforeseen rates of rapid technological adoption and digital transformations (Willis Towers Watson, 2021).

In the UK, one of the immediate responses to the pandemic was the development of comprehensive guidance to implementing digital technologies in health and care services. The processes ranged from the setting up of required technologies within care systems to delivering services digitally (Van Hattem et al., 2021). This move enabled, for example, the rollout of "Track and Trace" measures, the creation of online COVID-19 vaccination booking system, and the adoption of virtual health technologies providing remote consultations and care with healthcare professionals for non-COVID-19-related health concerns (Gunasekeran et al., 2021).

Pausing "normal" health services during national lockdowns created extremely long waiting lists and likely widening health inequalities. This has also led to profound changes in how health and care services have been, can be, and are expected to be delivered in the immediate future and beyond. Where health and care services, organisations, providers, and users had been resisting the use of digital solutions, they were faced with no other choice. The use of digital solutions during the pandemic became the 'new normal', with trends suggesting that as we move out of the pandemic their use will not fall away (Rosser, 2020). The lessons learned about health and care service models and methods of digital health systems implementation during the pandemic provided a clearer picture of barriers to adoption and measures that can be employed to circumvent these barriers with future digital health systems' employment (Gunasekeran et al., 2021). These developments present the sector with the opportunity to embed data-driven digital health solutions into everyday health and care practices.

1.2 - Healthcare Digitalisation Journey – Enablers and Drivers

Cloud computing is one of the main enablers of healthcare digitalisation; since around 2005, increasing integration of cloud computing into healthcare patient and management systems has enabled storing and sharing healthcare information across as many connected internet-based devices within IT infrastructures. At the beginning, cloud computing was mainly adopted in the form of electronic health records (EHRs), first introduced to NHS boards in 2005 (McMillan et al., 2018).

EHRs adoption initiated the process of interrelated technological development (enablers) and increased adoption and investment into digital health solutions (drivers), detailed in this report.

As healthcare IT infrastructures expanded, the growing patient data, later termed 'big data', enabled development of predictive analytics used to improve and personalise care at the time when mobile technologies, especially smartphones, started to 'personalise' daily lives of citizens worldwide (Gu et al., 2020). The period between 2016 and 2020 saw rapid technological development, including telehealth and machine learning, enabled by emergence and integration of 5G technology in 2018 (Georgiou et al., 2021) with 'big data', accelerating Internet speed and device load. Government initiatives to improve care and decrease healthcare costs were fast emerging, especially when the 2020 COVID-19 pandemic required immediate provision of remote care services (UK Government, 2022). Key investors, both businesses and government projects, have increased tech jobs, currently driving development and integration of new technologies within significantly digitalised healthcare system, reflected by the announced 2025 UK switch-off of all analogue services (BT, 2022). The timeline for the digitalisation of health and care is outlined in Figure 2 below.

This report will discuss the most recent developments in digital health and care against this background, identifying emerging trends stemming from the discussed chronological interplay between technological enablers and human drivers changing care practices forever.

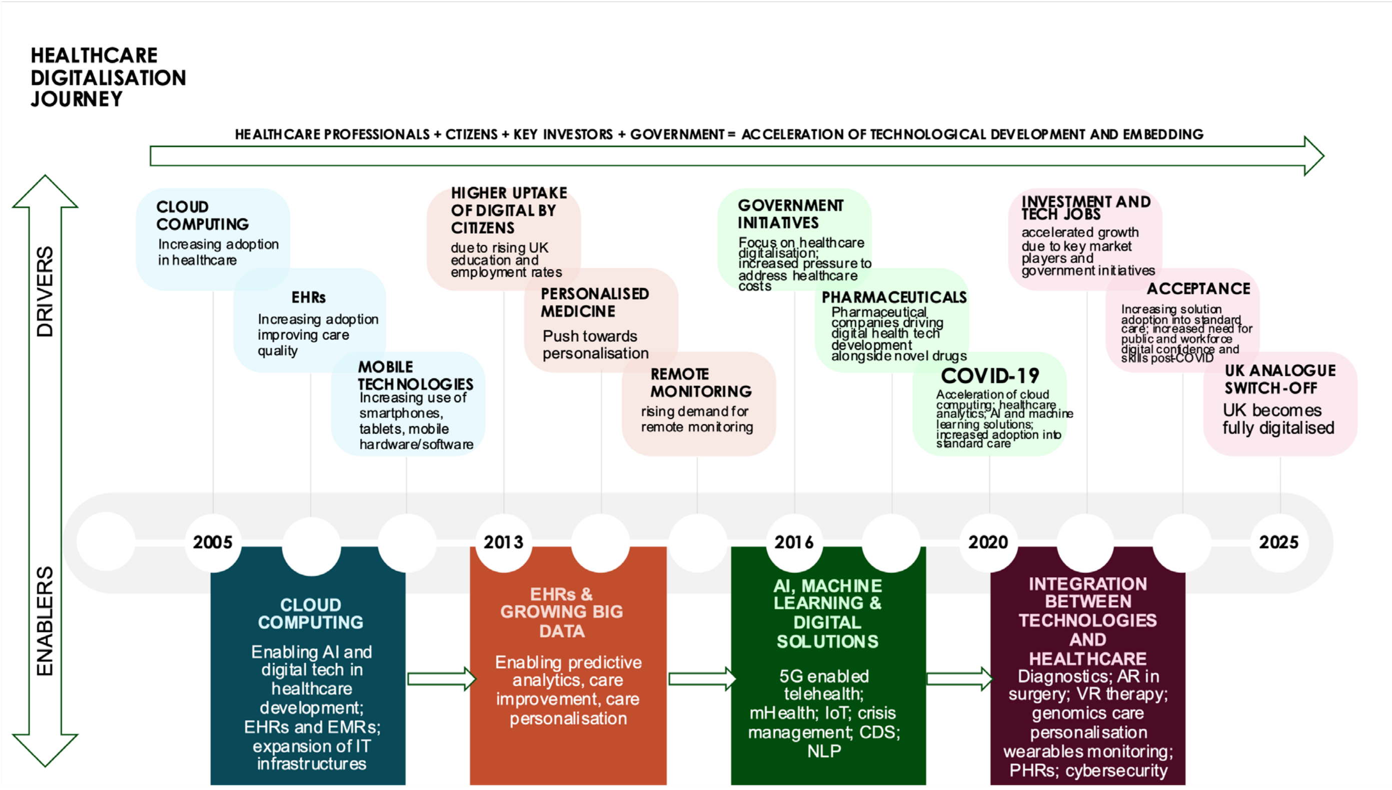

Figure 2. Infographic depicting the timeline for the digitalisation of health and care

2 - Digital Health and Care Market

Prior to the COVID-19 pandemic, the digital technology sector was estimated to be growing at six times the rate of rest of the UK's economy (Tech Nation, 2020a). As we emerge from the pandemic, it is expected that the tech sector and health and care sectors will be key drivers within the recovering global economy (Deutsch, 2021). As a key component of the overall digital technology market, the digital health and care market continues to grow alongside it. In 2020, the global digital health and care market size was estimated to have reached $96.5-141.8bn and was projected to grow by 15.1% to 17.4% at global Cumulative Annual Growth Rate (CAGR) over the next six to seven years (Global Market Insights (GMI), 2021; Grand View Research (GVR, 2021a). These projections estimate that the global market could reach anywhere between $295.4 to $426.9bn by 2028 (GMI, 2021; GVR, 2021a). Counter to this, Statista (2021a) have forecast that the global digital health and care market size could increase from $175bn in 2019 to $657bn in 2025, far exceeding estimations made by other market reporting agencies. Despite the variation in estimates, the outcome is the same: the global digital health and care market will continue to grow as it has over the last five years. This increase will be mirrored in the UK, where the current digital health and care market is expected to increase from $3.44bn in 2021 to $5.20bn in 2025, growing at a rate of 10.85% CAGR (Statista, 2021). As we examine the individual market sub-sectors, we can see that the pandemic caused an increase to the market growth rate, although this may be subject to change in the immediate aftermath of the pandemic.

The market growth can be attributed to a combination of enabler and catalyst technologies and initiatives, including increased use of smartphones, tablets and other mobile hardware and software platforms; the rapid expansion of the underlying digital health and healthcare IT infrastructures in industrialised nations; government-driven initiatives focussing on spreading digital health and care in the North American and European regions; a rising demand for remote patient-monitoring services; the global digital response to mitigate COVID-19 lockdown measures and the subsequent increase in digital acceptance for health and care; and a growing interest from and investment by venture capital organisations (GMI, 2021), something that has continued to increase for the seventh consecutive quarter by Q2 2021 (CBINSIGHTS, 2021). This was majorly contributed to by the large uptake in digital transformation initiatives in response to the pandemic. The growth trend has also manifested across Europe; however, Asia saw a recent investment decrease (CBINSIGHTS, 2021). CBINSIGHTS (2021) established that globally, the investments have predominantly been focused on the fields outlined in Figure 3, possibly acting as primary market drivers in the coming years.

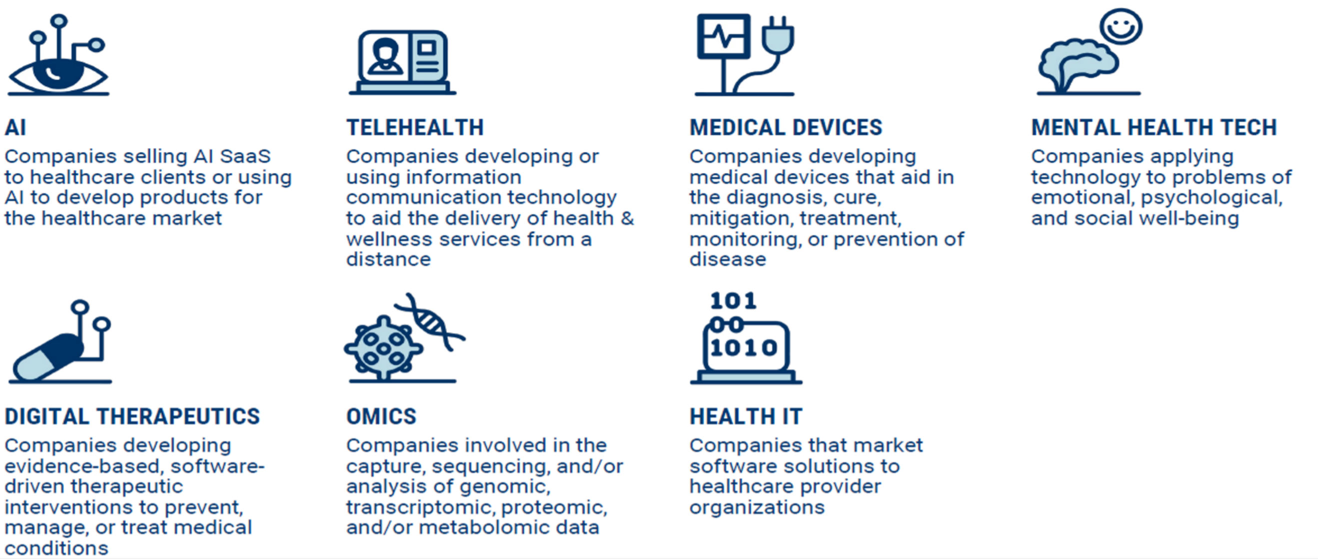

Figure 3. Depiction of segments of the digital health and care market that are receiving the most investor focus (CBSINISIGHTS, 2021).

The COVID-19 pandemic has disrupted all major global economic sectors; however, in the UK, the digital tech sector has persevered through the economic hardship witnessed during the COVID-19 pandemic, with sector job opportunities increasing at a rate of 2.6% a month, and over 75,353 job advertisements as of November 2020 (Tech Nation, 2020a). The digital health and care sector was also impacted less than others due to increased demand for digital interventions during the lockdown period.

A rise in digital tech job roles has propelled the UK economic recovery via the increase in above-average salaries. In the UK, the average salary for digital technology roles was estimated at £53,318 in 2020. By contrast, the average UK salary for non-digital tech roles was estimated at £36,903 (Tech Nation, 2020a). Within the more specialised digital tech roles, the average salary has markedly increased in comparison to these averages. For example, salaries for network security roles saw a rise of 69% in 2020 (Tech Nation, 2021). This was attributed to the highly significant increase in remote working that heavily relied on secure digital networks (i.e., Microsoft teams, Slack, etc.).

It is important to note that 37% of digital tech workforce operate in non-digital roles, such as marketing and legal, and that these roles will continue to contribute to the sector and future innovation (Tech Nation, 2021). Furthermore, while the salaries for the wider digital technology sector are higher than average, the salaries for digital, data and technology roles within the healthcare sector are significantly lower, although changing region to region (Tech Nation, 2020b) (Table 1).

Table 1. Table showing examples of median salaries for digital, data and tech jobs within the NHS pre-pandemic (adapted from Tech Nation 2020b).

Regions	No. advertised jobs overall	No. advertised dig tech jobs	% dig tech advertised jobs	Median Salary for digital, data and technology jobs, 2019
Edinburgh	1021	41	4.0%	£22,254
London	154538	2657	1.7%	£36,783
Manchester	52592	885	1.7%	£26,315
Newcastle	8940	170	1.9%	£33,834

The afore-described variation and range of the different market size projections is likely due to evaluators incorporating different regions in their projections or by examining the digital health sector from different perspectives. For the purposes of this market review, we will examine the market based on the four most common segments/sub-sectors of digital health used in market reviews, these being Telehealth, mHealth, Healthcare Analytics, and Digital Health Systems. Figure 4 breaks these segments down into their individual components that build up the estimated market values. In the following section, we will examine each individual sector with more focus to establish a clearer picture of the digital health and care market.

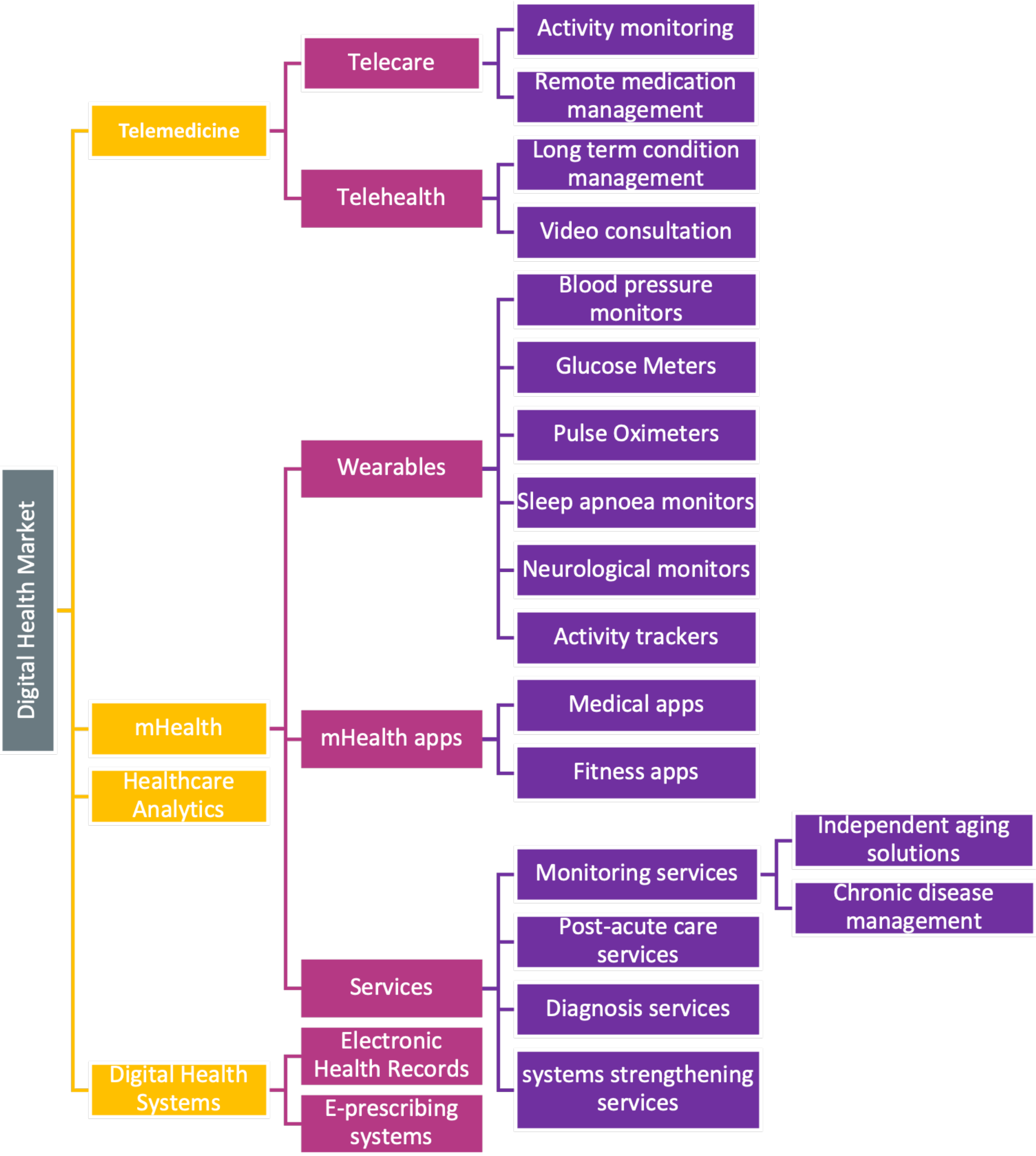

Figure 4. A breakdown of the digital health market segments based on market reporting by GMI (2021).

2.1 - Telehealth

Telehealth, often referred to as virtual health, involves the use of telecommunication technologies to deliver care-related services, information supporting patient care, administrative activities, and health education. It includes a broad spectrum of services including patient/clinician contact as well as patient education, advice, health interventions, and monitoring. The technologies in the telehealth market are not necessarily digital, though the use of analogue telehealth solutions is quickly declining as the use of digital solutions increases. In the UK, that development has been accelerated by the approaching deadline of 2025, when the UK telephone companies will finally switch off analogue services and only support digital Internet protocol technologies (BT, 2022). A key lesson learned during the COVID-19 pandemic was the incomplete and limited nature of digitalisation across multiple sectors, which struggled to cope with the infrastructural requirements of the rapid transition from analogue to digital; this could be seen, e.g., in the incompatibility across health services and the chosen digital responses to national lockdown measure (Faraj et al., 2021). In preparation, telecare services are aiming to provide digital alternatives in advance to ensure care continuation (East Renfrewshire Council, 2021).The deadline and the ongoing preparatory work will likely contribute to the significant increase in telehealth's market size in the immediate future.

Telehealth has seen an immense growth in overall use and market size in response to the COVID-19 pandemic when its use surged to almost 80-fold in comparison to pre-COVID levels. While this reduced in the following months, in early 2021 the usage stabilised at approximately 38 times higher level compared to pre-COVID figures (McKinsey and Company, 2021). This trend is presented in Figure 5 below.

The increase in the use of telehealth technology, alongside rising chronic condition prevalence, ageing populations, and demand for cost reduction, led to projections that the global telehealth and telemedicine markets could grow from an estimated $87.8bn in 2022 to £285.7bn by 2027, at a CAGR of 26.6% (Markets and Markets, 2022), with further estimates predicting the market size to reach 380.3bn by 2030 (Research and Markets, 2022).

In the UK, it is expected that the demand for telehealth services will remain high post-COVID, allowing for increased growth in the UK market. Pre-COVID, telehealth was predicted to show year-on-year growth from 2016 to 2021; having met this expectation, the telehealth market is expected to continue to grow from 2021 to 2026 as demographic and healthcare system structures continue to shift (IBISworld, 2021).

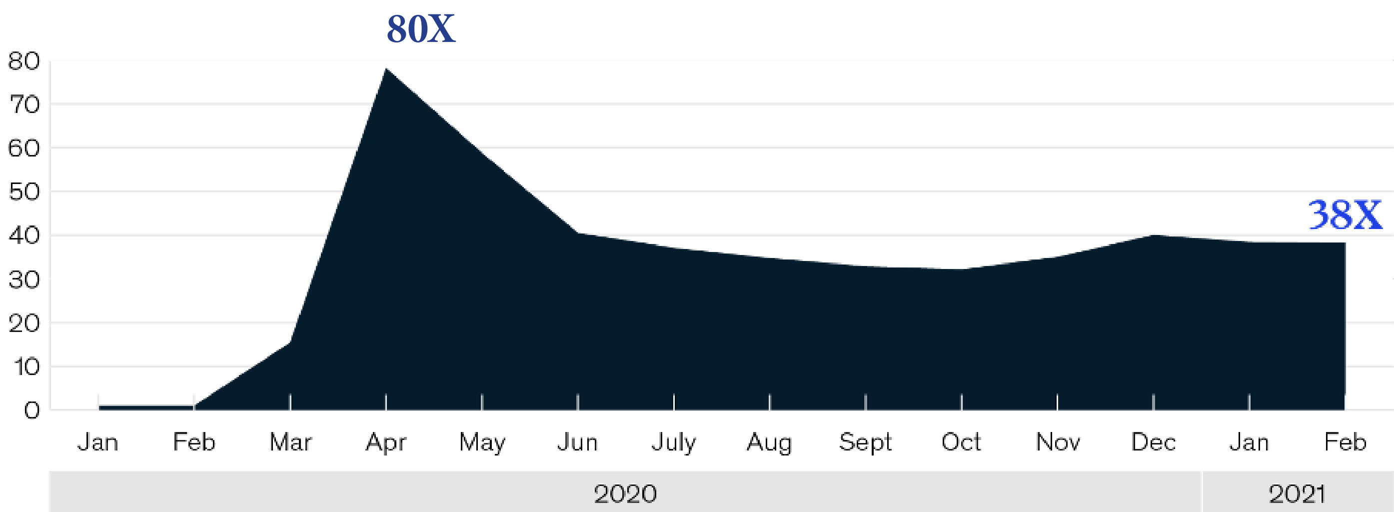

Figure 5. Depiction of the rapid growth of telehealth use during the COVID-19 period before stabilisation to present-day levels (McKinsey and Company, 2021).

2.2 - mHealth

mHealth relies on mobile communication devices for the delivery of health and care services and information, and often overlaps with telehealth solutions. The applications of mHealth include using mobile devices to collect community and clinical health data, delivering healthcare information for patients, healthcare providers and researchers, real-time patient monitoring, and the provision of direct care (DHI, 2021). Similar to telehealth, certain aspects of the mHealth sector are comprised of analogue technologies, albeit the sector has become more and more digitalised.

As the penetration of mobile technologies within health and care (along with other major sectors) continues to grow, the mHealth market has been projected to increase at a CAGR of 17.7% to 29.1%, potentially reaching a global market size of $57.57bn by 2026 (GVR, 2021b; Innovation Eye, 2020).

Based on observational evidence, the COVID-19 onset played a major role in the mHealth market expansion with the emergence of a large volume of symptom tracking, contact tracing, and knowledge and guidance applications alongside the need for more innovative approaches to health services.

The UK mHealth market is expected to follow global trends, rising at a CAGR of 22.4% to reach a market size of over $1.1 bn by 2026. Figure 6 visually depicts the difference to the projected market size before COVID-19 in 2019 (Research and Markets, 2021a). The projection is based on the UK education and employment rates enabling more users to engage with mHealth, alongside a developing market that is seeing an increase of digital innovations, such as Artificial Intelligence, for use in health and care (Innovation Eye, 2020).

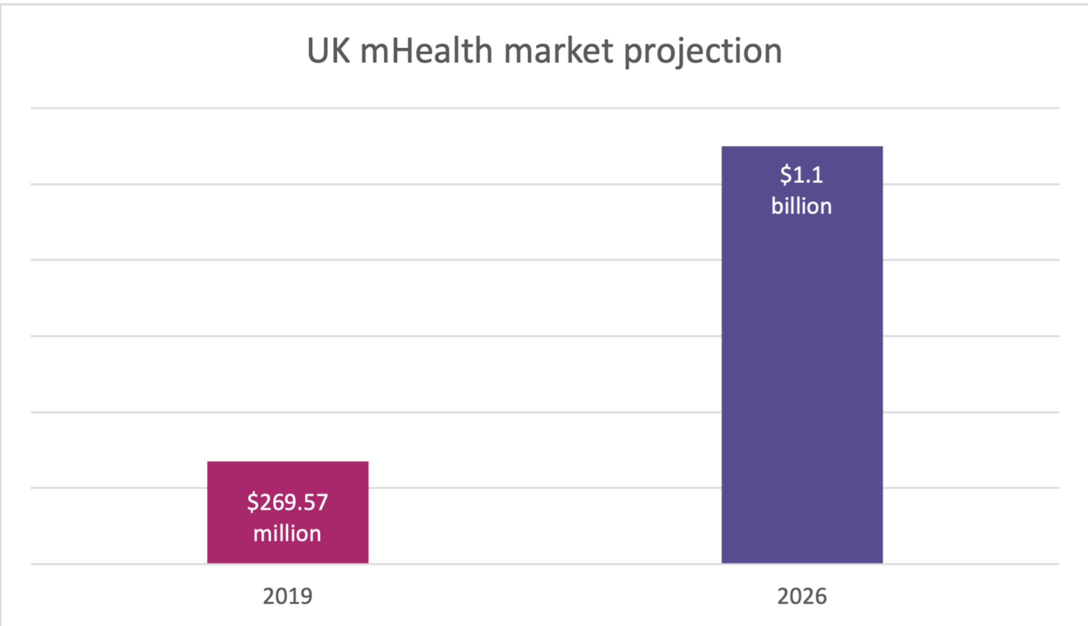

Figure 6. Figure depicting the market sizes between 2019 and 2026. Figure has been adapted from Research and Market (2021a).

2.3 - Healthcare Analytics

The digital transformation of healthcare generates a massive influx of data. Healthcare analytics focuses on technologies that support the analysis of health and care data, including clinical, pharmaceutical, cost, and patient behavioural data. The healthcare analytics market was projected to reach $75.1bn by 2026, growing at a CAGR of 28.9% from $21.1bn in, depicted in Figure 7. This is being driven by an increase in the adoption of electronic health record-style services, increased pressure to address costs, the ever-growing availability of big data in health and care, and investments growth (Markets and Markets, 2021). This is in addition to the COVID-19 impact, calling for better data analytics in health and care.

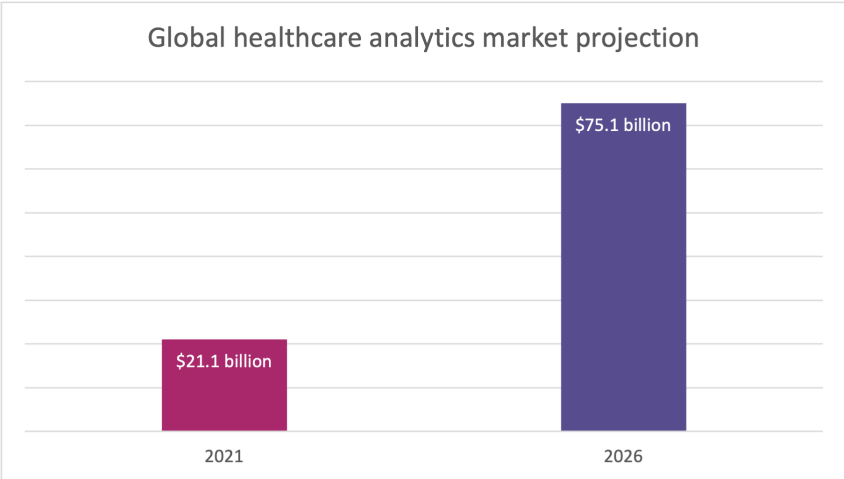

Figure 7. Figure depicting the market sizes between 2021 and 2026. Figure has been adapted from Markets and Markets (2021).

2.4 - Digital Health Systems

Digital health systems are replacing paper-based systems globally and include electronic health records (EHRs) and ePrescription (Figure 4). The global EHR market was valued at $26.8bn in 2020 and was projected to grow at a CAGR of approximately 3.7% to reach $35.1bn by 2028 (GVR, 2021c), depicted in Figure 8. The EHR market saw a slight decline at the onset of the pandemic but then began to grow again as the market stabilised.

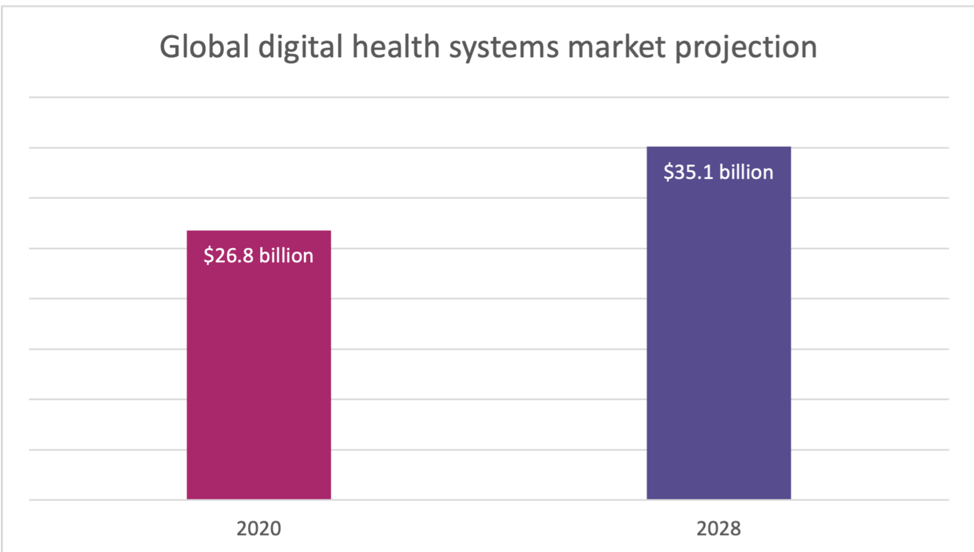

Figure 8. Figure depicting the market sizes between 2020 and 2028. Figure has been adapted from Markets and Markets (2020).

ePrescription services saw a similar growth pattern in keeping with the majority of the digital health market in response to COVID-19, i.e., the demand for online dispensing grew as a reaction to the pandemic. In the UK, there was a 45% increase in the use of online dispensing in 2020 (Wickware, 2020). This growth contributed to a projection that the ePrescription market could reach $3.3bn by 2025, growing at a CAGR of 23.3% from $1.2bn in 2020 (Market and Markets, 2020).

The COVID-19 pandemic has had a major impact upon the digital health and care market, both globally and in the UK, and these effects will continue, yielding both positive and negative outcomes for the sector. The digital health and care market will continue to expand in the coming years, with certain sub-sectors in digital health and care outperforming others, and surpassing previous, and possibly current projections, such as may be the case ,for example, with the digital telehealth market (McKinsey and Company, 2021).

The primary driver of the expanding market is an increased consumer/patient demand for digital solutions across health and care services, further catalysed by the need for digital solutions to government-mandated service changes during the pandemic. While this temporarily inflated demand is expected to fall, evidence has shown that it is likely to settle well above pre-pandemic demand levels (McKinsey and Company, 2021). This suggests a larger cultural shift towards the acceptance of digital solutions within the health and care sector, which, if managed correctly, could support the full realisation of digital health and care benefits.

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Part 1

Part 1: Technical Developments

Part 1 presents the technical developments in digital health and care post-COVID under the following overarching themes:

- The transformation of health and care services.
- Migration from analogue and legacy systems to modern digital approaches.
- The acceleration of digital innovation in health and care.

Chapter 3 'Transformation of Health and Care Services' refers to subsectors of digital health and care that will fundamentally change how health and care services are delivered both from the perspectives of the patient and the providers. The transformation will emerge through introducing novel solutions that transform current practices into something new. The first three chapters in section 3 - Cloud Computing (3.1), Big Data (3.2), and Artificial Intelligence (3.3) - are seen as enablers that lay down the foundations for the emerging innovative developments to take place.

Chapter 4 'Migration from Analogue and Legacy Systems to Digital' discusses the shift taking place in the delivery of health and care from traditional, face-to-face models, and from technologies that rely on physical telephone lines to more novel, digitally supported methods. The theme also includes the movement of providing care in the community or a homely setting instead hospitals; increasing the use of virtual or digitally enabled care methods to replace of traditional face-to-face care delivery where appropriate; and moving from health service-owned to person-owned health and care data.

Chapter 5 'Acceleration of Digital Innovation in Health and Care' brings up subsectors of digital health and care that have been predicted to grow as a result of COVID at a faster rate than previously predicted in terms of availability, implementation, and uptake. These include, for example, greater use of patient data obtained through remote monitoring technologies and an increase in the use of patient generated data from third party wearable and mobile technologies.

3 - Transformation of Health and Care Services

3.1 - Cloud Computing

Cloud computing involves the delivery of computer system resources, including data, via the Internet and remote servers for applications and data maintenance (Javaid et al., 2020). It allows storing, processing, analysis, and management of patient health data with increased efficiency and reduced cost (Mbunge and Muchemwa, 2022).

Cloud computing can significantly benefit healthcare services by increasing efficiency and providing business/Information System agility (Al-Marsy et al., 2021). Cloud providers are known for offering highly available and scalable solutions for health and care organisations, enabling the organisations to reduce capital costs associated with on-site implementation of data centres (dedicated physical spaces that allow for data-storage etc.). Implementing data centres on-site is usually expensive as they require high availability and no downtime due to the high-paced nature of health and care service (Al-Marsy et al., 2021; Aghdam et al., 2021). Legacy systems require multiple layers of redundancy and disaster recovery on top of high availability. This may require multiple data centres or co-located equipment to support service availability in non-cloud settings, all of which requires substantial capital costs (Aghdam et al., 2021). Cloud computing eliminates these additional costs as well as other infrastructure and maintenance costs. Instead, it allows for health and care organisations to access their digital resources and infrastructure as needed, with the cloud systems compensating for changes in demand, dynamically and at pace. This is done via the deployment and termination of resources as and when they are needed, greatly reducing operational costs (Al-Marsy et al., 2021).

Common cloud products include:

- software as a service, where cloud providers host software services customer organisations can access online (EHRs);
- platform as a service, where cloud providers make development tools available to customers via the cloud;
- infrastructure as a service, where cloud providers supply cloud-based infrastructure components to customers, such as storage, servers, and networks (Cresswell et al., 2022);

The global healthcare cloud computing market was valued at $33.4bn in 2021 and has been projected to reach $71.7bn by 2027, growing at a CAGR of 14.12% during 2022-2027 (Mordor Intelligence, 2021a). This is primarily being driven by the increased adoption of EHR and their supporting technologies across global health and care organisations, with a few key players consolidating the market. They include Amazon Web Services, Dell, IBM Oracle and Koninklijke Philips, with Microsoft also accelerating its healthcare cloud computing work in the recent years (Mordor Intelligence, 2021a).

As with other digital technologies, the COVID-19 pandemic accelerated the adoption of cloud computing technology in the health and care sectors. Cloud computing was used directly to combat the pandemic-related data overload as well as to support the delivery of technologies deployed in response to COVID-19 measures (Alhomdy et al., 2021). Cloud computing was primarily used for:

- monitoring COVID-19 cases and other health conditions;
- Analysing large sets of health data;
- Predicting future COVID-19 trends (Singh, 2021a);

The increase in use of cloud computing has pushed its providers to develop solutions for the health and care sectors, with a focus on leveraging cloud computing for AI-based research and development, novel telehealth solutions, IoT, and crisis management solutions (Aggarwal, 2021). Cloud computing has also changed other sectors, such as the education and public sectors, which will have positive knock-on effects on the administration and delivery of health and care services worldwide as the technology becomes more accepted within the population.

In the coming years, it is expected that cloud computing could allow greater accessibility to patient data, where with patient permission multiple health and care workers could access and update patient data in real-time. This could enable patients to access health information and resources, such as online prescription information, outside of the hospital setting.

If adopted at scale, cloud computing can improve the interaction between clinicians and patients, supporting improved communication and service delivery to enhance the overall patient experience. (Aggarwal, 2021)

Cloud computing can also enable the health and care sector to become more collaborative with third party tech, improving interoperability and enabling the IoT, while improving data analytics and cybersecurity within the sector (Dighe, 2022). As with majority sub-sectors within digital health and care, acceptance is a major emerging trend in the aftermath of the pandemic. Specifically, this refers to conscious acceptance, as the use of cloud computing in the workplace, digital entertainment and personal computing is both common and seemingly widely accepted by the general public. The role of digital acceptance for the purposes of digital health and care is further discussed below. The growing use of cloud computing is expected to play a key role, both within the health and care sector and beyond, for the foreseeable future (Ahsan and Siddique, 2022).

A recent study by Cresswell et al. (2022), in which key stakeholders in the field of healthcare cloud computing were interviewed, found that the current and at least short-term primary use for health and care cloud computing included use of scheduling software, videoconferencing, call centre management, imaging analysis, and patient data analytics. The themes of cost-effectiveness and scalability of solutions were prevalent throughout the interviews. However, the study identified several barriers to the implementation of cloud technology across the wider health and care landscape (Cresswell et al., 2022). Firstly, cost of data migration and acquisition in terms of both supply and demand was shown as high. Therefore, health services with mature IT infrastructures and legacy systems will have hurdles in transitioning to cloud-only solutions as they will have to replace both core infrastructures and integrate already-existing systems. Health and care services were deemed to be more likely to adopt hybrid-cloud solutions, which utilise infrastructure as a service to improve their digital capabilities. Secondly, some stakeholders were concerned that cloud technology could threaten established organisational hierarchies, which points to a need for more modern and agile information governance procedures to ensure legacy systems do not inhibit progress.

Finally, the study identified a lack of technical skills in health and care as a barrier to implementing cloud-based technology mirroring the concerns seen across the various digital health and care subsectors.

If these concerns can be addressed, cloud-computing implementation could drive the acceptance and uptake of digital health solutions in the health and care sectors (Cresswell et al., 2022).

3.2 - Big Data

According to IBM (2022a), big data analytics refers to the use of advanced analytic techniques against very large, diverse data sets (ranging from terabytes to zettabytes - ones that are too large for traditional relational databases to capture, manage or process), and that include structured, semi-structured and unstructured data pertaining to different sources. The use of digital devices in daily practice, as well as in healthcare and social care settings, results in continuous influx of patient data (vital signs, genomic data, digital biomarkers, etc.).

Big data in health and care emerged around 2010 as the term to describe the significantly vast and ever-growing volume and complexity of healthcare data stored in cloud (Ragupathi and Ragupathi, 2014). This data has been increasingly generated with rapid development and uptake of digital health solutions. At first, these were mainly electronic health records (EHRs), which then evolved into more complex data systems, such as Internet of (Medical) Things (IoT), enabling expansion of healthcare IT infrastructure by data sharing and, thus, generating more complex data from existing data (Gu et al., 2020). Healthcare big data has expanded not only with clinical data, but also with data from healthcare insurance claims, describing services and reimbursement information; pharmaceutical data, describing medication functions and mechanisms inside the body with toxicity and potential side effects; and patient behaviour/preference data, such as patients' buying preferences and financial capabilities obtained through companies selling consumer information, used in development of patient-oriented digital health solutions (Business Technology Office et al., 2013).

As alluded to big data, analytics are the foundation of the majority of IoT systems within health and care and have led to the development of modern health IoT solutions that include disease diagnosis, remote and real-time monitoring, prevention systems and emergency/alert systems (Kashani et al., 2021; Saheb and Izadi, 2019).

The global market of big data in healthcare has been growing at a faster rate compared to big data in other industries, such as finance, and is projected to grow at an annual growth rate (CAGR) of 36% by 2025 (Huo and Vesset, 2022).

Healthcare stakeholders, including providers, investors, and pharmaceutical experts, have been using big data for healthcare analytics to obtain insights addressing issues of variability in care quality and high cost of care. Use of big data to tackle these issues mainly revolves around discoveries enabling care personalisation and prevention improving health outcomes and decreasing costs associated with trial-and-error approach across care services (Pastorino et al., 2019). The full list of benefits of big data and big data analytics in healthcare is in Figure 9 (Vislotsky, 2020).

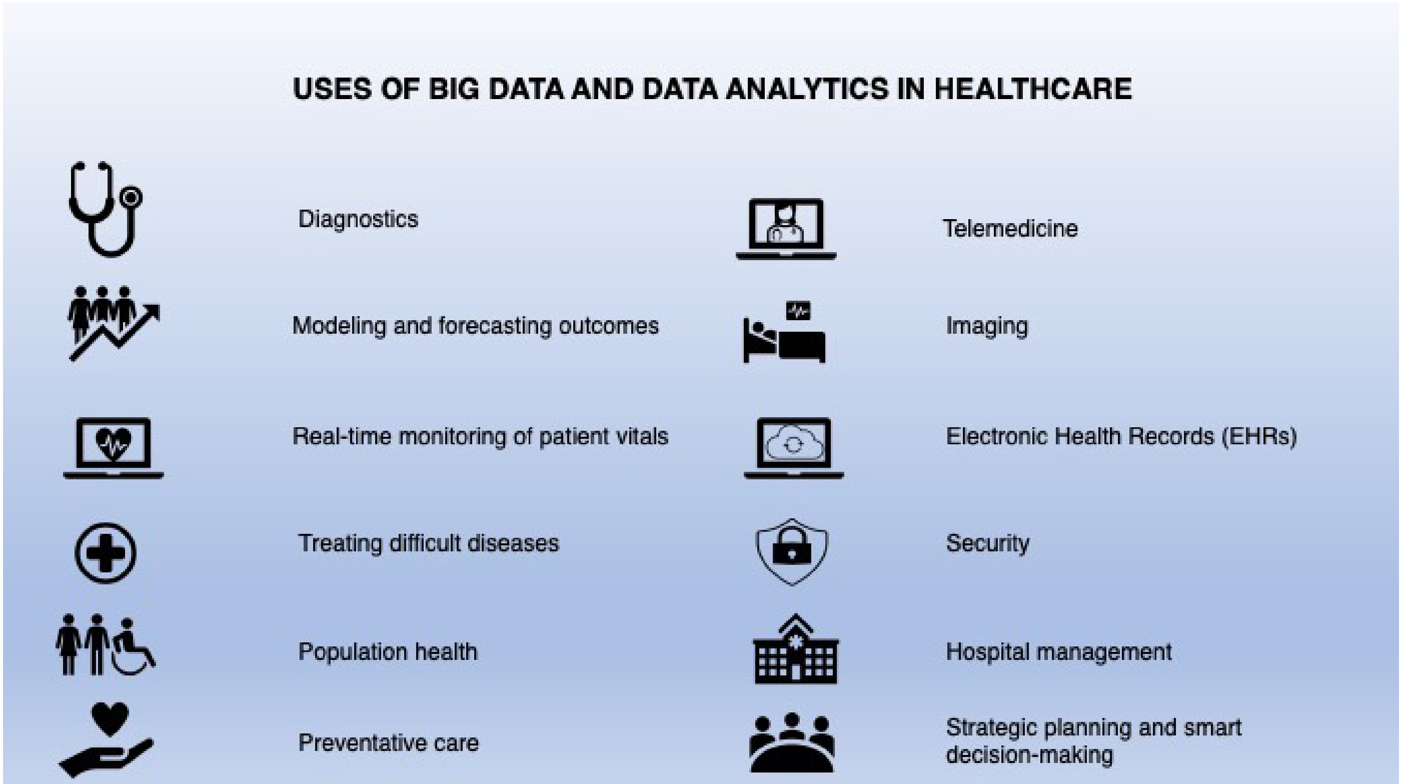

Figure 9. uses of big data and data analytics in health and care. Adapted from Vislotsky (2020).

Although big data can and is increasingly used to develop high-security healthcare systems protecting patient data, security and data privacy are still core challenges presenting barriers to wider employment and acceptance of big data solutions across healthcare services (Anam and Haque, 2020). The way forward is setting up appropriate infrastructures, such as reorganising legacy systems to standardise data integration storing and quality and enable data sharing between systems. Furthermore, setting up regulatory pathways including legislation, in-service risk assessment and auditing protocols, and employing safeguards such as data encryption, firewalls, up-to-date anti-virus software, and multi-factor authentication, while providing high-quality employee training, would ensure consistent, accurate and secure practice. This is associated with the general need to reorganise healthcare to integrate big data and other digital health solutions, including upskilling data scientists, managers, healthcare providers and decision-makers to understand, adopt and apply these solutions appropriately (Dash et al., 2019; Pastorino et al., 2019; Cozzoli et al., 2022).

A more notable example of big data in healthcare within the UK context is the UK Biobank initiative. Rich data of 500,000 NHS patients between ages 40 and 59 was collected at baseline prior any disease onset, with patients allowing regular routine biological sampling, physical health measure taking, and providing personal socio-economic information at regular intervals for years to come. The project aim is to associate the evolving measures with arising patients' disease outcomes in future years to improve known associations of disease and risk factors. This has been achieved by integrating and co-analysing collected data with the NHS patient data (Allen et al., 2012). Another notable UK example in big data is the 100,000 Genomes project by Public Health England, investigating genetic origins of common cancers. The participating NHS patients gave permission for the project scientists to sequence their genomes linking it to the patients' EHRs (Turnbull et al., 2018). However, the project's epidemiological usefulness may depend on associating its data with phenotypic information derived from projects such as the UK Biobank initiative providing a broader context of patients' genetic disease manifestations (Agrawal and Prabakaran, 2020). Thus, the key challenge of healthcare big data is its usefulness in clinical practice. In addition to the evident need for data integration, such as the examples of the two major projects, without specific knowledge and skills on part of providers and even clinical data scientists, the extremely vast and complex big data mining can be difficult to navigate and to provide meaningful, intelligent, and useful insights, which will be understood and adopted by providers (Borges do Nascimento et al., 2021). For example, it was recommended to develop visualisation techniques in form of charts, histograms, and heat maps with systematic labelling the providers will understand and thus absorb the information. These methods could also increase providers' acceptance of such tools (Vyslotsky, 2020).

The 2020 COVID-19 pandemic drove intelligent adaptation and employment of big data analytics for every-day practice, such as predicting bed occupancy and staffing requirements during infection surges in 2020-21 within the NHS, and as with other digital health technologies, post-pandemic period has seen a significant developmental and adoption increase (Mehta and Shukla, 2021).

The latest uses of big data in healthcare digital solutions show that it is increasingly employed in more personalised and user-friendly formats improving care quality (Catlow et al., 2022). For example, the most recent focuses have been on developing wearables such as smartwatches with health metrics connected to IoT sensors uploading real-time patient information to EHRs for remote monitoring and timely medical advice purposes, and machine learning, using big data and artificial intelligence (AI) algorithms teaching systems to identify patterns and improve decision-making with minimal human involvement (e.g., Batko and Ślęzak, 2022).

3.2.1 - Predictive Analytics

Predictive analytics is an aspect of advanced analytics that makes predictions about future outcomes using multiple statistical techniques including machine learning, predictive modelling, and data mining (IBM, 2022a). In health and care, predictive analytics enables processing and evaluation of enormous volume of historic and real-time data to develop forecasts, predictions and recommendations on individual patients or wider public health issues. It is expected that the technology will become more prevalent in health and care in the near future.

During the COVID-19 pandemic, predictive analytics solutions helped the NHS to respond and plan for large surges in demand for intensive care, which required escalation for clinical staff, hospital beds and ICU equipment (NHS, 2021). Predictive analytics provided estimations for bed occupancies and staffing requirements throughout the peaks and troughs of the pandemic across 2020 and 2021.

One of the key emerging trends for predictive analytics in the post-COVID era will be the implementation of machine leaning techniques to identify at-risk patients. The vast volume healthcare data can allow for AI and machine learning to identify actionable information from patient records stored in both structured and unstructured sources. Predictive analytics techniques that have been trained to analyse medical imagery for the purposes of diagnosis or disease identification will become more established and work in combination with mobile technologies to enable health and care professionals to provide further preventative and remote methods of care. (Torres, 2021)

The democratisation of AI, wherein user-friendly AI-based solutions are readily and ubiquitously available across health and social care, will occur as AI and machine learning techniques continue to mature. This will allow health and care professionals to run machine learning models without specialist digital skills or to rely on experts with said skills, something that will support health and care professionals in truly understanding patient health data and its impact on patient care. (Torres, 2021)

In private health systems, the development of predictive analytics will enable insurance providers to utilise data analytics to predict risk and high-risk claims, allowing them to tailor insurance policies for individual customers. Whilst this could have a negative impact on patients within these systems through potential discrimination and secondary/tertiary use of data beyond the purpose of care, it may enable them as customers to obtain a more personalised and cost-effective healthcare plan suiting their needs (Torres, 2021).

To perform predictive analytics tasks in the coming years, medical technologies will access health data by interacting with interoperable technical infrastructures, such as data warehouses and portals. Therefore, the realisation of the full benefits of predictive analytics will depend on reliable, secure, and intelligent hardware and software.

3.3 - Artificial Intelligence

As in all aspects of the digital technology sector, artificial intelligence (AI) is playing and will continue to play a pivotal role in the digital health and care sector. Throughout this report, AI and machine learning have been alluded to across the various sub-sections of digital health and care. As the proliferation of digital health technologies continues, the volume of generated and captured data will grow exponentially. This data will be used to train AI and machine learning models to monitor health conditions, provide more precise diagnostic support, allow for early warning alerts for health emergencies, support clinical decision-making, and monitor the performance and safety of digital solutions. This will create a recognisable value proposition to patients in the near future (Holmes and Watkins, 2021). Natural Language Processing (NLP) technologies will begin to make clinical and biomedical research more efficient and mining the vast research literature base will provide insights that support researchers in their work (Holmes and Watkins, 2021). Going forward, AI and machine learning will be used in clinical trials examining neurological disorders via the analysis of digital biomarkers (captured via video and digital device use, etc.) and standard biomarkers (i.e., heart rate, ECG, blood pressure, etc.) to inform new evidence for potential treatments.

While AI will continue to play a significant role in the form of predictive analytics (see 3.2.1), it will ideally begin to be used across interoperable systems to streamline patient management, monitoring and triage, and to improve efficiency across the entirety of the health and care service. Dawoodbhoy et al. (2021) examined the possibilities of AI within the NHS concluding, while the above trends (and those mentioned throughout this report) offer tremendous opportunity, greater collaborative investment and infrastructure are needed to realise them. Figure 10 summarises the possible uses for AI in healthcare.

Figure 10. Possible future applications of AI in health and care. Adapted from Dawoodbhoy et al. (2021).

A major barrier to adoption of AI in health and care services is the validation, approval, and acceptance of AI solutions as 'a medical device' by health and care professionals. Very few clinical AI solutions have undergone the full process of approval by governing bodies, been accepted by clinicians, implemented into standard practice, and integrated into service infrastructures (Davenport and Bean, 2022). However, AI used in administration can relatively quickly impact health and care services, as the clinical approval process is not necessary. This could involve use of AI to streamline patient workflows or utilising machine learning and predictive analytics to support and improve supply chain management. Managing the administrative processes like this could have real cost benefits for health and care services worldwide as these have been proven to make up significant portions of overall costs. For example, in the United States administrative costs accounted for 34% of health and care costs in 2017 (Davenport and Bean, 2022). In 2022, AI (across all sectors) will begin to be integrated more and more with cloud-based solutions, as well as be used to manage basic IT solutions, which detect common issues, self-correcting minor malfunctions. AI will also have the capability to start structuring unstructured datasets via NLPs and machine learning techniques (Bahirat, 2021).

3.3.1 - Clinical Decision Support

Clinical Decision Support (CDS) solutions are intended to improve the delivery of health and care by supporting clinical decisions with targeted clinical knowledge, patient data/information and other health information (Sutton et al., 2020). Traditional CDS solutions are software designed to directly support clinical decision making by matching individual patient characteristics to computerised clinical knowledge bases (Sutton et al., 2020).

The CDS market was estimated to be $1.69bn in 2021 and has been projected to reach $2.82bn by 2027. This is being driven by continuous technological advancement in the field, the increased adoption of cloud-based computing, a growing competitive landscape, and the expectation and need for improving care quality and reducing human errors were possible (Mordor Intelligence, 2021b).

AI-based CDS tools have the potential to improve care delivery through the analysis of large datasets providing diagnostic assistance and treatment guidance, and the evaluation of disease prognosis and progression. To realise this aim, people from all subsectors of health and care need to be involved in the development of CDS tools to ensure that these tools have sufficient value for everyone involved so that their implementation is successful (Edelmann, 2021).

In the coming years, health and care professionals are going to utilise digital CDS tools more and more. This may partly be due to the digital transformation of health and care systems generating an ever-increasing amount of health data for use by health and care professionals and a need for a computational tool assisting in the data analyses to support decision-making (Butte, 2021). Emerging decision support tools will be integrated/built into EHR/EMR solutions and will require the ability to automatically collect health data.

As AI develops and is increasingly utilised within digital health systems, there is an opportunity for more patient-facing decision support tools to be developed. These could enable patients to access their own health data and leverage it for the benefit of their health and wellbeing, through improved self-management and possible shared decision-making (Butte, 2021).

3.4 - Virtual Reality

Virtual Reality (VR) is a computer-generated 3D simulation in which individuals can interact with their environment in a seemingly realistic manner via the use of specific hardware. Currently, the standard for VR technologies is the use of VR headsets with a head-mounted display. In some instances, VR has utilised tactile and olfactory stimuli, in addition to the standard visual and auditory stimuli (Emmelkamp and Meyerbröker, 2021). The VR healthcare market has been projected to grow from $240.91mn in 2018 to $2.38bn by 2026 (Allied Market Research, 2020). This is driven by both the advancement and uptake of VR tech within the sector. The current VR applications are listed below.

- **Medical Training:** Currently, medical students learn anatomy using cadavers, which can be difficult to access, and do not provide insight beyond basic anatomy.According to Visualise (2022), VR enables users to view and access parts of the anatomy that would otherwise be impossible to reach. VR could allow for even the most minute details of the anatomy to be viewed in 360° Computer Generated Imagery, as well as enabling the creation of multiple training scenarios for common surgical procedures and everyday medical scenarios.
- **Patient Education**: VR can allow patients to be virtually taken through their own medical procedures, enhancing their treatment knowledge, and helping to improve patient satisfaction (Visualise, 2022).
- **Mental Health and Psychological Therapy:** VR has the unique ability to transport users to simulated situations in which psychological or mental health issues occur. This allows for the precise real-time data capture of a patient's reaction to specific stimuli in a safe and controlled virtual environment (Torous et al., 2021). VR has also been used to gather dementia research data and support learning for users with autism.
- **Pain Management and Physical Therapy:** Immersive VR has been shown to distract patients undergoing physical therapy and subsequently help reduce their pain levels. Evidence suggests that VR enhances patients' engagement with their physical therapy across long recovery periods. (Visualise, 2022) See case study RelieVRx below.
- **Disease Awareness and Patient Experience:** VR has the potential to help raise awareness of certain health conditions (i.e., with attached social stigma, such as mental health and chronic conditions) by educating both healthcare professionals and the general public with condition-specific immersive content (Visualise, 2022).

The main emerging trend in the field of VR in health and care is that it will be used more in research and development, education, and care delivery. VR Technologies will become more effective across multiple aspects of health and care, helping to enhance the health and care experience for both service providers and users. To realise the full advantages of VR, hardware costs will need to decrease. As the technologies become more widely accessible and adopted across health and care sectors, and beyond, the resulting increase in supply-demand could drive down costs.

Case Study: RelieVRx

RelieVRx is a prescription system that uses classic VR components of a headset and a controller for the user to self-administer at home. A 'Breathing Amplifier' is attached to the headset, directing the user's breath towards the microphone used in relaxation exercises, such as deep breathing (Rubin, 2021). Manufactured by AppliedVR, the VR technology involves well-researched behavioural therapeutic models in the field of chronic pain and pain reduction. Its main focus is on helping users to learn to improve their pain self-management over time from both cognitive and behavioural perspectives. RelieVRx exercises include attention-shifting; deep relaxation; raising interoceptive awareness (meaning identifying, accessing, understanding, and appropriately responding to internal patterns); expanding perspectives; self-compassion; immersive enjoyment; healthy movement; pain acceptance; visualisation; and pain and rehabilitation education. The programme includes 56 sessions, which are two to 16 minutes long. The manufacturers suggest that users should engage with the exercises daily for eight weeks to gain the full programme benefits, which include decrease in pain interference, hopefully allowing users to resume with their regular daily activities (Rubin, 2021). As RelieVRx is less invasive than traditional treatments and revolves around psychotherapeutic models associating physical and mental/cognitive experiences, it could improve individuals' pain and mental health self-management and empower with more involvement in their own treatment (Darnall et al., 2020).

There is empirical evidence supporting RelieVRx as an effective treatment option for the chronic lower back pain population. For example, FDA found greater improvements in RelieVRx group compared to the control group engaging with a regular pain management programme in their randomized, double-blinded controlled trial (RCT) involving 179 chronic back pain adults (FDA, 2021). However, further controlled trials are currently conducted, such as employing a placebo VR control condition (Garcia et al. 2021); and a three-arm RCT including RelieVRx as a skill-based programme versus a pain distraction VR programme versus a placebo VR (Birckhead et al., 2021). The further trials will help assess the technology's effectiveness and safety of use to ensure its wider implementation is regulated appropriately.

3.5 - Augmented Reality

Augmented reality (AR) is an approach in which visually immersive technology overlays digital content on the real world (Lloyd, 2021). The AR healthcare market has been projected to grow from $609.6mn in 2018 to $4.34 bn by 2026. Similar to VR, AR has obvious application for education and training in health and care, allowing users to visualise and interact with 3D visualisations of all aspects of the anatomy. Furthermore, AR can also provide huge benefits in patient education, allowing clinicians to walk through simulated surgical procedures or explain medicines mechanisms within the body (Health Management, 2018).

In practice, AR has potential in supporting surgery using two-way interactive video conferencing, which affords surgeons remote access to surgeries, allowing them even to assist (Mahajan, 2021). AR can also help in drug delivery (and with other healthcare processes), for example, by mapping human anatomy over patients, or mapping and displaying nerves and blood vessels in both training and standard practice (Mahajan, 2021). Figure 11 provides examples of these technologies (AccuVein, 2022; Mahajan, 2021; Visualise, 2022).

Figure 11. Images showcase examples of AR and VR use in health and care. 1) AR tool for mapping blood vessels 2) VR simulation of surgical procedure 3) AR anatomy education (AccuVein, 2022; Mahajan, 2021; Visualise, 2022).

3.6 - Digital Pharmaceuticals

As with all stakeholders within the health and care sector, the pharmaceutical industry (pharma) is beginning to leverage digital technologies to its advantage. There are several trends shaping the future of pharma, including pharmaceutical companies emphasising the development of digital health technologies alongside novel drugs (The Medical Futurist, 2021).

This initiative aims to create a more valuable experience for the patient and improve adherence to prescription drugs, while collecting more data and feedback for the drug developer. A more novel trend is the concept of digital pills, where drugs are embedded with technology. Its purpose is to enhance prescription-adherence and provide remote monitoring of drug ingestion/delivery and patient reaction. See case study Ability MyCite below below.

In the coming years, the pharmaceutical industry will employ VR to conduct clinical trials via computer simulation. This development has been driven forward in reaction to the impact of the COVID-19 pandemic substantially slowing down or completely halting clinical trials.

Another use of VR in pharma could be prescribing VR for patients suffering from stress disorders or chronic pain (as highlighted in the VR section) (The Medical Futurist, 2021). As previously mentioned, pharma will begin to use AR to educate patients on drug ingestion/delivery and on how different drugs affect the body.

Case Study: Abilify MyCite

The digital pill (DP) has been on the rise among currently emerging digital health trends in the pharmaceuticals. DP involves medication ingredients combined with digestible sensors to monitor medication ingestion, aiming to decrease medication non-adherence and collect various personal data (e.g., behaviours) (Peters-Strickland et al., 2018). Medication non-adherence, which has been associated e.g., with high cholesterol or hypertension, refers to irregular medication taking (right dose at the right time) (Martani et al., 2020). Moreover, improving medication adherence could also tackle related public health issues, such as antibiotic resistance, infectious diseases, and AIDS (Upadhyay, 2017).

In 2017, Food and Drug Administration (FDA) approved Abilify MyCite, first FDA-approved DP (Upadhyay, 2017). The pill is a version of antipsychotic Abilify (aripiprazole) used in treatment of schizophrenia, bipolar disorder, and supplementary treatment for adult depression (Wamsley, 2017).

Abilify MyCite

Abilify MyCite, manufactured by Japanese Otsuka Pharmaceutical, incorporates classic medication ingredients with a tiny ingestible event market (IEM) sensor, made by company Proteus (Pharmaceutical Technology Editors, 2018). The sensor operates by detecting and recording date and time of medication ingestion, activated by coming into contact with stomach acids. A sensor patch worn by the patient detects IEM sensor signals after ingestion.This data is then transmitted to the patient's MyCite smartphone app and a Web portal for information sharing. The patient can view their data on the app and share it with up to five healthcare providers/family members/carers. The app generates push notifications to the patient's smartphone as medication reminders. Lastly, the patch needs to be replaced weekly by medical professionals (Caliendo and Hilas, 2019; Shewalkar et al., 2021).

While DP monitoring has proven potentially cost-effective in preventing medication non-adherence, which costs e.g., the NHS up to £500M annually (Taylor, 2013), there are also various ethical issues to consider in the adoption of digital pills (e.g., provary questions, whether DP are safe to use with mental health patients or questions relating to patient scrutiny by insurance companies) (de Miguel Beriain and Morla Gonzalez, 2020; Meek, 2020).

3.7 - Digital Pharmacy

During the pandemic, the role of the local pharmacy expanded to include the following services:

- General information and education
  - First point of contact for health information
  - Providing education on COVID symptoms, infections, hygiene and social distancing measures
- COVID-19 clinical services
  - Screening patients
  - Providing antigen testing, delivering face masks, contact tracing and GP referrals
- COVID-19 vaccinations
  - Providing education on vaccines
  - Administering vaccines
  - Distributing vaccines to GPs (Durand et al., 2022)

The remit of the community pharmacy incorporated several novel public health services over the course of the pandemic. The performance of these services played key role in the national health services response to the pandemic and has furthered the concept that the community pharmacy can play a larger role in the provision of primary care (Durand et al., 2022). The implementation of digital pharmacy solutions could help in realising this.

With regards to local community pharmacies (and other forms of dispensaries), there are a number of key digital trends that are expected in the immediate future. These include use of digital technologies that:

- enable online prescription refills;
- will increase home delivery for prescription drugs;
- can employ AI solutions to predict both supply and demand;
- can streamline order fulfilment and supply chain management;
- support the implementation of digital telehealth solutions allowing the delivery of virtual health assessments; and
- increase in clinical validity and efficacy of novel digital health diagnostic tools, as well as accelerated development of digital therapeutics (Deloitte, 2020; Revieve, 2020);

3.8 - Digital Mental Health

Digital mental health refers to the provision of mental health services delivered via digital means, be it digital devices, service models, clinical management platforms, applications, and more. The current provision of digital mental health focuses predominantly on remote therapies via telehealth technologies and video conferencing, computerised Cognitive Behavioural Therapy, digital learning, and mental health applications (Morrison, 2021). COVID-19 has driven the increase in virtual care and psychiatry for mental health patients. For example, Canada has seen over 850% increase in virtual psychiatric care during the pandemic (Gratzer et al., 2021).

The latest developments in the field of digital mental health include the use of AI to create a more personalised and precise approach to mental health care through prediction and diagnosis of mental health conditions. In addition, AI is integrated in chatbots and in tools utilising language/voice analysis via NLP technologies (D'Alfonso, 2020). This use of AI could expand to the use of 'Digital Phenotyping' (see glossary) that utilises mobile devices as digital nets to capture specific data helping predict, diagnose and/or treat mental health conditions (D'Alfonso, 2020). See Wysa case study below.

Case Study: Wysa

Chatbots are at the heart of recently emerged digital mental health technologies, incorporating artificial intelligence (AI). These computer programmes are able to converse with human users through online platforms (Mandriota, 2022). Wysa is a smartphone app offering cognitive-behavioural therapeutic (CBT) exercises to improve mental health using AI Pocket Penguin Coach system chatbots (Wysa, 2022).

The chatbot is programmed to help users recognise their feelings and how feelings affect their mental health within the CBT model. CBT is a widely employed therapeutic model aiming to help clients change their negative thoughts and related behaviours which decrease their mental wellbeing. It mostly consists of building self-management skills by performing actions such as journaling feelings and behaviours (Williams and Garland, 2002). Wysa offers CBT self-care exercises, including meditation, yoga, and guided journaling, lasting five to 10 minutes to improve users' relationships with their feelings and increase self-management and resilience related to mental health. It also has an option of push notifications with therapeutic messages, thus reengaging users with the app throughout the day (Choosing Therapy, 2022). Furthermore, Wysa chatbot is programmed to compare user interactions with widely employed depression and anxiety disorders questionnaires and to suggest talking to a human therapist if users show high symptom levels (Betuel, 2021). This ensures ethical practice and shows app developers' awareness of the app's therapeutic limitations.

The Wysa team are planning to develop Wysa into a voice-based platform, currently working with Apple's SiriKit, to provide a more traditional user experience. There are also plans to involve biomarkers and create opportunities for the app to be further integrated into healthcare (Singh, 2021b). Thus, the app could develop into a diagnostic tool, and, if involving chronic pain conditions, could monitor not only psychological but also physical symptoms, providing tailored chronic illness self-management support.

Gamification - the application of game design techniques and methods within non-game environments - is another new development in digital mental health. Gamification will be increasingly utilised within digital mental health solutions using progression feedback, scoring systems, achievements and narrative approaches to create more enjoyable, engaging and rewarding experiences aiming to enhance adherence to mental health therapies (Litvin et al., 2020; Sinha, 2021).

As previously mentioned, VR will also be used within digital mental health to capture real-time patient data responding to stimuli in controlled environments. This will provide healthcare professionals with a realistic insight into real-world manifestations of mental health conditions aiding diagnosis and treatment decisions. VR and AR will also be used as an education or training tool for both health and care professionals and patients, to help staff and patients understand mental health conditions and their treatment.

3.9 - Genomics

Over 20 years have passed since the modern era of genomics began with the publication of the human genome. More recently, the cost of DNA sequencing has begun to drop and is expected to continue decreasing into the future. This trend, in combination with the advancements in AI, data analytics and other digital health technologies, will enable the development of more personalised medicine (Green et al., 2020). The push towards personalised medicine, in combination with decreased sequencing costs, have yielded several novel products and services. The market is expected to become more competitive as more players enter the market. This has led to the global genomics market projected to grow from $23.11bn in 2020 to $94.65bn by 2028 (Business Insights, 2022).

In the future, genomics could be used in healthcare planning to determine, via DNA sequencing, which medications patients will require based on their genetics. Similarly, genomics, in combination with AI, could be used for more precise prediction of risk for and diagnosis of certain diseases, including genetic risk factors for cancers and long-term conditions (Johnson et al., 2021). The pandemic saw a global search for COVID-19 treatments, which in turn boosted the genomics research and development, with a focus on tailor-made gene-focused diagnosis for infectious and other diseases. It is expected that this will continue to develop and grow in the immediate future (Ng, 2020).

Whilst the future of genomics in digital health seems promising and the UK as a whole is in a strong position internationally, the genomics industry is still somewhat in its infancy. Thus, it faces several challenges that need to be overcome to ensure health and care services can benefit from it. These include improving the bioinformatics and genomics skills nationally to enhance the application of genomics in health and care services; improving the commercialisation and scaling-up technologies to support businesses in the industry; and, reducing the barriers to adoption across the NHS services by strengthening the relationship between academic research and corresponding clinical implementation (Deloitte, 2022).

4 - Migration from Analogue and Legacy Systems to Digital

4.1 - Telehealth and Telemedicine

COVID-19 pandemic has drastically increased the uptake of telehealth and telemedicine technologies for virtual care provision, trend expected to continue beyond the pandemic. A McKinsey and Company (2021) survey showed that 76% of patients were interested in using telehealth solutions going forward compared to 11% pre-pandemic. Additionally, 57% of service providers viewed telehealth more favourably in the post-pandemic era. It is expected that this increased uptake can lead to several knock-on develpments based on telehealth advantages. These include reduction in care planning costs alongside an increase in patient engagement and adherence to care plans (Marley, 2021). Application of telehealth solutions can facilitate alternative models of care, such as Hospital at Home (Figure 12) - an innovative care model that aims to provide hospital-level care in a patient's home as an alternative to the acute hospital setting (Johns Hopkins, 2022).

Figure 12. Image demonstrating Hospital at Home in action

Hospital at Home care works best when it is part of an integrated acute and community-based service model to meet local population need. It has been in existence in a few countries across the world for over 25 years, however, its first service in Scotland was introduced in 2011. While research has not determined specific trends for Hospital at Home in the coming years, there is a consensus that this service model will become more established into standard health and care practice. This is likely being driven by the integration of digital health solutions into Hospital at Home programmes as well as the cultural shift towards the use of digital health due to the COVID-19 pandemic.

The continued development of digital telepsychiatry and teletherapy solutions will help improve mental health care delivery, allowing patients in need of mental health-related treatment to access appropriate care via digital means. In parallel, the use of paediatric telehealth technologies will increase, as the next generation of parents, who are already familiar with digital services, begin to utilise paediatric care (Marley, 2021).

In the coming years, with the national switch to digital Internet protocol technologies, there is likely to be an increase in the development of digital telehealth technologies that can improve the patient/user experience by providing more convenient access to health and care services.

The patient's expectation will be that telehealth and telemedicine solutions are seamlessly integrated into a single comprehensive service. Additionally, solutions should begin to have integrated data sharing functionality allowing healthcare professionals to gain a more detailed picture of the patient's health profile. This integration will include interoperability with all aspects of the digital health ecosystem including the technologies listed throughout this report. A key change will be the adoption of 5G capabilities, improving the technical quality and efficiency of all telehealth solutions.

While the technology involved is unlikely to show any drastic change, digital telehealth and telemedicine-enabled virtual health care will continue to grow. The 2025 deadline for the 'switch off' of legacy analogue systems is fast approaching, further increasing the use of digital telehealth and telemedicine solutions by sheer necessity. This unavoidable increase in use of digital solutions may help developers realise the full potential that being part of a digital infrastructure can bring to individual solutions, for example, connecting them with other individual hardware as part of a suite of digital telehealth solutions. Health and care costs can be expected to be driven down due to savings on time and infrastructural costs associated with non-essential face-to-face consultations. However, there are still challenges to overcome, including developing trust in the technology for both service users and providers and overcoming issues of equity and equality within digitalised health services (Kluwer, 2022).

4.2 - Electronic Health Records and Electronic Medical Records

Electronic Health Records (EHRs) and Electronic Medical Records (EMRs) have long been part of standard modern medical practice. EHRs are electronic/digital versions of a patient's medical history kept by their healthcare provider, and these include all administrative clinical patient data (Keshta and Odeh, 2021). Employment of EHRs have increased accessibility of health information and supported multidisciplinary care management via improved connectivity between healthcare professionals (Kiplagat et al., 2018).

EMRs contain patient-related health data and are made up of legal and administrative records composed in a hospital environment, allowing staff to optimise tracking patient's medical/treatment history (Keshta and Odeh, 2021). Traditionally, EHRs and EMRs have been stored locally at healthcare institutions. However, this is changing through the digitalisation of these technologies and the use of cloud computing, bringing advantages such as:

- lowering costs via reduction in hardware, software and service needs;
- increased security via the use of encryption, authentication processes and digital signatures, etc.; and
- enhanced scalability and interoperability (Ahmadi and Aslani, 2018).

The digitisation of patient medical data into EHRs and EMRs has been a long-term goal of multiple health and care service providers. Their use is seen as fundamental within the modernisation of clinician-patient care experience. EAccording to Encora (2021), current developments for EHRs include:

- The adoption of agile approaches for accelerated deployment methodologies that can help healthcare providers reduce the costs of implementation.
- The reduction of EHR release cycle times - this can allow for the continuous delivery of new functionalities to customers (both health service providers or users), and can reduce risks and receive feedback more efficiently and effectively.
- The creation of app extensions to provide interoperability with functions/features that EHRs might lack. This could also allow for the rapid deployment of independent solutions that can integrate closely with EHR systems.
- The expansion of the EHR footprint to include current and emerging digital capabilities.
- The ability for users, including providers and patients, to customise their own experience via modular cloud based EHR solutions that can integrate at scale (Encora, 2021).

Alongside these predicted trends, it is thought that the use of AI features such as NLP can help improve the way healthcare professionals and their patients interact with EHR and EMR systems. This allows for the extraction of clinically significant insights from free-text data within patient medical records (Edelmann, 2021). As further AI-based features are introduced to EHRs and EMRs, the solutions will be better able to utilise data and improve healthcare professionals' efficiency (nix, 2021). The growing uptake of wearable health technologies will also allow for increased and improved patient engagement with their own health, such as wearable fitness watches collecting various health data. The challenge for any AI-based solutions is that data needs to be available in a standardised format across health services. Health organisations will be required to work closely with data specialists to begin storing and processing most relevant and valuable health and care data. AI could also help identify patterns in EHR/EHM data to perform outcome predictions aiding healthcare professionals to individually-tailor treatments, thus improving personalised care provision (Edelmann, 2021).

While the emergence of 5G technologies has been predicted to increase the Internet speed and device loads of all digital hardware solutions, healthcare may not yet be ready. Current documentation, health records, lab results, notes and scans are often incompatible or in varying formats, thus successful communication between different platforms is made difficult. Until health and care services determine and establish the appropriate data storage format standards for leveraging 5G, EHRs will not benefit from the related technological advancements (Dugar, 2021).

4.3 - Personal Health and Care Records

Personal Health and Care Records (PHRs) have had and will continue to have a transformative effect on the personalisation of health and care, and patient engagement by enabling individuals to access and manage their health data. A PHR is an application or online platform through which patients can maintain and manage both their own health information, but also when authorised the information of others, in a private and secure space (NHS, 2022; Nazi, 2021). The global market for PHRs is expected to grow from $7.07mn in 2020 to $14.87mn by 2028 (Research and Markets, 2021b). Market researchers have observed several key drivers for this growth that include greater acceptance of, and increased user need for advanced digital technologies, an increase in PHR supporting government initiatives, and growth in digital infrastructure technologies like cloud computing (Research and Markets, 2021b).

In recent years there has been greater consumer demand for online access to personal health information; however, the adoption and sustained use of PHRs and similar technologies continues to be less than expected (Nazi, 2021). Future develpments of PHRs are inherently tied to those in health and care. It is a well-established projection that worldwide health and care services are facing aging populations with greater prevalence of chronic disease within the same population. With this combination of an increasingly older population with multiple long-term conditions health and care services will require new innovative approaches to the delivery of health and care that focus on prevention for both the individual and overall population, behavioural changes, prevention, and the expansion of virtual care. PHRs can be the foundation on which access to these services is built (Nazi, 2021). Similarly, PHRs could enable convenient access to mental health data and support patient engagement with mental health treatments. The proliferation of digital health technologies and increased use of said technologies is radically increasing the frequency, amount, and categories of patient health data. PHRs can allow this data to be used for the benefit of the patient's health and care.The security of these platforms will be critical to their implementation as will their interoperability to other digital technologies within the Internet of Things (IoT) (Nazi, 2021).

In the coming years, consumer technology will likely become increasingly combined with AI powered tools.

This will offer new functions and features that allow users to interact with their PHR remotely, with an expectancy of a consistent user experience across all methods of access. A systematic review by Fang et al. (2021) identified suggestions across 58 articles that could be implemented in the future to improve PHRs, that are supported by blockchain. These came under three key themes:

- User experience
  - Improving user interfaces
  - Introduction of biometric user authentication
  - Allowing patient permitted next-of-kin or caregivers access to PHRs
  - Incorporate incentive mechanics to increase user engagement
  - Incorporate analytics tools for user to gain personal health insights and help them manage their health
- Integration with existing systems
  - Integrating PHRs with existing EMR and EHR systems
  - Integrating PHRs with IoT devices
  - Adopting service wide health care data standards
- Compliance with regulations and development of governance processes
  - PHRs will need to comply with regulations on health care data privacy
  - Developing legal and clinical governance processes for PHRs

Whilst the future for PHRs appears promising, to realise their full benefit, the health and care services and their users need to fundamentally change how they perceive PHRs. The convergence of actual health and care trends, for example, the ageing population and the increased prevalence of long-term conditions, may enable this change in a similar fashion to how COVID catalysed change across the digital health and care sector. PHRs could provide a single solution that enables the automated collection and harmonisation of data from various hardware and software solutions, with sufficient controls for data sharing. If fully realised, PHRs can work alongside other emerging technologies to place the citizen at the centre of their own health and care.

5 - Acceleration of Digital Innovation in Health and Care

5.1 - mHealth

As discussed in section 2.2, it is expected that the mHealth market will continue to grow as the uptake of smartphone and tablet devices increases. As of the end of 2021, there are over 350,000 digital health apps available across various app stores, with over 90,000 having been created in 2020 alone (Olsen, 2021). Recent studies have shown that mobile health applications have a positive impact on targeted health-related behaviours and clinical health outcomes (Han and Lee, 2018). While mHealth often refers to mobile health applications, the implementation of mHealth solutions, as is happening with telehealth, will more likely come in the form of wearable technologies and remote monitoring solutions, with mobile-based user interfaces as the primary method to interact with future digital health services.

Some key trends have been identified for mHealth solutions, including applications becoming more user-centric in their design and functioning to ensure that apps are actually used for their intended purpose. Better integration of mHealth solutions with other hardware and software will enable clinicians to access an entire ecosystem of patient data. As solutions become more established, the security of mHealth solutions will improve and health and care professionals will be more likely to utilise mHealth solutions within their standard health and care practice (Szwaba, 2020).

The COVID-19 pandemic created new demands for mHealth solutions in terms of their application in the provision of remote monitoring and remote consultation services, which was due to fear of infection in clinical environments during the height of the pandemic. Research by Alzahrani et al. (2022) posits that adherence to mHealth solutions, characterised by low adherence levels, is directly tied to the solutions' perceived service quality.Their research suggests that in future, developers, health decision-makers and governing bodies can identify the most beneficial aspects in individual mHealth solutions and take early steps to maximise their efficiency and efficacy.

5.2 - Remote Patient Monitoring and Care

Remote patient monitoring and care is a method of health and care delivery that uses various digital, information and/or tele-communication technologies to collect patient data or deliver care outside of the traditional health and care settings (cf. Taylor et al., 2021). Currently, the remote patient monitoring market is expected to reach $28.27bn by the end of 2021 and has been projected to grow to $48.42bnby 2026 (Cision, 2021). As remote monitoring and care sit across all aspects of digital health and care, primarily being represented in telehealth and mHealth, this expansion is being driven by increased uptake of remote monitoring technologies. These technologies provide patients with a means to perform self-monitoring at home or in a homely setting, and the research underpinning this report include:

- wearable technologies
- health tracking applications
- digital biomarkers
- Internet of (Medical) Things (IoT)
- Hospital at Home

These technologies often overlap within the same sub-groups and share similar future trends and challenges. While the use of remote monitoring technologies has steadily been growing in recent years, the COVID-19 pandemic has fundamentally changed the perception of digital health technologies and it is expected that the accelerated adoption and use of these tech, catalysed by the pandemic, will continue to grow in the post COVID-19 world.

5.3 - Wearable Technologies

The global wearable medical technology market was valued at $16.6bn in 2020 and is projected to reach $111.9bn by 2028 (GVR, 2021d). This increase is likely due to an ever-increasing uptake of wearable technologies, driven by an ageing population, improved tech supply, rising demand for remote monitoring, enhanced functionality and improved integration with other technologies and services. This market's technology includes, for example, fitness trackers (e.g., Fitbit) or smart watches (e.g., Apple watch), wearable Electrocardiogram (ECG) Monitors, wearable Blood Pressure Monitors, and Biosensors (Digital Health Central, 2021).

5.3.1 -Fitness Trackers and Smart Watches

Fitness trackers and smart watches represent the largest proportion of the wearable market, and are the most widely available products. Health metrics these devices record vary product to product, but their measurements are becoming more sophisticated every year as technology develops. These data will likely include ECG and heart rate data that is already recorded by available smart watch technology. However, device apps measuring health metrics will need to be recognised as medical devices permitted for use within the NHS services. Without that, the data will provide little to no value for the user, and any resulting information-sharing with healthcare professionals will not be possible, and potentially detrimental to the patient's health. In the coming years, smart watches are expected to develop female health, diabetes, and sleep apnoea trackers as part of the standard device packages (Digital Health Central, 2021).

In future, smart watch and other wearable device data could become increasingly integrated with health and care systems, allowing for more informed and shared treatment decision-making between the patient and their health and care team.

5.3.2 -Wearable Monitors

In recent years, wearable health monitors have become more established in the field of remote monitoring. The most notable of these are wearable ECG monitors, which are often integrated into smart watches, but also include chest-strap monitors and ECG patches (Bayoumy et al., 2021). In the future, it is expected that the market for these devices will grow extensively, with the global market value projected to reach $2.14bn in 2025 from $1.63bn in 2021 (Research and Markets, 2021c). The increase in use is driven by multiple factors, including consumer demand for devices that allow self-monitoring as well as health and fitness tracking and a growing body of evidence that supports the use of wearable ECG monitors in cardiovascular risk assessment and cardiovascular disease prevention, diagnosis, and management. However, further clinical research is needed to establish the technologies' benefits within the field of cardiovascular medicine. The research gaps are related to concerns over device accuracy, patient privacy and costs, and how to identify actionable data. There is also a requirement for concurrent development of comprehensive evaluation frameworks, regulatory policies and medical education curricula and practical clinical guidelines to enable these devices to be integrated into standard practice (Bayoumy et al., 2021).

Other wearable monitors include blood pressure monitors and patches. Currently, there are numerous wearable blood pressure devices under development with a number already on the market as individual products or integrated within current generation smart watches. Similar to ECG monitors, these devices will become more accurate, clinically precise, and more readily available in the coming years. This includes both the cuffed and cuffless wearable blood pressure monitors. The expectations for these technologies have led to a projected global market size of $1.44bn in 2025, from $666mn in 2017 (Fortune Business Insights, 2019).

The overall trend for wearable technologies is that hardware and software will become more precise and clinically accurate. Additionally, newer technologies, like biomechanical sensors, will become more established. These sensors can be integrated into clothing and shoes to monitor cardiac output, lung fluid volume and weight.

Futhermore, novel tattoo-like sensors based upon microfluidics are under development and have shown promise in monitoring of haemodynamics (Bayoumy et al., 2021). While the biomechanical sensors are at the early development stages and require extensive clinical validation before their use in health and care settings, they represent the future of all wearable health technologies. The devices will be manufactured increasingly smaller in size, more integrated into day-to-day life, and more accepted within health and care environments.

The adoption of all wearable technologies into standard health and care practices is reliant on health service infrastructures interoperability with third-party technologies and having both the appropriate clinical and data governance in place. Alongside this, it is required to employ meaningful efforts encouraging changing the culture surrounding lack of acceptance of digital health solutions across the health and social care sectors.

5.3.3 -Digital Biomarkers

Digital biomarkers are defined as objective and quantifiable physiological and behavioural data that are collected and measured via digital devices, including mobile devices, wearables, implants or digestibles (Karger, 2022). These data can range from physical activity to internal physiological processes captured by smart devices. The digital biomarkers have the potential to explain, influence, and/or predict health-related outcomes across health and care. Digital biomarkers face many challenges in terms of development, such as a lack of regulatory oversight, limited funding, low trust in data sharing, and a shortage of open-source data and code (Bent et al., 2021). The field of digital biomarkers is very much in its infancy, with most of the work currently performed in a research context, lacking health and care domain knowledge.

Biomarker research will continue in the coming years, potentially allowing for the validation of digital biomarkers and enabling multidisciplinary collaborations. Bent et al. (2021) have proposed the development of a Digital Biomarker Discovery Pipeline, an open-source software platform to support these collaborative efforts.

The field shows promise in various areas of health and care, especially in the field of neurodegenerative disorders where physical symptoms of neurodegeneration such as loss of finger dexterity can be observed and tracked via use of digital devices (Dorsey et al., 2017). However, it is difficult to predict the future of digital biomarkers in the current stages of digital health and care.

5.3.4 -Internet of (Medical) Things (IoT)

Internet of (Medical) Things (IoT) describes a network of hardware that connect and communicate to each other via the Internet. The coming together of Internet of (Medical) Things (IoT) within the health and care sector enabled smart management of standard healthcare processes, self-care and self-management, falls detection, remote monitoring, and more. However, these functions have yet to be fully implemented into standard practice. Multiple studies have evaluated the field of IoT and identified several future trends in the field. These include:

- **Blockchain** is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a network. It has been widely identified as the most appropriate technology for the healthcare system to provide secure management and analysis of big health data. It will further allow for peer-to-peer and distributed communication without the need for any centralised authorities or duplication of data entry. (IBM, 2022b; Qadri et al., 2020; Kashani et al., 2021)
- **Tactile internet**, an Internet network that combines ultra-low latency with extremely high availability, reliability, and security, is the next step in IoT and mobile internet (Kavanagh and Mundy, 2021). This superior Internet sensorial connectivity, in which communication standardisation among devices can produce stimuli and senses, creates perception capability in the digital world (Kashani et al., 2021). In healthcare this may be applied in remote surgeries, interactive medical training, trauma rehabilitation, virtual and augmented reality training, and care (Ruan et al., 2017).

- **Software Defined Networks (SDN) and Network Function Virtualisation (NFV):** SDN technology is an approach to network management that allows for dynamic, efficient network configurations enabling improved network performance and monitoring. SDNs enable administrators to manage hardware in a network from a central location, reducing the workload in an organisation, saving on costs, as well as centralising management and network security (Comcast Business, 2020). NFV is a form of network architecture concept that uses virtualisation technologies to virtualise network node functions into building blocks that can connect or link together to create communication services. This means services can be separated from dedicated hardware as virtual machines assume their role, reducing hardware costs, centralising control and allowing for on-demand network changes (vmware, 2021). SDN will enable improved management health and care IoT process, whilst NFV will provide speed and flexibility in the construction, management, and deployment of novel IoT services in the sector (Kashani et al., 2021).
- **Online Social Networks:** Online social networks, such as LinkedIn or Twitter, could act as trustworthy online platforms for the interface of service applications between health service providers and users (i.e., patients). These networks could enable IoT devices to connect user-generated data to health service providers via computational resource and storage-rich social networks. This could help in prediction of health status amongst users (Hao and Wang, 2017; Kashani et al., 2021).
- **Internet of Nano Things (IoNT):** The IoNT has been defined as the interconnection of nanoscale devices with the current communication technologies and the Internet (Akhtar and Perwei, 2020). The emergence of this new aspect of IoT could lead to numerous applications in health and care, including organ-accurate drug delivery via nanorobots, nanosensors, precision medicine, minimally invasive surgery and future applications that are currently unknown (Pramanik et al., 2020; Kashani et al., 2021).

The future of these trends and IoT in health and care face challenges in terms of:

- Scalability - to date, IoT health systems have operated on a small scale with their validity based upon this small scale.
- Interoperability and standardisation – more open-source frameworks are required with reliable connections, and standards need to be set to allow interoperability between horizontal platforms and other devices, operating systems, and applications regardless of make, model or manufacturer.
- Mobility - in healthcare, IoT mobility refers to the ability to use network support for patients that can always connect to gateways. It is necessary to make IoT networks fault-tolerant and able to provide access to information regardless of location.
- Real testbed environments - IoT approaches on health and care require implementation in real environments. Studies have shown that only 24% of healthcare IoT studies have used real-world environments, with the majority using simulated testbeds. To determine the true validity and efficacy of IoT solutions in health and care, real testbed implementation is required in future. (Kashani et al., 2021)

5.3.5 -Testing, Tracking and Diagnostics

Testing, tracking, and diagnostics refers to the various diagnostic testing performed by health services and the tracking of certain diseases, a primary example being the Coronavirus, cause of the COVID-19 pandemic. In a digital health context, the involved technologies and solutions continue to show huge promise as they advance, with patients able to perform diagnostic tests remotely and communicate the results to their health service providers in real-time. The combination of digital technologies and diagnostic tests can greatly improve both the patient's health outcomes and overall experience of the health and care service by supporting a more efficient testing to diagnosis process and the subsequent tracking. This will be employed in tandem with a reduction in resource and capacity pressures in health and care services allowing for the most appropriate redeployment of their resources. (Healthcare Transformers, 2021)

Key trends include the use of digital technology in supporting rapid point of care testing and the emergence of home diagnostic solutions. These new technologies can accelerate the time it takes to receive test results through removing the need to travel and through circumnavigating legacy components of the health service such as administrative processes, waiting times and use of staff capacity. Increased adoption and development of wearable medical technologies and biosensors will allow for real-time diagnostics at any location, and the further development of clinical decision support solutions can expediate the overall diagnosis process. A key trend will be the development of data-driven lab optimisation solutions, which refers to changes in work practices that have been identified through data analysis and using AI and machine learning to identify potential waste. This will allow clinical laboratories to better manage their testing loads via elimination of unnecessary tests and delivering better value with those that are necessary. (Healthcare Transformers, 2021)

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Part 2

Part 2. Softer Developments

Part 2 of this report discusses the softer developments in digital health and care following COVID, many of which have arisen as a result of the rapid technical developments discussed in Part 1.

Chapter 6 discusses the theme 'acceptance of digital in health and care'. This does not simply refer to the increased acceptance of digital technologies as part of health and care, a phenomenon that has been observed both during and after the pandemic; it also refers to the greater sector-wide efforts by various stakeholders and leaders to establish a cultural shift that can advance the digital transformation of the sectors.

The Chapter begins with discussing the importance of establishing and maintaining trust in digital health (Chapter 6.1) both on part of the citizens and the professionals. Cyber security is addressed as part of this topic in Chapter 6.1.1. Chapter 6.2 focusses on acceptance of digital health as described above, with Chapter 6.3 highlighting the importance of taking the right steps to ensure equality and equity of access to health and care services; building the public's confidence in digital health solutions; and equipping the entire population with the necessary skills to develop, use and benefit from digital health solutions.

Chapter 6.4 considers the implications that the accelerated adoption of digital solutions into health and care services have for the workforce – for those who design, develop, deliver, implement and service digital solutions for use by health and care; those whose daily work is transformed by the arrival of digital solutions; and for the new – or the newly important - job roles that are now required as part of health and care as a result of the digital transformation.

6 - Acceptance of Digital in Health and Care

6.1 - Building Trust in Digital Health and Care

Establishing trust in digital solutions among health and care service providers and users is key to acceptance of digital transformation of services. This applies to all sectors undergoing digital transformation. As digitalisation progresses, the technologies and processes become more complex, which increases uncertainty and ambiguity and have the potential to increase volatility in the processes, impacting public's trust on digital (Deloitte, 2021) (Figure 13).

Figure 13. Framework showing causes of people mistrusting digital technology (Deloitte, 2021).

Deloitte (2021) have identified several impactful trends relating to trust in future digital health and care. These include digital ethics that govern how digital technology is both developed and used across society. Digital ethics will become more necessary in the face of digital ubiquity, which refers to the omnipresence of digital transformation across society. Furthermore, digital trust in health will need to combat polarisation in the digital environment to ensure that the segregation and division often seen in digital environments does not impact the field of digital health. Thus, digital participation and ownership will play a key role in establishing trust in digital health, as will digital cohesion, where digital technology will provide real-life value on the part of the user more clearly. The same phenomena applies to how digital technologies are designed and introduced into standard social care.

Another key aspect for the future of digital trust will be the establishment of digital confidence across the population. This refers to the creation of perceived value in digital technology via the improvement of digital skills and training. The more capable users become, the more likely they are to use, value and trust digital technology (Deloitte, 2021). A more negative aspect emerging in relation to digital trust concerns human commodification, where the individual is reduced to a good or a product within the digital economy. This is of specific concern in digital health and care, where ensuring patient/user's needs, safety and autonomy has to be at the forefront of service planning and delivery.

All in all, considerations of trust need to be embedded at all stages of development of digital health and care solutions, building upon transparency, and understanding, enabled by strategic agility across the digital technology sector. We can reduce the complexity and ambiguity, volatility, and uncertainty of digital transformation through education and leadership. (Deloitte, 2021)

6.1.1 - Cybersecurity

The increased adoption and use of digital technologies in health and care bring along with it concerns about cybersecurity: how do we keep health and care service, devices, and data safe from cyber-attacks? These concerns – and challenges - are amplified due to the lack of cybersecurity professionals in health and care, a trend that applies not only to the current but also the future workforce. This problem is compounded by the minimal supply of cybersecurity specialists with a blend of critical knowledge from both health and care and other relevant sectors. (Helser, 2022)

While cyberattacks in the health sector are nothing new, the sector has become more and more of a target in recent years with the COVID-19 pandemic ushering in a wave of cyberattacks, targeting hospitals, health professionals, patients, commercial entities, supply chains, universities, research laboratories and public health organisations (Wilner et al., 2022). Health and care sectors, forming part of the crucial infrastructure in any nation, make them the perfect target for cybercrime. Hacking into health and care systems provides access to a vast amount of data that has both high intelligence and monetary value and is becoming increasingly digitised every year. During the pandemic, cybercriminals exploited the rapid uptake of remote-working technologies, digital telehealth and remote monitoring healthcare solutions, and an overworked and distracted health and care workforce for the purposes of their own individual, organisational, or in some cases, national gain .(Mahendru, 2020)

The unprecedented circumstances of the pandemic forced governing bodies to loosen regulatory restrictions on privacy and security for the purposes of combating the virus, and to mitigate the impact of COVID-related restrictions. This provided hackers with more leverage to deploy ransomware, snooping programs, phishing attacks and more against the health and care sector. (Mahendru, 2020)

While this is a negative trend, it has however helped to accelerate a change in the rhetoric surrounding healthcare cybersecurity, moving it from not only a concern related to public health organisations and personal safety but to one of national security across the world .(Wilner et al., 2022)

This reprioritisation of cybersecurity in health and care, in combination with the accelerated uptake of digital health technologies, has driven the emergence of several trends in the field. In the immediate future, health and care organisations will have to develop procedures for segmentation and isolation of legacy technologies to prevent cyber-attacks. Organisations will begin to place a priority on and advocate for cybersecurity in digital health and care solutions during any purchasing and/or procurement processes (Lauver, 2021). This will lead to considering cybersecurity questions of these solutions already at the design stage. Top trends identified by cybersecurity experts for healthcare in the post-pandemic era include:

- A focus on the defence of health and care supply chains.
- Headhunting newly emerging talented cybersecurity professionals to protect medical devices and placing a greater focus on training the next generation of health and care cybersecurity specialists.
- A global crack-down on ransomware.
- Carrying out greater scrutiny on emerging health and care technologies, like AI, from a cybersecurity perspective.
- The increasing vulnerability disclosure from manufacturers, with more openness about security flaws in their software and hardware.(Lauver, 2021)

6.2 - Acceptance of Digital Tech in Health and Care

Digital technology has become a constant presence across all aspects of modern society. However, despite high levels of acceptance of digital in online banking, e-commerce, smart-home devices and entertainment, this has been low to moderate in health and social care, particularly in the lead up to the COVID-19 pandemic. (Baumeister et al., 2014; Ebert et al., 2015; Gunasekeran et al., 2021; Philippi et al., 2021)

Acceptability of digital health is often viewed in the same context as the widely deployed Technology Acceptance Model, wherein perceived ease of use and usefulness of a technology positively influences the intent to use said technology, which in turn drives the adoption and acceptability of new technologies (Perski and Short, 2021). Additionally, the individual's ability to use a novel technology has been shown to increase user acceptance, while a lack of experience with digital technology results in lack of interest to use the technology, and therefore decreases user acceptance (Ehrari et al., 2022). The implication here is that a more digitally literate and skilled population will be more accepting of the deployment of digital technologies in health and care services.

The COVID-19 pandemic has provided stakeholders in the field of digital health and care the opportunity to observe digital acceptance in real-time due to the rapid adoption of digital technologies in health and care services, and the significant changes in service delivery required to mitigate the impact of COVID-19 and lockdown procedures (Hutchings, 2020). Continued public acceptance of these technologies is vital to their continued deployment and use beyond the pandemic.

Going forward, leadership within the digital health and care sector, alongside governing bodies and health and care service providers, need to support further research into digital acceptance in health and care to facilitate the development of frameworks and approaches for improving acceptability of digital technology, drawing on lessons learned and focussing on user-centred design (Perski and Short, 2021). Simultaneously, there needs to be a concerted effort to address the various factors that contribute to improving digital technology acceptance. This includes improving the provision of digital skills training and education to increase digital literacy of the overall population.

6.3 - Equity in Digital Health and Care

The growing influence of digital within health and care systems presents the sector with a need to address long-standing societal disparities to ensure a more equitable health and care services. The very nature of digital health and digital care indicate socioeconomic inequalities, disparities in digital skills and education, differences in age, housing, and geographic location, which all impact digital health and care equity. At the same time, digital technology has the potential to greatly improve health and care equity through overcoming structural challenges for marginalised populations by removing barriers of time and distance, and by providing a more personalised approach to communication. To achieve more equitable outcomes, the roll-out of digital health and care solutions needs to proactively engage with prospective service users and providers from planning and design to implementation. The solutions should be built and tested in the populations who need and can benefit from them, employing intentional implementation and build from established and trusted relationships (Lyles et al., 2021). Furthermore, investment in making digital infrastructures available to all, as well as on digital literacy and skills education for citizens and employees alike is crucial. (Crawford and Serhal, 2020; Lyles et al., 2021).

The COVID-19 pandemic saw the rapid implementation and scaling up of several digital solutions to provide access to health services during the pandemic. These solutions may have had unintended consequences for health and digital health equity. In reaction to this, Crawford and Serhal (2020) developed the Digital Health Equity Framework to enable stakeholders in the field to understand the various ways in which digital determinants of health can impact digital health equity and employ this in their work. This framework can be seen in Figure 14 below.

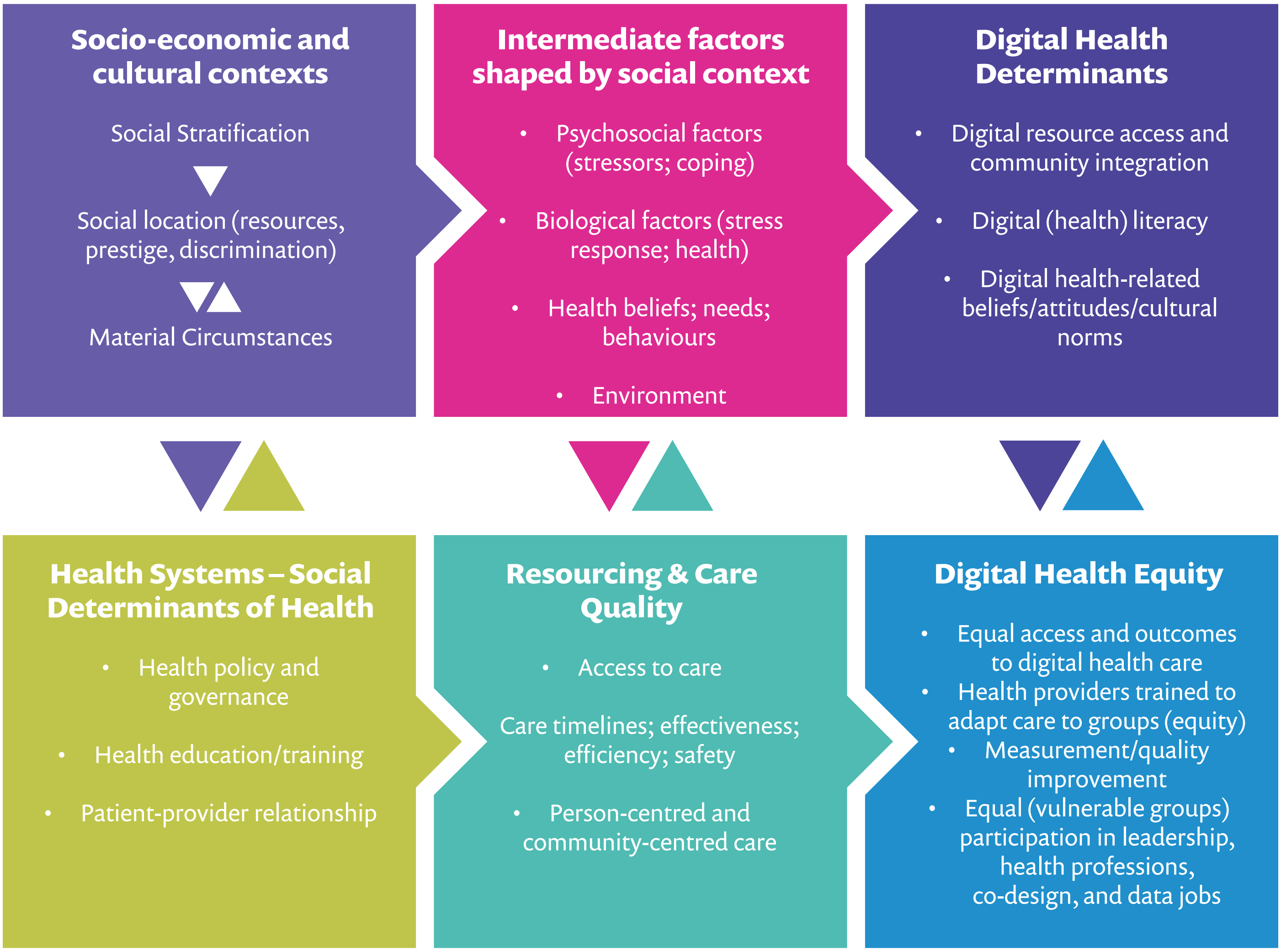

Figure 14. The Digital Health Equity Framework developed by Crawford and Serhal (2020).

6.4 - Implications for Workforce Development

The accelerated global adoption of digital solutions to support health and care delivery brought on by COVID-19, and the resulting scaling up of digital transformation of the sectors, have affected the workforce in multiple ways. The rest of the section discusses the implications this change for the workforce.

For the purposes of the ensuing discussion on the impact of digital transformation on health and care staff, the workforce can be understood in terms of categories shown below (Figure 15).

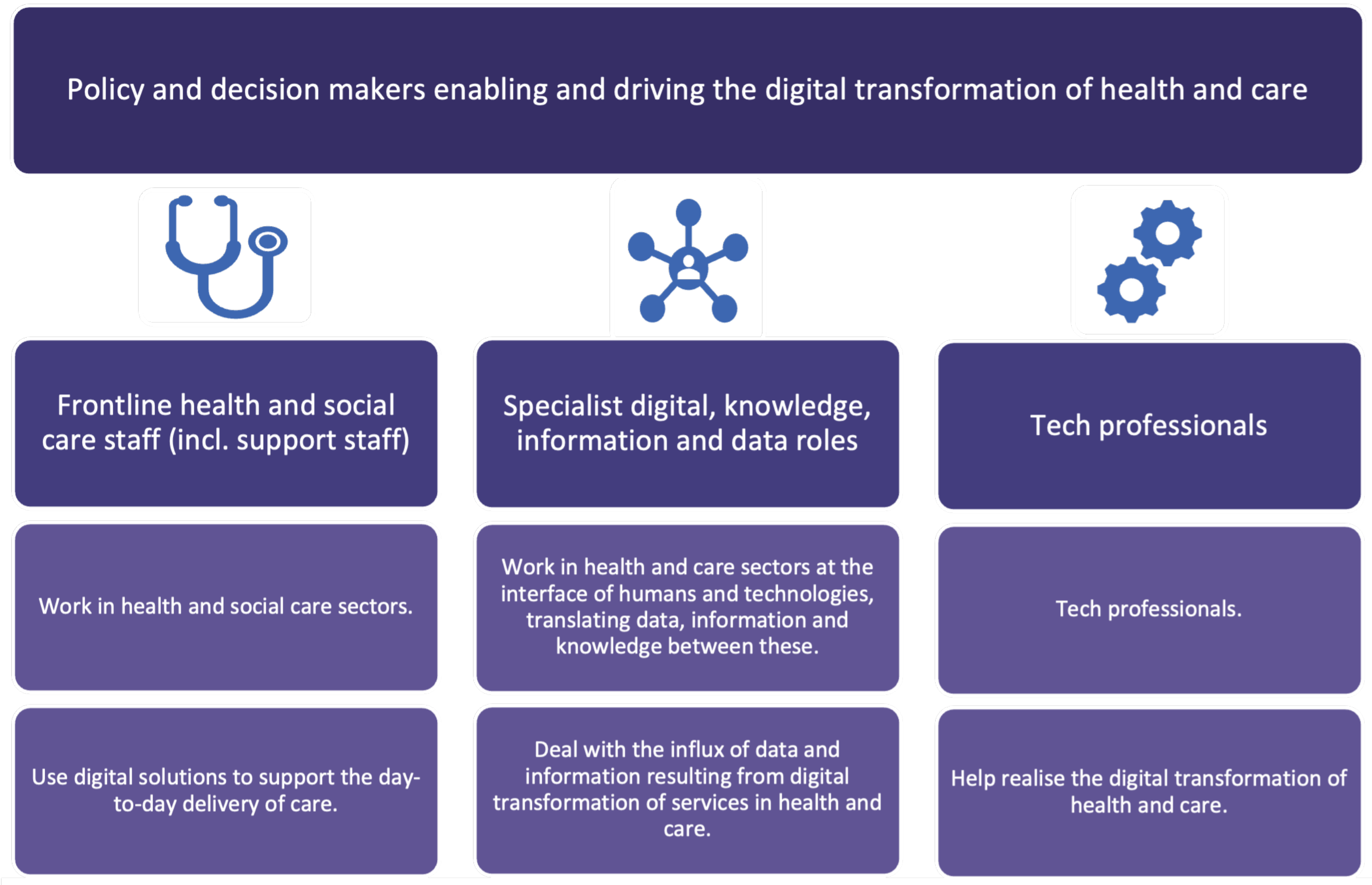

Figure 15. The division of digital health and care workforce into three categories with category descriptions.

6.4.1 - Digital Upskilling of all Health and Social Care Workforce

The immediate implication of digital transformation of health and care delivery, including specific digitally supported medical procedures, is that the workforce will be required to learn entirely new ways of working, previously unrequired of them. This entails putting in place large-scale upskilling and Continuous Professional Development (CPD) programmes that cater to all aspects of the health and care workforce. In Scotland, NHS Education Scotland and the Scottish Government have funded a Digitally Enabled Workforce programme that offers upskilling opportunities to frontline staff via the Turas platform. This includes targeted specialist courses for the specialist Knowledge, Information and Data staff, as well as training in digital transformation for leaders and managers of health and care services (Digital Health & Care Scotland, 2021). In addition to this, the Scottish Social Services Council (2019) published a plan for developing digital capability of its workforce, including leadership.

6.4.2 - Embedding Digital as Core Part of Curricula

According to a review of the education landscape in Scotland, carried out by the DHI (Rimpiläinen, 2022a), students across all aspects of medicine, health, and social care are still largely being trained to work in the analogue world. In other words, curricula across Scottish Further Education (FE) and Higher Education (HE) do not prepare the students to work in digitally enabled work environments. Working in a digitally supported environment does not only entail learning how to use different digital devices, but also how:

- care is delivered remotely,
- how to engage with patients via digital means,
- how to triage and assess patients' needs,
- how to interpret data, or
- how to monitor health issues from a distance.

The importance of human soft skills, such as communication, empathy, critical thinking, and problem solving, is only increasing with the introduction of digitally- enabled and supported ways of delivering health and care (Rimpiläinen et al., 2019; Socha-Dietrich, 2021; Konstantinidis et al., 2022). At the same time, medical, health and social care professionals also need training to understand principles of data management and cybersecurity, the ethical aspects of digitally enabled working practices and associated legal frameworks, as well as research and entrepreneurial opportunities (Machleid et al., 2020; TechNation 2021). As the Organisation for Economic Co-operation and Development (OECD) (2020, p.5) put it, the health and care workforce have to become both "high-tech and high-touch".

To diminish the digital skills gap in medicine, health, and social care, the concept of 'digital' needs to be embedded as a core part of the related curricula rather than being offered as optional or elective modules. For this change to take place, national occupational standards need updating with the digital transformation in mind. Simultaneously, educators within these disciplines need to understand what digitally enabled health and social care services mean for the workforce, and therefore, what the learning needs of the future professionals are (Rimpiläinen, 2022b; Socha-Dietrich, 2021). This may mean a total refresh of how these subjects are taught, with digitally supported ways of delivering care being woven into the content of each degree (cf. Rimpiläinen, 2022b).

6.4.3 - Addressing the Skills Shortage in Digital Health and Care Tech Sector

The digital tech sector is the fastest growing economic sector globally, including the digital health and care tech sector. The demand for digital tech professionals is growing exponentially across the economy (Skills Development Scotland, 2019), while at the same time the interest in and the volume of educational opportunities leading into these roles has fallen by about 30% in the UK, mostly in computing sciences (Murray, 2020). This has created a very heated employment market, where health and care sectors struggle to compete for skilled talent in terms of salaries. To combat that, the health and care sectors need to create unique employment offers to stand out as viable career opportunities for the future digital tech professionals. For instance, the value-based employment offers should make an appeal to the potential employees' desire to help others and to make a tangible contribution to a fast-changing and growing sector; to support the human right to healthcare through technology; or to contribute to creating a greener, more sustainable health and care service delivery.

Furthermore, additional work is required to make the public more aware of the different career options available in digital health and care so that our future workforce (currently in primary or secondary education) are able to consider these new roles as potential careers and to orient their studies towards working in them.

6.4.4 - Exponential Growth in Demand for Specialist Digital and Data Staff Health and Care

The digital transformation of health and care services is increasing the demand for professionals to handle the resulting data volume, information, and related knowledge increase. Health Education England (HEE, 2021) projects the need for 'KIND' (knowledge, information, and data) workforce (DHI, 2019), with specialist digital skills in health and care, to grow by almost 70%. The demand for clinical informaticians alone is predicted to rise by 672% by 2030 (HEE, 2021). There is an immediate urgency to train more professionals to enter these roles.

There will also need to be an increase in the number of education opportunities that lead into roles in digital health and medical tech. Moreover, there is a need for closer collaboration and communication between the education sector and the industry: this will ensure the educators are aware of the emerging skills needs industry has for future staff, allowing them to tailor modules or courses in time to anticipate the need, rather than letting a skills shortage or skills gap to emerge before it is picked up to be addressed. Cross-pollination and exposure of digital disciplines to the health and care sectors may facilitate the emergence of a sufficiently skilled future workforce able to apply their historically domain-agnostic skills within the context of health and care (Rimpiläinen, 2022a; 2022b).

6.4.5 - Educational Strategy to Diversify Curricula

Combining expertise in health and care with expertise in digital technologies means a surge of interdisciplinary job roles. These include:

- health data engineers,
- nursing informatics specialists,
- social care informaticians,
- digital medical record officers,
- clinical coders,
- data governance analysts,
- health intelligence officers,
- healthcare digital project managers,
- digital health solutions architects,
- UX designers in health and care,
- electronic health record supervisors,
- cyber security specialists,
- clinical bioinformaticians,
- bio statisticians,
- clinical product owners, and
- digital transformation specialists (Rimpiläinen et al., 2019; HEE Digital Readiness Programme 2021; Scottish Government 2021b; ISfTeH, 2020).

To support the emergence of this workforce, and to ensure the success of the digital transformation, there is a need to diversify curricula and career paths by integrating clinical and technical skillsets both within curricula, companies, and professional institutions. In addition, in order to appropriately regulate new digital health and medical technologies, policy makers and regulators are required to be educated on the specifics in these innovations, which are at the intersection of healthcare and technology (Demirkan and Spohrer, 2018; Rawston and Baulderstone, 2022).

Universities and further education colleges have a good variety of courses available across multiple disciplines, which, if strategically combined, could be utilised to create pathways leading into interdisciplinary roles in health and care sectors (Rimpiläinen, 2022b; Rawston and Baulderstone, 2022).

6.4.6 - Importance of Workforce Planning

The successful digital transformation of health and care necessitates careful workforce planning. This is required to guide educational policy to meet the sector's workforce needs, but also to assess what impact the possible re-organisation of health and care services, in combination with the changing health and care needs, might have on the workforce demand (Socha-Dietrich, 2021; Rawston and Baulderstone, 2022). Modern workforce planning needs to incorporate envisioning what the medium- and long-term future outcomes and progression of new roles and new professional boundaries might look like to ensure long-term sustainable workforce solutions (Rawston and Baulderstone, 2022).

Both OECD (Socha-Dietrich 2021) and TechNation (2021) have called for the NHS to invest in the full supply model for in-demand roles. To attract and sustain a pipeline of skilled staff, career destinations have to be clearly defined for people to aim at. OECD states:

> *"Without the availability of full-time jobs with a sustainable career track, few talented individuals will choose to leave the practice of medicine, nursing, or pharmacy to obtain additional training and certification in digital technology. The same applies to informaticians or system optimisers, who will not be interested in obtaining additional knowledge in health care, if the sector does not offer them attractive jobs" (Socha-Dietrich 2021, p. 57).*

Currently, the educational pathways and career opportunities in digital health and care are not very clearly defined (Rimpiläinen 2022b). To improve this situation, the industry as well as health and care sectors need to better define the "landing zones" for the future professionals transitioning from education. To support this, shared workforce terminology and standardised job titles should be created across the NHS for specialist digital and tech staff (TechNation 2021).

Workforce planning needs to also consider digitally enabled care models that may emerge in the future (Socha-Dietrich, 2021). TechNation (2021) advocate the use of labour market analytics as a tool in workforce planning. This will help the sector to understand the level of need for the different in-demand digital, data, knowledge, cyber and tech roles. Furthermore, Rawston and Baulderstone (2022) promote the use of AI and predictive analytics to help with demand forecasting (assessing future service needs and its workforce demand), workforce optimisation (identifying ways to re-organise and allocate staff and tasks and ways of working to improve service efficiency), and education, skills, and training (supporting staff to digitally upskill and reskill).

However, in scanning for future digitally enabled care models the OECD proposes the workforce planning needs be based on qualitative intelligence as opposed to traditional projections based solely on quantitative information. This intelligence includes scenarios that describe future care models configurations as well as informed assumptions on how the models will alter the care needs of the public (SochaDietrich, 2021).

7 - Emerging Trends in Digital Health and Care post-COVID

In writing this report and analysing both the technical and softer developments in digital health and care post-COVID, the DHI identified several overarching themes (which have been discussed in the preceding chapters) and emerging trends that could be observed across the digital health and care sector.

The trends were identified through a collective thematic analysis of the main text of this report, where common themes were clustered and given broader categorisation that signposted to the overall direction of the sector. Given the complexity of the landscape and the multiple connections between the technical and softer developments and the associated technologies and phenomena, it was not possible to organise the report content according to trends. Instead, we will discuss them here.

Emerging trends showing the direction of future development of the digital health and care sector are:

1. Greater personalisation of health and care
2. More efficient, effective and precise use of health care data
3. Growing health data autonomy for citizens
4. Overall emphasis on wellbeing and prevention of ill health
5. Care moving away from hospitals into community setting
6. Transformation in skills needs and workforce requirements in health and care

Figure 16: Emerging trends in digital health and care - repetition from page 9.

The first overarching trend, 'greater personalisation of health and care', emerged from across multiple subsectors of digital health and care. These subsectors represent digital solutions which, through utilising patient specific and person-generated data, provide users with more precise, patient-centred approaches to health and care delivery. This trend can be observed across the majority of the report (see table 2 below, which details how these trends relate to each chapter of the report).

Table 2.A table showing the occurrences of the overarching trends throughout the main text of this report.

		Greater personalisation health and care	More efficient, effective, and precise use of healthcare data	Greater health data autonomy for citizens	Overall emphasis on wellbeing and prevention of ill health	Care moving away from hospitals into community setting	The transformation in skills needs and workforce requirements in H&C
Transformation of Health and Care Services	Cloud computing			■		■	
	Big Data	■	■	■	■	■	■
	Artificial Intelligence	■	■	■	■	■	
	Virtual and Augmented Reality		■		■	■	■
	Digital Pharmaceuticals	■	■	■	■	■	
	Digital Pharmacy	■	■	■	■	■	
	Digital Mental Health	■	■	■		■	
	Genomics	■	■		■		
Migration	Telehealth and Telemedicine				■	■	
	EHRs and EMRs	■	■	■		■	
	PHRs	■	■	■		■	
Acceleration of digital innovation	mHealth	■	■		■	■	
	Remote Patient Monitoring & Care	■			■	■	■
	Wearables technologies	■	■	■	■	■	■
Acceptance	Building trust in digital health	■	■	■			■
	Acceptance of digital health					■	■
	Equity in digital health					■	■
	Impact workforce development						■

Secondly, 'more efficient, effective, and precise use of health data' emerged as a commonly shared trend across the sector, closely relating to trend number one. This trend is being driven by the combination of advances in AI, machine learning, predictive and data analytics, with an ever-growing body of health data from both the individual citizen and overall population as well as advancements in cybersecurity and increased interoperability of solutions across the sector.

The third trend, 'growing health data autonomy for citizens', was found to be driven by the expected technical advancements in multiple subsectors, specifically EHRs, EMRs and PHRs, that will allow citizens to have oversight and control over their health data. Similarly, as the proliferation of digital solutions continues, citizens will be able to collect and monitor their own personal health data, with potential for them to integrate this data into their EHRs, EMRs and PHRs.

The fourth trend identified is the 'overall emphasis on wellbeing and prevention of ill health', which closely links with the theme 'care moving away from hospitals into community settings'. Almost every technical subsector in digital health and care is contributing to preventative health and care. For example, using AI and predictive analytics alongside data, provided by remote monitoring or interventions delivered via digital telehealth solutions, healthcare providers can identify and address emerging health and care requirements of both individual citizens and overall populations, before they escalate into poor health conditions or health emergencies. Similarly, community pharmacies are being given more responsibilities in managing minor community health needs as well as a way to promote wellbeing advice outside of the hospital setting.

Finally, underpinning all other trends is 'the transformation in skills needs and workforce requirements in health and care'. The health and care sectors are suffering from digital skills gap, while at the same time, the digital health and care industry has a digital skills shortage. To realise the true potential of any of the subsectors of digital health and care, there needs to be a unified, concentrated effort to transform the education and skills provision for health and care workforce both nationally and worldwide. This is not only required to ensure we have a highly skilled workforce that can develop and maintain digital health and care solutions, but to guarantee we have a health and care workforce that can implement, manage, and use these solutions as part of their day-to-day service delivery. Furthermore, these efforts can help to create a more digitally literate population that can use digital health and care solutions to manage their own health and wellbeing. All of this will help in increasing the acceptance of digital in health and care, and will be key components in warranting the emerging trends identified in this report can be realised and implemented as part of standard health and care service delivery.

8 - Conclusions

This report has considered the impact COVID-19 pandemic has had on the digital health and care sector. The most significant effect is the accelerated adoption of digital solutions to support health and care services at scale. As the virus spread, countries around the world introduced national lockdowns and other measures to reduce the spread of the pandemic, to protect the citizens and the health and care services, and to allow time for vaccine development. Digital solutions were the primary tool in achieving these aims; indeed, the demand for alternative methods for face-to-face service delivery skyrocketed in 2020, immediately changing the dynamics of health and care delivery (Willis Towers Watson, 2021). Fortunately, due to the efforts of the digital health and care industry, the supply of digital solutions was able to meet the sweeping increase in demand. This is in turn reflected in the market size of digital health and care technologies. While the hike in demand for and use of digital health and care solutions has reduced as nations have come out of lockdown, the demand for such services has stabilised at significantly higher levels than pre-pandemic, suggesting an unprecedented increase in public trust on digital technology. Indeed, the legacy of COVID-19 pandemic may be the acceptance and, possibly, the expectation that digital solutions will be used alongside, and in support of, standard practices to deliver health and care services from now on (McKinsey and Company, 2021).

This report presents a number of emerging trends that will influence the sector and will help to transform health and care services in the post-pandemic era through the introduction of novel digital technologies, overseeing the migration of legacy systems and technologies from analogue mode of delivery to digital, accelerating the rate of digital innovation in health and care, and increasing the acceptance of digital solutions and services by the general public and health and care professionals alike.

The new level of acceptance provides the sector with a promising foundation to build upon for digitally transforming health and care delivery. This requires setting up a sector-wide, standardised method for co-designing, delivering and implementing digital solutions in an ethical, equitable, green and person-centred way; sector-wide guidelines for clinical validation and economic analysis of digital health solutions; a plan for modernising legacy service models; strategy for cultivating a culture of trust and acceptance in digital technology; and investment in addressing the digital skills gap, the growing skills shortages, and responding to emergent workforce and skills requirements. Finally, the national leaders need to understand the importance citizens' digital capabilities (or lack thereof) in the picture – only once every stakeholder has the required digital skills and capabilities, can health and care sectors truly reap the benefits of scaled up, digitally supported, preventative health and care.

Scotland's refreshed digital health and care strategy lays out a vision that seeks to leverage current and emerging digital health and care technologies with the aim of giving citizens better access and more autonomy over their own health and care. This includes building a people-centred safe, secure, and ethical digital foundation for the health and care services and allowing industry stakeholders appropriate access to data they need to improve Scotland's health and care systems (Scottish Government, 2021). The strategy seeks to introduce a rolling three-year delivery plan that, if successfully implemented, could help Scotland in realising the trends discussed in this report.

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