Monograph:

Chambers, D. orcid.org/0000-0002-0154-0469, Cantrell, A. and Booth, A. (2021) Rapid evidence review : challenges to implementing digital and data-driven technologies in health and social care. Report. The University of Sheffield , Sheffield.

The University Of Sheffield.

School Of Health And Related Research.

Rapid evidence review: challenges to implementing digital and data-driven technologies in health and social care

Date: August 2020

Prepared for: The Health Foundation

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Rapid evidence review: Challenges to implementing digital and data-driven technology in health and social care

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Executive summary

The aim of this rapid evidence review was to identify the main challenges involved in implementing digital and data-driven technologies in health and social care. We aimed to address the following research questions:

RQ1: what are the main challenges involved in successfully implementing and using digital and data-driven technologies in health and social care?

RQ2: what is the nature of these challenges and how do they arise?

RQ3: what does the literature suggest is required to overcome these challenges?

The review was carried out in two stages: an initial scoping phase (phase 1) followed by more detailed analysis of selected evidence (phase 2). Studies were selected for inclusion in phase 2 mainly on the basis of relevance to real-world implementation in the UK NHS and similar health systems in high-income countries.

The initial literature search identified 1545 items of which 204 were judged relevant for phase 1 coding and 126 were carried forward to phase 2. A supplementary search for data-driven technologies identified an additional six studies, making a total of 132 included in the phase 2 analysis. We synthesised the included studies using a modified version of an existing framework that classified challenges as individual, organisational or technical.

The most frequently reported challenges at the individual level were associated with lack of motivation of healthcare professionals, patients and the public to engage with new digital or data-driven technologies and distrust of the technologies themselves, particularly in relation to safety and reliability. A large number of organisational challenges were identified. Cultural differences between organisations can be a barrier to effective joint working, especially when

leadership is either over-centralised or insufficiently clear in setting objectives. Within organisations, major challenges arise from failure to address the needs and concerns of staff (e.g. around training and changes to job roles) and to recognise that different professionals will have different, sometimes conflicting, needs.

Lack of evidence of effectiveness and/or cost-effectiveness has been a significant challenge to the implementation of digital and data-driven technologies. This may become less of a factor as the evidence base develops, especially if decision-makers take a flexible attitude to the types and sources of evidence they are prepared to consider. On the other hand, poorly reported studies making exaggerated claims based on small samples run the risk of creating distrust and suspicion of ‘hype’.

Significant technical barriers relate to the design and usability of hardware and software; inadequate IT infrastructure; and the availability of secure, high-quality patient data. However, mundane issues such as the impact of app usage on smartphone battery life should not be ignored as such issues can be a major obstacle to use of the technology.

A small but important group of studies suggest that the main source of challenges is high complexity in the technologies themselves, the local context in which they are implemented and/or the wider health system and societal context. Complex challenges are defined as dynamic, unpredictable and not easily disaggregated into constituent components.

The literature suggests that overcoming these challenges requires active support throughout the implementation process. This includes active engagement with patients and the public and developing the evidence base through a continuous process of evaluation. Implementation is more likely to be successful when the introduction of new technology is seen to align with organisational goals and values. Implementation should take account of complexity and seek to reduce it as far as possible.

Successful implementation of new technologies requires the development of digital knowledge and skills in the health and care workforce, including the development of new roles for clinicians to act as ‘digital champions’. Transfer of tasks between different sectors (e.g. digital care pathways allowing patients to be managed in primary care rather than as hospital outpatients) may provide opportunities for staff to acquire new skills.

While the future is uncertain, it is possible that a shift towards digital delivery of health and social care will be accelerated following the current coronavirus pandemic.

Background

Digital health technologies include apps, programs and software used in the health and care system, together with the equipment needed to support them (including video-conferencing and other communications technologies). Data-driven technologies are those that work by collecting, using and analysing data, particularly systems using artificial intelligence and machine learning. The potential of such technologies to improve health and health care is well known and there are many examples of their successful use in practice. At the same time, it is clear that bringing new digital and data-driven technologies into practice can be challenging because of the multitude of issues that need to be addressed during the implementation process. Specific areas where challenges may be encountered include infrastructure, education and training, staff and user 'buy-in', organisational culture, and the need to redesign roles and take up new ways of working. This list is not exhaustive and the challenges encountered vary according to the nature of the technology and the context for implementation.

The aim of this rapid evidence review was to identify the main challenges involved in implementing digital and data-driven technologies in health and social care. We aimed to address the following research questions:

RQ1: what are the main challenges involved in successfully implementing and using digital and data-driven technologies in health and social care?

RQ2: what is the nature of these challenges and how do they arise?

RQ3: what does the literature suggest is required to overcome these challenges?

Methods

The review was carried out in two stages: an initial scoping phase (phase 1) followed by more detailed analysis of selected evidence (phase 2). Studies were selected for inclusion in phase 2 mainly on the basis of relevance to real-world implementation in the UK NHS and similar health systems in high-income countries.

Literature search

We searched Medline, CINAHL, HMIC, Science and Social Sciences Citation Indexes and Social Policy & Practice for relevant studies in March 2020. The search combined broad terms for digital and data-driven technologies and specific technologies with terms for implementation studies and synonyms for challenges and the specific challenges listed in the brief: infrastructure, education and training, staff and patient buy-in and organisational culture. A final set of terms covered the health/social care setting. The search was limited to English language studies published in 2010 or later. The final Medline search strategy is presented in Appendix 1. Searches for grey literature included broad searches of Google and Google Scholar and searches of the websites of relevant organisations. Grey literature was also identified from the Social Policy and Practice database. An additional focused search for studies of machine learning and other data-driven technologies was performed as part of phase 2 of the project.

Inclusion criteria

References identified by the literature search were screened by a single reviewer based on the title and abstract. Studies were included for phase 1 if they met the following criteria:

- Participants: health or social care professionals and their employing organisations, patients or service users in high-income country settings
- Intervention: any intervention to implement digital or data-driven technology in a 'real world' setting. This includes supporting implementation by seeking to identify barriers before, during or after implementation
- Comparator: any relevant comparator (e.g. before and after implementation); non-comparative studies were also included
- Outcomes: identification of barriers and facilitators to implementation; actions taken or recommended to overcome specific barriers

Studies of any design were eligible, including literature reviews and expert reports as well as formal research studies.

Phase 1 coding and analysis

References were imported into EPPI-Reviewer software for coding and analysis. The following data were extracted for studies that were judged from the title/abstract to meet the inclusion criteria:

- Bibliographic reference or URL
- Type of technology
- Setting
- Implementation intervention
- Implementation challenges
- Suggested solutions
- Study suitable for inclusion in phase 2?

We grouped the studies by type of technology and presented the results as a brief narrative summary for discussion with the Health Foundation. Based on the nature and volume of the included literature, it was agreed that phase 2 of the review would continue to focus on the full range of digital and data-driven technologies with an additional focused search to identify more studies on machine learning and other data-driven technologies. Studies were selected for inclusion in phase 2 of the review based on relevance to the research questions (e.g. UK study, relatively recent study) and strength of methodology (e.g. systematic review or evidence-based guidance or policy document).

Phase 2 coding and analysis

Phase 2 of the review (on which this report is mainly based) involved more detailed data extraction and evidence synthesis based on examination of full-text reports. We proposed to use a 'best fit framework synthesis' approach to synthesising the evidence (Carroll 2013). Following a search of the literature to identify existing frameworks, we decided to use a modified version of a framework developed by Schreiweis et al. (2019) to investigate barriers to e-health use. This framework classifies barriers as individual (e.g. beliefs, motivation and behaviour), environmental/organisational (e.g. those resulting from organisational structures, values and decision-making processes) and technical (e.g. poor Internet connections, limited access to equipment) while recognising that these are not mutually exclusive. The modified version used in the review (Appendix 2) places increased emphasis on organisational barriers and explicitly allows for inclusion of emergent barriers discovered during the synthesis process.

Given the focus on implementation and the fact that this is primarily a mapping review, we did not formally assess the included studies for risk of bias. We based the phase 2 analysis on what we considered the more robust evidence to support decision-making in UK health and social care, based on criteria including: study conducted in the UK; relatively recent study (e.g. 2015 or later); findings based on multiple studies (e.g. systematic review, a set of related primary studies or an evidence-based guideline or policy document); independent evaluation; and use of qualitative methodology rather than survey/questionnaire to elicit opinions.

Highlighting the key evidence

The following evidence sources were considered particularly valuable and insights derived from them have been highlighted in **bold** in this report (including the reference list):

- Systematic reviews of primary studies
- Rigorous UK trials or evaluations of implementation interventions (e.g. Snooks et al. 2019)
- Groups of UK primary research studies that together offer rich insights into barriers to implementation of new digital technologies in NHS settings, specifically the work of Cresswell and colleagues and Greenhalgh and colleagues
- Recent expert reports published by UK stakeholders (particularly relevant for RQ3).

Results/Discussion

The initial literature search identified 1545 items of which 204 were judged relevant for phase 1 coding and 126 were carried forward to phase 2. The supplementary search for data-driven technologies identified an additional six studies, making a total of 132 included in the phase 2 analysis reported below.

Summary of included studies

Study types

Of the 132 phase 2 studies, 92 were classified as research, 36 as literature reviews and 4 as 'grey literature'. Seventy were classified as UK studies and 62 were international (e.g. reviews) or came from other European countries, North America or Australia/New Zealand. The majority of studies (113) identified barriers and/or facilitators to implementation using qualitative or quantitative methods. Studies were carried out before, during or after implementation of a new technology. Relatively few studies (26/132 or 19.6%) reported that implementation was accompanied by interventions to support the implementation, such as technical assistance (9 studies), implementation teams (3), a formal implementation plan (6), ongoing training (6) or changes to workflow (4).

Technology types

Studies could be coded for more than one technology type if appropriate. Table 1 summarises coding by technology type. The predominance of digital over data-driven technologies reflects the fact that implementation of the latter group is more recent.

Table 1: frequency of technology types

Code: Technology type	**Count**
Telehealth/telemedicine	22
Telecare	6
mHealth	26
Information systems	42
Communication systems	15
Equipment	10
Machine learning	10
Image analysis	3
Data processing	4
Predictive modelling	1
Data/text mining	0

Digital: general	15
Data-driven: general	2

Settings

Secondary/specialist care was the most common setting (83 studies), followed by primary care (25), social care (22), public/population health (9) and management/administration (6). Again, studies were coded in multiple categories if appropriate. Table 2 illustrates the distribution of technology types across different settings.

Studies of challenges to implementation in social care settings most commonly examine telehealth and telecare technologies (as defined by study authors and recognising that terms are used inconsistently in the literature) including new service models (Cook 2016; Slone 2018) and technologies for assisted living (Damodaran 2010). Included studies also examined digital education about dementia for professionals (Moehead 2020); digital reminiscence therapy (Collins 2016); robots in care homes (Huisman 2019); and fall detectors (Ward 2012). Reviews of broader topics were also identified, including occupational therapy (Ninnis 2019); applications to improve social participation of people with dementia (**Pinto-Bruno 2017**); and factors influencing older people's acceptance of technology (Tsertsidis 2019).

The following sections describe the findings in terms of the pre-specified research questions and the evidence synthesis framework in Appendix 2.

Table 2: distribution of technology types by settings

Code	**Primary care**	**Secondary/specialist care**	**Public/population health**	**Social care**	**Management/administration**	**Not applicable**
Telehealth/telemedicine	6	27	0	7	1	2
Telecare	0	5	0	6	1	0
mHealth	7	25	14	1	0	4
Information systems	14	42	11	4	5	4
Communication systems	5	12	3	3	2	0
Equipment	2	12	3	4	0	2
Machine learning	0	14	2	0	1	2
Image analysis	0	4	1	0	0	0
Data processing	1	3	0	2	1	0
Predictive modelling	1	1	0	0	1	0
Data/text mining	0	0	1	0	0	0
Robotics	0	0	0	1	0	0
Other digital	0	0	1	0	0	0
Digital: general	2	10	5	6	1	3
Data-driven: general	0	1	0	0	1	5

RQ1: What are the main challenges?

Individual barriers

Cognition: Lack of skills/knowledge was identified as a barrier for various technology types (Table 3), primarily for patients (Baker 2017; Hall 2014; **Topol 2019**) but also for health professionals (Taklan 2012; Wozney 2017). Older patients experienced barriers to use of telehealth or telecare systems at home (Hall 2014; Cook 2016), while both patients and professionals reported lacking skills/confidence to handle minor technical issues in online consultations (Shaw 2018). A closely related group of barriers referred to the ability to learn new skills to engage with digital and data-driven technologies (Table 3). Palliative care staff found an electronic record system difficult to use initially (Hall 2012) while a study of videoconferencing for mental health practitioners highlighted the need for clinicians to learn new skills and be aware of limitations in communication imposed by the technology (Page 2019). Ability to learn can be an issue for patients also, for example in using an app for people with HIV that offered customized alert of medication time windows (Cho 2019).

Motivation: A second group of barriers at the individual level relates to lack of motivation for individuals to engage with new technologies (Table 4). Reasons for reduced motivation include perceived low value to the individual, unclear benefits (including perceived or actual increases in workload for the individual) and preference for an alternative solution (including the status quo). **Cresswell et al. (2017) reported that less engaged users were more likely to use 'workarounds' rather than work with colleagues to develop solutions to technical problems.**

Motivation may increase or decrease over time and a few studies identified sustaining use of new technologies over the long-term (e.g. 6 months or more) as a potential barrier. This was reported for patients using apps or telemedicine for self-management (Hidalgo-Mazzei 2018; Qian 2019) or to promote physical activity (**Petersen 2019**). Lemon et al. (2018) found that nurses' enthusiasm for a new telemedicine system faded over time, with design inconsistency and perceived complexity becoming more noticeable.

Table 3: summary of studies on barriers related to cognition

Type of barrier	Example(s)	Technology	Staff or users involved	Additional information
Cognition				
Lack of skills/knowledge	Baker 2017	Equipment (tablet)	Older disadvantaged people	Participants' social isolation a barrier to virtual networks
	Cook 2016	Telehealth/telecare	Patients	Need for reassurance, influence of referrers
	Hall 2014	Telehealth/telemedicine	Patients	Participants expressed need for training and tailoring
	O'Connor 2016	**Digital (general)**	**Patients**	**More investment is needed to improve computer literacy and ensure technologies are accessible and affordable for those who wish to sign up to them**
	Shaw 2018	Communication systems (online consultations)	Patients and clinicians	Lack of skills/confidence to handle minor technical issues
	Takian 2012	Information systems (EHR)	Mental health trust staff	Low IT literacy
	Topol 2019	**Digital general**	**Patients**	**Capacity and willingness to engage, any barriers to their use of technology, such as limited movement caused by joint problems such as arthritis, access to computing hardware and connectivity.**
	Wozney 2017	Digital (e-mental health)	Key informants in implementing organisations	Computer literacy skills [patients and providers], knowledge gaps about cyber security, limited knowledge of available services
Ability to learn	Cho 2019	mHealth	People with HIV	Barriers related to ease of use, HIV-related stigma and disclosure of HIV status, customized alert of medication time windows based on individual routine set-up, and preference for device design

	Hall 2012	Information systems (electronic record)	Palliative care	Users found difficult to use initially
	Page 2019	Video conferencing	Forensic MH practitioners	Additional skills are demanded of clinicians including familiarisation with the equipment and an awareness of the restrictions in communication using videoconferencing

Table 4: summary of studies on barriers related to individual motivation

Type of barrier	**Example(s)**	**Technology**	**Staff or users involved**	**Additional information**
Motivation				
Low value to individual	Cranfield 2015	Information systems (CPOE and PACS)	Hospital specialists	Implementation success depended on perceived ease of use etc. (PACS > CPOE)
	Cresswell 2017 (HSR)	Information systems (Computerized physician order entry (CPOE) and computerized decision support (CDS))	Hospital prescribers	Less engaged individuals use 'workarounds' rather than working to develop solutions
	Greenhalgh 2010	**Information systems (EHR)**		**Individual use varied widely, influenced by small details (e.g. time required to obtain patient consent)**
	Takian 2012	Information systems (EHR)	Mental health trust staff	Perceived as time-consuming
	Tsertsidis 2019	Digital (general)	Older people	Individual concerns/problems regarding technology (technical errors, etc.). But some negative concerns that appeared in the pre-implementation stage appear as positive characteristics in the post-implementation stage.
Unclear benefits	Ginestra 2019	Machine learning (sepsis algorithm)	Hospital clinicians	The majority of clinicians reported no change in perception of the patient's risk for sepsis after a system alert
	Jacob 2019	mHealth	Hospital clinicians	Attitude to technology, existing workload
	Liss 2018	mHealth	Patients	Varying willingness to use tracking app for low-acuity visits
	Ward 2012	Equipment (fall detectors)	Social care	The range of technologies currently available through health and social services to users was limited. Health and

				social care staff appeared to be less convinced of the benefits of fall detectors than end-users.
	Zayas-Caban 2010	Digital: general	Home	Design and implementation processes resulted in poor fit with some patients' healthcare tasks and the home environment and, in some cases, resulted in lack of use.
Perceived increased workload	**Cresswell 2014**	**Information systems (Computerized physician order entry (CPOE) and clinical decision support (CDS))**	**Hospital specialists**	
	Keyworth 2018	**Digital (general)**		
	Shaw 2018	Communication systems (online consultations)	Hospital clinicians	Reluctant to use system because 'too busy'
Prefer alternative solution	**Greenhalgh 2014**	**Data processing ('Choose and book')**	**GPs and patients**	**Both groups resisted the idea that patients could make a 'rational' choice of hospital without help from the GP**
	Pappas 2011	Information systems	Computer-aided history takers (CAHTs)	CAHTS seen as inherently limited when detecting non-verbal communication, may pose irrelevant questions and frustrate the users with technical problems. Barriers such as a preference for pen-and-paper methods and concerns about data loss and security still exist and affect the adoption of CAHTS

Accessibility: Barriers related to accessibility include limited access to hardware and/or software, including accessibility for people with disabilities (Russ 2020). Physical access was mainly an issue that affected patients, health professionals being more likely to report problems such as lack of time to access technologies, especially in the early stages of implementation (Akehurst 2018).

Failure to provide information in an optimum format can also be a barrier to access. Studies included in the review reported that people with MS using an app found excessive text-based content fatiguing (Babbage 2019), while a tech-based CBT system for young people relied too much on reading and writing skills and provided over-generalised content (**McCashin 2019**). From the health professionals' viewpoint, a study of online consultations reported that the system was unable to accommodate what was described as the 'messiness' of real-life consultations in general practice (Casey 2017).

Lack of trust: Distrust of new technologies by health professionals and patients or service users is a major challenge for implementation (Table 6). The included studies provide examples of distrust of a variety of technologies, mainly from health professionals but also from patients and the public. Reasons for distrust often reflect concerns about possible impact on patient safety. One study reported a perceived threat to clinicians' identity and independence (Cook 2016). Lack of public trust in the organisations that supply the technologies (i.e. 'tech companies') was reported in one study (**Joshi 2019**) but is likely to be under-represented in academic health and medical databases because much research in this field is undertaken by other disciplines.

Table 5: summary of studies on barriers related to accessibility

Type of barrier	Example(s)	Technology	Staff or users involved	Additional information
Accessibility	Cook 2016	Telehealth/telecare	Patients	Engagement with service depended on perceived usefulness and usability
Lack of accurate information	Richards 2019	mHealth (app)	Cancer patients	Barriers to information exchange and understanding in consultations, and identification of reliable information sources between consultations
Lack of time for learning/CPD	Akehurst 2018	Information systems (online care pathways)	GPs	
Physical problems , e.g. disability	Russ 2020	mHealth (app)	Surgical patients	Need to improve accessibility for people with disabilities
Format of information	Babbage 2019	mHealth	People with MS	Users found too much text fatiguing
	Casey 2017	Communication systems (online consultation)	GPs, practice staff and patients	'Messiness' of GP consultation hard to accommodate in online consult system
	McCashin 2019	**Communication systems (tech-assisted CBT)**	**Patients (young people)**	**Over-reliance on reading and writing skills and dissatisfaction with overly generalized content and comparison with commercial technologies**

Table 6: summary of studies on barriers related to lack of trust in technology

Type of barrier	Example(s)	Technology	Staff involved	Additional information
Lack of trust in technology	Amarouche 2017	Information systems (online referral)	Hospital staff	Referrers continue to follow-up by phone
	Beede 2020	Machine learning (diabetic retinopathy screening)	Patients, nurses	Need for true informed consent
	Bellemo 2019	Machine learning	Specialists	Concern over accuracy of interpretation of images and AI system potentially overruling clinicians' judgement
	Bradford 2013	**Telehealth/telemedicine**	**Palliative care**	**Some clinicians viewed technology as impersonal**
	Cook 2016	Telehealth/telecare	Patients	Perceived threat to identity and independence
	Cranfield 2015	Information systems (CPOE and PACS)	Hospital specialists	
	Cresswell 2012	**Information systems (EHR)**	**Hospital specialists**	**Use of workarounds**
	Cresswell 2014	**Information systems (Computerized physician order entry (CPOE) and clinical decision support (CDS))**	**Hospital specialists**	**Concern over risk of duplicate prescribing**
	Holt 2018	Information systems (Risk assessment software)	GPs	Unwilling to see patients they considered unsuitable for anticoagulant treatment
‘	Kayyani 2017	Telehealth/telemedicine	Range of HCPs	'Misconceptions', including fear of losing face-to-face contact with patients and vital care information, patients' beliefs and confidence in using technology
	Meeks 2016	Information systems (EHR)	Hospital staff	Patient safety-related barriers at different levels
	Nielsen 2019	**Machine learning (diabetic retinopathy screening)**	**Health professionals**	**Ethical concerns regarding lack of trust in the diagnostic accuracy of computers.**

Table 7: summary of studies of political barriers associated with national implementation programmes

Type of barrier	Example(s)	Technology	Staff involved	Additional information
Problems with national implementation programmes	**Cresswell 2012 (HIJ)**	**Information systems (EHR)**	**Hospital specialists and managers**	**Changing political and economic landscape**
	Cresswell 2012 (HIJ)	**Information systems (EHR)**	**Hospital specialists and managers**	**Hospitals started from different points, progress and barriers depended on local context**
	Cresswell 2019	**Information systems (decision support)**	**Hospital specialists and managers**	**Respondents identified need for a strong national programme to improve usability and avoid unintended consequences**
	Joshi 2019	**Data-driven (general)**	**All leaders**	**Need for leadership and co-operation at all levels (including international partnerships)**
	Robertson 2010	Information systems (EHR)	Hospital specialists and managers	Centrally negotiated contracts limit scope for local flexibility. Support for 'middle out' approach (see paper)
	Sheikh 2011	Information systems (EHR)	Hospital specialists and managers	Numerous factors caused delays in national programme
	Takian 2012	Information systems (EHR)	Hospital specialists and managers	Changing context (political, social, technical) complicates evaluation of EHR implementation

Other individual barriers: A few studies identified ‘emergent’ barriers that fell outside the study framework. Health professionals’ attitudes towards smartphone use, which some regard as unprofessional in clinical settings, may present a barrier to mHealth in some settings (Carani 2013; Payne 2014; **Qudah 2019**).

Two linked studies of a digital risk scoring tool identified concerns among health visitors about classifying infants in terms of obesity risk because of concerns about stigma (Redsell 2017; Rose 2019). However, such issues may not be specific to digital interventions. Another feature of this research was the role of parents in helping health visitors who were less confident in using the technology.

Overview: In summary, the most frequently reported challenges at the individual level were associated with lack of motivation to engage with new digital or data-driven technologies and distrust of the technologies themselves, particularly in relation to safety and reliability.

Organisational barriers

Financial barriers: Actual or perceived high costs for equipment and staff have frequently proved a barrier to implementation of digital technologies (Wozney 2017), particularly telehealth (Hall 2014; Kayyani 2017) and telecare (Slone 2018). Data on costs may be cited together with limited evidence on effectiveness (see below) to argue that investment in these technologies is not a good use of scarce resources. However, Kern et al. (2020) recently reported that reduced costs for imaging equipment have led to a major barrier to tele-ophthalmology implementation being overcome.

Political barriers can arise at various levels: national, regional, local or inter-organisational. Studies of national programmes in the UK and England to implement electronic medical records and decision support systems identified problems caused by inflexible top-down leadership (including centrally negotiated contracts) and changes in political priorities at the national level (Table 7). However, a more recent study in Scotland reported a perceived need for **strong national leadership to support implementation of decision support systems**

(**Cresswell 2019**). A report devoted to data-driven technologies (**Joshi 2019**) argues for **leadership and co-operation at all levels, including international partnerships**.

The AHSN Network report on AI in the UK health and care system (Ream 2018) identified regulation as a potential political barrier that could delay implementation of data-driven technologies. Political concerns about the potential of new technologies to increase inequality at the expense of people who have difficulty accessing the technology also need to be addressed (Walters 2017).

Buy-in: At the organisational level, achieving 'buy-in' from staff and patients/service users is closely related to overcoming the individual level barriers discussed above. Included studies suggest that 'buy-in' requires sustained engagement with staff that addresses concerns of specific groups and that relates implementation of new technology to the goals and values of the organisation (Table 8). Low levels of uptake or negative responses from service users can be a major barrier to implementation of technologies such as online consultation (Edwards 2017) or apps designed for service users (Westwood 2017). In a report for the RSA, **Singh (2019)** argues for 'collective conversations' supported by the NHS to address users' concerns.

Table 8: summary of studies addressing staff 'buy-in'

Type of barrier	**Example(s)**	**Technology**	**Staff involved**	**Additional information**
'Buy-in'				
From staff	Akehurst 2018	Information systems (online care pathways)	GPs	Heavy initial promotion by CCG
	Bellemo 2019	Machine learning	Specialists	Concern over interpretation of images
	Cresswell 2017 (HSR)	**Information systems (Computerized physician order entry (CPOE) and computerized decision support (CDS))**	**Hospital prescribers**	**Need for sustained engagement across user groups around system enhancement and the development of user competencies and effective use**
	Keyworth 2018	**Digital (general)**		**Fit with organisation's goals and priorities**
	Patel 2013	Telehealth/telemedicine	Dentistry	Need for strategic alignment with clinical and organizational goals, clinical engagement and strong political support. The challenges within each stakeholder group must be specifically targeted.
	Singh 2019 (RSA)	**AI general**		**Advocates 'clinical champions' to support AI implementation across the NHS**

Table 9: summary of studies addressing barriers related to organisational culture

Type of barrier	Example(s)	Technology	Staff involved	Additional information
Organisational culture				
Possible legal repercussions	Bellemo 2019	Machine learning (diabetic retinopathy screening)	Specialists	
	Gardiner 2012	Telehealth/telemedicine	Specialists	Legal implications need to be carefully considered if it is to be safely integrated into daily practice
Need for substantial collaboration	Caffery 2019	Telehealth/telemedicine	Ophthalmologists	
Manage expectations of impact	Charani 2017	mHealth	Doctors and pharmacists	Authors state study shows need to manage expectations of mHealth impact and use appropriate indicators
Different organisations	**Greenhalgh 2010**	**Information systems (EHR)**	**Primary and secondary care**	**Interaction between multiple stakeholders from different worlds (clinical, political, technical, commercial) with different values, priorities, and ways of working**
	Petrakaki 2014	Information systems (electronic prescribing)		Different perceptions of risk (and responsibility/blame) across organisations
	Pourmand 2018	mHealth	Emergency departments	Responsibility to protect patient privacy and confidentiality
	Ward 2017	Digital (general)	Drug misuse	Collaboration between organisations required for implementation
General	Jacob 2019	mHealth	Hospital clinicians	Endorsement; internal politics; cultural views of mobile use at work

	Kenicer 2012	Computerised CBT	Patients	Policies prevent staff from routinely contacting patients via email, skype or instant messenger
	Takian 2012 (case study)	Information systems (EHR)	Mental health trust staff	Significant cultural and work environment changes required
	Thomas 2019	mHealth (dementia screening app)	Primary care	Evaluation using action research to highlight some of the challenges of overcoming an overtly medicalised approach
	Wozney 2017	Digital (e-mental health)	Key informants in implementing organisations	Intensity effect sizes showed the highest concentration of statements (>10% of all comments) related to funding, credibility, knowledge gaps, and patient empowerment

Organisational structure may support or impede effective implementation of new technologies depending on the context. Studies of electronic health record implementation have demonstrated that **organisational decision-making at the hospital level can be affected by political and patient pressure to demonstrate progress (Cresswell 2012).** At the local level, Muirhead (2016) argues for a model of 'distributed leadership' (in which individuals share their knowledge for the benefit of the system as a whole) to tackle barriers that prevent organisations from working together. This is closely related to organisational culture as discussed in the following section.

Barriers related to organisational culture (Table 9) may arise within organisations and particularly when different organisations need to collaborate to implement new technologies. Organisations may have concerns about potential legal repercussions. For example, who is responsible for the consequences of an incorrect diagnosis supplied by a machine learning system performing diabetic retinopathy screening (Bellemo 2019) or specialists giving opinions based on data supplied by telehealth systems (Gardiner 2012)? A study of mHealth implementation (Charani 2017) identified a need for organisations to manage expectations of the impact of new technology and to use appropriate indicators to measure impact. Organisational policies themselves may present a barrier to change. For example, a computerised CBT service in Scotland was hindered by a policy that staff should not routinely contact patients via email, skype or instant messenger (Kenicer 2012). Taklan et al. (2012) reported that significant cultural and work environment changes were required to support electronic health record implementation in a mental health trust.

Collaboration is often fundamental to implementation (Caffery 2017; Ward 2019) and various included studies highlight challenges to effective collaboration. In particular, **Greenhalgh (2010)** highlights how relevant stakeholders may come from different backgrounds (e.g., clinical, political, technical, commercial) with different values, priorities, and ways of working. Different organisations may perceive risk and associated concepts like responsibility and blame on very different ways (Petrakaki 2014).

Education and training: The need for organisations to provide additional training has been identified as a barrier for various new technologies, including electronic medical records

(Albuquerque 2011; Takian 2012); online referral (Amarouche 2017) and care pathways (Connell 2019); video conferencing (de Weger 2013) and in care home settings (Wild 2016). For example, inadequate training was identified as a factor that inhibited implementation of electronic records in a mental health trust (Takian 2012).

Work environment/broader context: The organisational context in which new technologies are implemented involves a mixture of individual, organisational and technical barriers. Included studies identified barriers associated with pressure on the organisation's resources and with particular staff groups feeling that their roles could be undermined or their income reduced (Table 10).

Table 10: Summary of studies of pressures at the organisational level

Example(s)	Technology	Staff involved	Additional information
Bradford 2013	**Telehealth/telemedicine**	**Palliative care**	**Technology threatens nurses' income**
Burgin 2014	Information systems (electronic medical records/prescribing)	Hospital pharmacists	Risk of reduced patient contact and visibility to patients
Collins 2016	Communication systems (digital reminiscence therapy)	Care providers	'Lack of staff and time'
Ninnis 2019	Digital (general)	Occupational therapists	Perceived threat to OT role
Shaw 2018	Communication systems (online consultations)	Clinicians	Pressure on human and financial resources in all departments

Implementation of new technologies frequently involves transfer of tasks from one group of staff to another. For example, online care pathways may see GPs taking on tasks previously performed by secondary care clinicians (Akehurst 2018), while digital consultation transfers tasks from GPs to other practice staff and to patients themselves (Casey 2017). This type of change can create tensions within organisations (Cranfield 2015) but new roles and ways of working can also help to address challenges as discussed below (see RQ3).

Information governance barriers (i.e., those related to information/data management) were identified, particularly during the transition from paper-based to digital information systems. **The Topol review into workforce needs for digital health (Topol 2018) identified gaps in**

information governance; lack of expertise; and suggested a 'code of conduct' to guide ethical decision-making. Dealing with such problems is time-consuming (Noble 2012) bur essential as poor-quality data (e.g. paper and digital records used simultaneously) can create confusion (Carani 2013) and potentially threaten safety. A closely related barrier is the need to tailor information for specific groups of users. For example, staff working for out-of-hours services may need more detailed information from electronic records than those working during core hours (Craig 2015) but be less likely to access electronic records (Hall 2012).

Overview: A large number of organisational challenges have been identified. Cultural differences between organisations can be a barrier to effective joint working, especially when leadership is either over-centralised or insufficiently clear in setting objectives. Within organisations, major challenges arise from failure to address the needs and concerns of staff (e.g. around training and changes to job roles) and to recognise that different professionals will have different, sometimes conflicting, needs.

The role of supporting evidence

Decision-makers require robust evidence of effectiveness (including cost-effectiveness) to justify implementing changes to the delivery of services. Changes are likely to involve costs, not only to acquire new technologies and associated equipment but also to train and support staff in their use and deal with any problems that arise during implementation. In health and social care, technical problems can threaten patient safety, strengthening the case for caution in introducing technological innovations. costs etc.

In the case of digital and data-driven technologies, development of supporting evidence can be a problem for two main reasons. The evidence-based health care movement stresses the importance of randomised trials but these may be difficult to conduct for this type of technology; for example, randomised trials are rarely performed for diagnostic tests. Secondly, there may be a tension between the need to get a new technology into practice and the time required to accumulate evidence from rigorous research studies.

Studies included in the review show that lack of supporting evidence has been a barrier to implementation in a range of settings (Table 11). Only one included study provided definite evidence of lack of effectiveness of a digital technology following supported implementation

(**Snooks 2019**). An important recent systematic review (**Nagendran 2020**) assessed the rigour and reporting quality of studies of 'deep learning' technologies in medical imaging. The authors noted that **there were few prospective studies and these were often poorly reported, with limited transparency**. Where studies compared the performance of machine learning systems with that of human clinicians, sample sizes were often small.

Overview: In summary, lack of evidence of effectiveness and/or cost-effectiveness has been a significant challenge to the implementation of digital and data-driven technologies. This may become less of a factor as the evidence base develops, especially if decision-makers take a flexible attitude to the types and sources of evidence they are prepared to consider. On the other hand, **poorly reported studies making exaggerated claims based on small samples run the risk of creating distrust and suspicion of 'hype' as highlighted by Nagendran et al. (2020).**

Table 11: summary of studies identifying barriers related to supporting evidence

Type of barrier	**Example(s)**	**Technology**	**Staff involved**	**Additional information**
Supporting evidence	Bradley 2010	Telehealth/telemedicine	Primary care and specialist dentistry	Lack of evidence for diagnostic accuracy or cost effectiveness
	Bush 2016	**Telehealth/telemedicine**	**Audiologists**	**Lack of evidence for cost effectiveness/reimbursement**
	Byambasuren 2018	**mHealth**	**Primary care**	**Lack of robust (RCT) evidence a barrier to prescribing apps**
	Delahanty 2018	Machine learning (mortality risk adjustment algorithm)	ICU	Need to demonstrate performance in multiple samples (overcomes licensing and labour cost barriers)
	Nagendran 2020	**Machine learning in medical imaging**		**Need for robust evidence to support claims of equivalence with experts; poorly reported studies and hype a barrier. Exaggerated claims may be harmful**
	O'Neil 2018	Telehealth/telemedicine (VR)	Neurorehabilitation	Limited evidence, perceived as no better than traditional approaches
	Pinto-Bruno 2017	**Digital (general)**	**Dementia**	**Lack of specific outcome measures**
	Ream 2018 (AHSN)	**General AI**		**Need to provide evidence and allow interpretation of algorithms**
	Singh 2019 (RSA)	**General AI**		**Need to provide appropriate evidence on, e.g. transition to clinic; mitigation of bias; proven benefits; effects on workflow; opportunities for workforce development. Includes use of pilots and 'sandboxes'**
	Snooks 2019	**Predictive risk stratification model (PRISM)**	**Primary care clinicians**	**PRISM implementation increased use of health services: NHS costs per participant increased by £76 (95% CI £46 to £106)**

Technical barriers

Poor design of equipment and/or software was identified as a barrier for technologies aimed at both patients (Baker 2017; Creber 2016; Liss 2018; **MacDonald 2018**) and health professionals (**Cresswell 2012**; Hall 2012; Holt 2018). Few apps aimed at patients met prespecified criteria for quality, content, or functionality (Creber 2016) and patients also encountered barriers caused by poor interface design (Baker 2017; **MacDonald 2018**) and lack of desired functionality (**MacDonald 2018**).

Cresswell et al. (2012) reported health professionals' perception of an electronic health record system as an 'immature' technology. Other design-related issues identified were disruptive screen alerts (Holt 2018); slow start-up and software failures (Huisman 2019); and a palliative care record system that was less suitable for patients with conditions other than cancer (Hall 2012).

A closely related group of barriers was associated with *poor fit to the work environment*. **This phenomenon was frequently associated with the use of 'workarounds' to tackle unforeseen problems (Cresswell 2012, 2017**; Beede 2020). An electronic prescribing system for hospital inpatients encountered barriers associated with both the design of the system itself and its integration within the hospital care environment (Puaar 2018). Studies of technologies intended for home use by patients have reported that devices were unsuited to the needs of the users and/or to real-world home settings (Cherry 2017; Ninnis 2019; **Piau 2019**).

IT infrastructure is associated with challenges particularly for telehealth/telecare and information systems (Table 12). The challenges identified ranged from Internet connection problems and shortages of equipment to requirements for better or more integrated systems to take advantage of new technologies. A study not included in the table identified a need for continued outside support to enable use of GIS (geographic information systems) in primary care (Bazemore 2010).

Table 12: summary of studies identifying barriers related to IT infrastructure

Type of barrier	Example(s)	Technology	Staff involved	Additional information
IT infrastructure	Baker 2017	Equipment (tablet)	Older disadvantaged people	Network connection problems
	Blackburn 2011	**Telehealth/care (Digital interactive TV)**	**Review**	**Requirement for a high-bandwidth communications infrastructure**
	Bush 2016	**Telehealth/telemedicine**	**Audiologists**	**Internet bandwidth issues**
	Caffery 2019	Telehealth/telemedicine	Ophthalmologists	Substantial infrastructure required
	Kenicer 2012	Computerised CBT	Patients	Lack of dedicated computers for patients
	Stoves 2010	E-consultation for kidney disease	Primary and secondary care	Need for secondary care IT infrastructures to embrace primary care systems
	Takian 2012	Information systems (EHR)	Mental health trust staff	Need/opportunity to strengthen IT infrastructure

Table 13: summary of studies identifying barriers related to data

Type of barrier	Example(s)	Technology	Staff involved	Additional information
Standards				
	Mozaffar 2018	Information systems		Need to adapt non-UK products for UK market
	Noble 2012	Information systems (mapping)		Downloading, cleaning and mapping data from electronic general practice records posed some

				technical challenges, and judgement was required to group data at an appropriate geographical level
	Siaw 2017	Information systems	Primary care	The lack of a common terminology and universal secure messaging system and limited "clinical coding" were significant barriers to data collection, integration and sharing.
	Tufail 2016	Image analysis	Retinopathy screening	Performance of some systems varied with age, ethnicity and camera type. Potential governance issues mentioned
	Van Lent 2012	Predictive modelling	Hospitals	Limited evidence to guide implementation
Patient data	Bellemo 2019	Machine learning	Specialists	Need for robust data to train system
	Burton 2019	Machine learning (diagnostics)	Microbiologists	Need to treat data from children and pregnant women differently
	Joshi 2019	**Data-driven (general)**		**Data security issues, obtaining access to data**
	Topol 2019	**Digital (general)**		**Uneven NHS data quality**
Data exchange	Antoniou 2012	Telehealth/telemedicine	Surgeons	Video and audio latency with low transfer rates (<128 kbps) and inadequate guidance regarding the correct plane for dissection
	Cresswell 2017 (254)	**Information systems (electronic prescribing)**	**Hospital prescribers**	**Integration and interfacing problems obstructed effective information transfer**
	Beede 2020	Machine learning (diabetic retinopathy screening)	Patients, nurses	Gradeability of images; Internet speed and connectivity
	Muirhead 2016	Information systems		Need to develop understanding of different orgs' data sets, including what specific fields meant and where it was appropriate to include them
	Wozney 2017	Digital (e-mental health)	Key informants in implementing organisations	Need for EMR integration

Data: The review included a substantial group of studies that dealt with barriers related to data, including standards, availability and security of patient data and problems related to data exchange (Table 13). In particular, recent studies continued to identify access to high quality patient data as a barrier to 'training' machine learning systems (Bellemo 2019; **Joshi 2019**). This area is likely to increase in importance in the future in view of the continuing growth of interest in use of 'big data' and data-driven technologies.

Finally a few studies identified other technical barriers. Reduction in smartphone battery life continues to be an obstacle to the use of mHealth apps (Webb 2016; Murphy 2020). A study of online consultations (Shaw 2018) reported that multiple minor technical barriers occurred in all consultations.

Overview: Significant technical barriers relate to the design and usability of hardware and software; inadequate IT infrastructure; and the availability of secure, high-quality patient data. However, mundane issues such as the impact of app usage on smartphone battery life should not be ignored as such issues can be a major obstacle to use of the technology.

RQ2: What is the nature of these challenges and how do they arise?

The evidence presented above suggests that the classification of barriers as individual, organisational and technical is useful and covers the great majority of challenges reported in the literature. However, these groupings are not mutually exclusive and there are considerable elements of overlap and mutual reinforcement between them. A simple framework to address the broader question of the nature of these challenges and how they arise relates the different types of challenges to the context of the health and care system and the nature of the technologies themselves.

Context of innovation

The context of the UK health and social care system is characterised by 'pressure on human and financial resources in all departments' (Shaw 2018) and 'lack of staff and time' (Collins 2016). In recent years, spending on the NHS has generally not kept pace with increases in demand, while local authority social care services have been subjected to substantial cuts in expenditure. This creates a highly challenging environment for introducing changes to services because even changes that are beneficial in the long-term are likely to involve some short-term disruption. The review found evidence of this at both the organisational and individual level.

The importance of context for understanding challenges to implementation of new technologies has been studied most intensively for electronic health records and similar digital technologies replacing paper-based systems. Cresswell and colleagues at the University of Edinburgh have published many studies in this area and their paper in the *Health Informatics Journal* (**Cresswell 2012**) summarises the key barriers that arose during the process of implementation in England (Table 14). While some of the details may change over time and specific barriers may arise for other technologies, the themes identified in this study and the work of other researchers (**Greenhalgh 2010**; Taklan 2012) are likely to be broadly applicable to the implementation of new digital or data-driven technologies in the UK NHS and social care.

Table 14: Source and nature of barriers to implementation of electronic health records (adapted from **Cresswell et al. 2012**)

Source of barrier	**Framework level**	**Nature of barrier(s)**
Political and economic factors	Organisational	Changes in political and economic priorities Centrally agreed contracts limit scope for adaptations to meet local needs Political and patient pressure to demonstrate progress Perceived powerlessness at local level
Different starting points	Organisational	Different implementation strategies needed Different strategies for coping with national pressures Uncertainty about how to measure progress
Software characteristics	Organisational/technical	‘Immature’ technology affects planning and user engagement as well as usability
Individual ‘workarounds’	Individual/technical	Need for unplanned measures to cope with software limitations

		Health professionals attempt to counter threats to perceived professional identity and maintain contact with patients

In summary, the combination of pressure on resources, potential for conflict between national and local priorities, the range of different organisations and professional groups involved, limitations of the technology (discussed in more detail below) and individual attitudes and actions helps to explain the range of challenges to implementation of new technologies in the UK context. There is, however, major uncertainty as to how the background context will be affected by the current coronavirus crisis. While the pressure on the health and care system is unlikely to decrease, the need for distancing and restrictions on travel have favoured the rapid uptake of digital technologies in some settings, e.g. online consultations in primary care. It remains to be seen whether this trend will be sustained in the future.

Nature of technology

This section draws mainly on the work of Greenhalgh and colleagues (**Greenhalgh 2017, 2018**). These authors used extensive data on six technology-based innovations to develop a framework (the nonadoption, abandonment, scale-up, spread, and sustainability (NASSS) framework) to predict the success or otherwise of uptake of such innovations into practice. The NASSS framework covers seven domains: the condition or illness, the technology, the value proposition, the adopter system (comprising professional staff, patient, and lay caregivers), the organization(s), the wider (institutional and societal) context, and the interaction and mutual adaptation between all these domains over time. Within each domain, challenges to adoption are classified as simple (straightforward, predictable, few components), complicated (multiple interacting components or issues), or complex (dynamic, unpredictable, not easily disaggregated into constituent components). The authors noted that technologies 'characterized by complicatedness proved difficult but not impossible to implement. Those characterized by complexity in multiple NASSS domains rarely, if ever, became mainstreamed'.

The NASS framework summarises complexity in technology-based innovations as follows: a technology is complex if 'it has multiple interacting components, requires close embedding within already-complex technical systems, lacks dependability, provides an unreliable, incomplete or contested picture of the condition, requires advanced knowledge to use it or exists only as a bespoke solution that is vulnerable to supplier withdrawal' (**Greenhalgh 2018**). The evidence summarised in the previous section suggests that the adopter system and the wider context for implementation of digital and data-driven technologies are also characterised by a high degree of complexity.

This research appears to offer valuable insights into the features of digital and data-driven technologies that may create complexity and hence potentially increase the challenges of implementation into routine practice. The framework can also be used to assess complexity in the wider context. Organisations seeking to implement new technologies can seek to reduce complexity wherever possible or if this is not possible plan a realistic implementation strategy that takes account of the challenges likely to be encountered.

RQ3: What does the literature suggest is required to overcome these challenges?

While the main focus of this rapid evidence review is on identifying challenges, this section draws on recent expert reports (**Joshi 2019; Singh 2019; Ream 2018; Topol 2019**) written with the objective of supporting implementation of digital and data-driven technologies, particularly applications of artificial intelligence (AI). We have included studies from the evidence review where appropriate to support these expert reports.

Active support for implementation

Studies included in the evidence review support the need for implementation to be actively supported from the outset (Akehurst 2018), with **support and engagement sustained for as long as necessary (Cresswell 2017). The report on AI produced by the AHSN Network (Ream 2018) emphasises the need to engage with health professionals and create an ethical framework to increase trust and ensure transparency**.

The report published by the RSA (Singh 2019) argues that support from patients as well as health professionals is key to successful implementation. In particular, the report advocates the use of deliberative methods like citizens' juries to involve patients and the wider public in debate and decision-making processes.

The expert reports also recognise the need to support implementation through development of the evidence base (**Joshi 2019; Singh 2019**). **In particular, they support piloting and**

ongoing evaluation at the local level. According to the RSA report, such initiatives 'can help overcome multiple residual issues around implementation, from misalignment of financial incentives, to misalignment of corporate and clinical cultures and patient expectations' **(Singh 2019**). **Local evaluations also help to build capacity and capability as advocated by the AHSN Network (Ream 2018).**

Implementation of new technologies can also be supported by changes to the wider social context. **For AI –based technologies, according to the AHSN network, this includes ensuring that the regulatory framework is fit for purpose and testing new funding and commercial models (Ream 2018). Development of the AI sector also requires a sound data infrastructure and access to high quality data sets, supported by interoperability and sharing standards (Ream 2018).** This is closely related to developments in the workforce as discussed below (see 'New roles/ways of working).

Alignment with organisational goals/objectives

Studies included in the evidence review identified alignment with organisational goals and objectives as important for obtaining staff 'buy-in' to new technologies (**Keyworth 2018**; Patel 2013). **For the AHSN Network, this means relating AI solutions to real problems identified by users of the health system, either staff or patients (Ream 2018).**

New roles/ways of working

Expert reports emphasise the need to develop digital skills in the health and care workforce through specialist training (**Joshi 2019; Topol 2019**). The emergence of new specialist roles is closely related to development of the general workforce. Siaw (2017) argues for a multidisciplinary clinical informatics profession to bridge the divide between health, management and computer science in health care policy development and implementation with a patient-centred approach. Jacob et al. (2019) focus on mHealth applications, identifying potential new roles for digital health clinicians both in healthcare institutions and in digital health providers. Increased clinician involvement in the design and development of apps, for example, would be expected to improve their quality and integration with patient care. Jacob et al. also see an important role for digitally literate clinicians in education and awareness raising (Jacob 2019).

A closely related role is that of 'clinical champion' as advocated for AI by the RSA report (**Singh 2019**). According to the report, 'this would not be a network of hero-professionals; rather they would largely be system-focussed public entrepreneurs who work below the radar to help shift attitudes and practices and provide inspiration to others so as to collectively build a culture of innovation'.

In addition to specialist roles, studies included in the evidence review point to the potential for tasks to be transferred between different parts where they may be carried out more efficiently and also potentially provide new opportunities for staff working in those sectors. For example, online care pathways enable primary care to co-ordinate care for patients previously managed in secondary care (Akehurst 2018), while online consultation systems may free up GPs' time by transferring tasks to other practice staff (Casey 2017).

In conclusion, the evidence suggests that digital and data-driven technologies have the potential to further transform the way health care is delivered. While the future is uncertain, it is possible that a shift towards digital delivery of health and social care will be accelerated following the current coronavirus pandemic.

Conclusions

There is an extensive literature dealing with challenges to implementing digital and data-driven technologies in health, with over 130 studies contributing to the second phase of the evidence review. The analytical framework used was helpful for synthesising the studies although there was some overlap and reinforcement between the different levels (individual, organisational and technical) at which challenges occurred.

The most frequently reported challenges at the individual level were associated with lack of motivation to engage with new digital or data-driven technologies and distrust of the technologies themselves, particularly in relation to safety and reliability. A large number of organisational challenges were identified. Cultural differences between organisations can be a barrier to effective joint working, especially when leadership is either over-centralised or insufficiently clear in setting objectives. Within organisations, major challenges arise from failure to address the needs and concerns of staff (e.g. around training and changes to job roles) and to recognise that different professionals will have different, sometimes conflicting, needs.

Lack of evidence of effectiveness and/or cost-effectiveness has been a significant challenge to the implementation of digital and data-driven technologies. This may become less of a factor as the evidence base develops, especially if decision-makers take a flexible attitude to the types and sources of evidence they are prepared to consider. On the other hand, poorly reported studies making exaggerated claims based on small samples run the risk of creating distrust and suspicion of ‘hype’.

Significant technical barriers relate to the design and usability of hardware and software; inadequate IT infrastructure; and the availability of secure, high-quality patient data. However, mundane issues such as the impact of app usage on smartphone battery life should not be ignored as such issues can be a major obstacle to use of the technology.

A small but important group of studies suggest that the main source of challenges is high complexity in the technologies themselves, the local context in which they are implemented and/or the wider health system and societal context. Complex challenges are defined as dynamic, unpredictable and not easily disaggregated into constituent components.

The literature suggests that overcoming these challenges requires active support throughout the implementation process. This includes active engagement with patients and the public and developing the evidence base through a continuous process of evaluation. Implementation is more likely to be successful when the introduction of new technology is seen to align with organisational goals and values. Implementation should take account of complexity and seek to reduce it as far as possible.

Successful implementation of new technologies requires the development of digital knowledge and skills in the health and care workforce, including the development of new roles for clinicians to act as ‘digital champions’. Transfer of tasks between different sectors (e.g. secondary to primary care) may provide opportunities for staff to acquire new skills.

While the future is uncertain, it is possible that a shift towards digital delivery of health and social care will be accelerated following the current coronavirus pandemic.

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Note: references highlighted in **bold** have been identified as particularly valuable evidence sources (see 'Highlighting the key evidence' above)

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Appendix 1: Medline search strategy

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations and Daily <1946 to March 09, 2020>

Search Strategy:

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1 "digital technolog$".ab,ti. (1626)
2 (app or apps or application$ or software).ab,ti. (1324317)
3 Smartphone/ (3964)
4 Mobile Applications/ (5365)
5 or/1-4 (1328328)
6 exp Artificial Intelligence/ (92861)
7 ("artificial intelligence" or ai or machine learning).ab,ti. (53089)
8 6 or 7 (133352)
9 5 or 8 (1437969)
10 Health Plan Implementation/ (5759)
11 information dissemination/ (16221)
12 exp "diffusion of innovation"/ (19551)
13 action research.ti,ab. (3832)
14 healthcare innovation.ti,ab. (105)
15 "bench to bedside".ti,ab. (3164)
16 "barriers and facilitators".ti,ab. (5800)
17 (barriers and facilitators).ti. (2558)
18 (translational adj (medicine or science or research)).ti,ab. (11407)
19 (information adj3 dissemination).ti,ab. (2529)
20 knowledge adoption.ti,ab. (12)
21 (knowledge adj (brokering or communication)).ti,ab. (246)
22 (knowledge adj (cycle or development or application)).ti,ab. (790)
23 (knowledge adj (diffusion or exchange)).ti,ab. (605)
24 (knowledge adj (mobili*ation or synthesis)).ti,ab. (340)
25 (knowledge adj (transfer or translation or transformation)).ti,ab. (4175)
26 (knowledge adj (update or utili*ation)).ti,ab. (156)
27 "know do gap".ti,ab. (71)
28 integrated knowledge.ti,ab. (408)
29 integrating knowledge.ti,ab. (202)
30 "knowledge to action".ti,ab. (675)

31 "linkage and exchange".ti,ab. (32)
32 organi?ational innovation.ti,ab. (104)
33 technology transfer.ti,ab. (993)
34 (translational adj (medicine or research or science)).ti,ab. (11407)
35 "transmission of knowledge".ti,ab. (335)
36 "research into practice".ti,ab. (897)
37 (research adj2 integration).ti,ab. (667)
38 (research adj2 utili?ation).ti,ab. (1273)
39 (implementation or implementing).ti,ab. (284672)
40 (dissemination or disseminating).ti,ab. (62756)
41 (transfer* adj2 knowledge).ti,ab. (2968)
42 "barriers and facilitators".ti,ab. (5800)
43 sustainability.ti,ab. (21278)
44 ((change or changing) adj (behavio?r or practice)).ti,ab. (2866)
45 or/10-44 (420052)
46 (challenge$ or barrier$ or obstacle$ or advantage$ or limitation$ or facilitator$).ti,ab. (1604934)
47 *Education/ (9323)
48 *"Patient Acceptance of Health Care"/ (26930)
49 *"Attitude of Health Personnel"/ (61595)
50 *organizational culture/ (5451)
51 (infrastructure or education or training or "staff buy-in" or "patient buy-in" or "organi?ational culture" or "role redesign").ab,ti. (795905)
52 (compatabil$ or communica$ or accessib$ or time or afford$ or cost$).ab,ti. (3904508)
53 or/46-52 (5694910)
54 (hospital or clinic or "primary adj2 care" or surgery or "acute trust" or "foundation trust").ab,ti. (2098979)
55 (real-world or live).ab,ti. (198197)
56 ("social care" or "social service$" or "community health" or "general practice").ab,ti. (71795)
57 (compatabil$ or communica$ or accessib$ or time or afford$ or cost$).ab,ti. (3904508)
58 54 or 55 or 56 (2340061)
59 5 and 45 and 53 and 58 (4508)
60 8 and 45 and 53 and 58 (577)
61 exp United Kingdom/ (360920)
62 (national health service$ or njs$).ab,in,ti. (17538)
63 (english not ((published or publication$ or translat$ or written or language$ or speak$ or literature or citation$) adj5 english)).ti,ab. (93987)
64 (gb or "g.b." or britain$ or (british$ not "british columbia") or uk or "u.k." or united kingdom$ or (england$ not "new england") or northern ireland$ or northern irish$ or scotland$ or scottish$ or ((wales or "south wales") not "new south wales") or welsh$).ab,in,jw,ti. (2019679)

65 (bath or "bath's" or ((birmingham not alabama*) or ("birmingham's" not alabama*) or bradford or "bradford's" or brighton or "brighton's" or bristol or "bristol's" or carlisle* or "carlisle's" or (cambridge not (massachusetts* or boston* or harvard*)) or ("cambridge's" not (massachusetts* or boston* or harvard*)) or (canterbury not zealand*) or ("canterbury's" not zealand*) or chelmsford or "chelmsford's" or chester or "chester's" or chichester or "chichester's" or coventry or "coventry's" or derby or "derby's" or (durham not (carolina* or nc)) or ("durham's" not (carolina* or nc)) or ely or "ely's" or exeter or "exeter's" or gloucester or "gloucester's" or hereford or "hereford's" or hull or "hull's" or lancaster or "lancaster's" or leeds* or leicester or "leicester's" or (lincoln not nebraska*) or ("lincoln's" not nebraska*) or (liverpool not (new south wales* or nsw)) or ("liverpool's" not (new south wales* or nsw)) or ((london not (ontario* or ont or toronto*)) or ("london's" not (ontario* or ont or toronto*)) or manchester or "manchester's" or (newcastle not (new south wales* or nsw)) or ("newcastle's" not (new south wales* or nsw)) or norwich or "norwich's" or nottingham or "nottingham's" or oxford or "oxford's" or peterborough or "peterborough's" or plymouth or "plymouth's" or portsmouth or "portsmouth's" or preston or "preston's" or ripon or "ripon's" or salford or "salford's" or salisbury or "salisbury's" or sheffield or "sheffield's" or southampton or "southampton's" or st albans or stoke or "stoke's" or sunderland or "sunderland's" or truro or "truro's" or wakefield or "wakefield's" or wells or westminster or "westminster's" or winchester or "winchester's" or wolverhampton or "wolverhampton's" or (worcester not (massachusetts* or boston* or harvard*)) or ("worcester's" not (massachusetts* or boston* or harvard*)) or (york not ("new york*" or ny or ontario* or ont or toronto*)) or ("york's" not ("new york*" or ny or ontario* or ont or toronto*))))).ti,ab,in. (1368135)

66 (bangor or "bangor's" or cardiff or "cardiff's" or newport or "newport's" or st asaph or "st asaph's" or st davids or swansea or "swansea's").ti,ab,in. (53661)

67 (aberdeen or "aberdeen's" or dundee or "dundee's" or edinburgh or "edinburgh's" or glasgow or "glasgow's" or inverness or (perth not australia*) or ("perth's" not australia*) or stirling or "stirling's").ti,ab,in. (203733)

68 (armagh or "armagh's" or belfast or "belfast's" or lisburn or "lisburn's" or londonderry or "londonderry's" or derry or "derry's" or newry or "newry's").ti,ab,in. (25254)

69 or/61-68 (2588367)

70 (exp africa/ or exp americas/ or exp antarctic regions/ or exp arctic regions/ or exp asia/ or exp oceania/) not (exp great britain/ or europe/) {Including Related Terms} (10046)

71 69 not 70 (2584186)

72 MEDLINE.tw. (113356)

73 systematic review.tw. (148173)

74 meta analysis.pt. (111646)

75 or/72-74 (267400)

76 59 and 71 (627)

77 limit 76 to (english language and humans and yr="2010 -Current") (312)

78 59 and 75 (155)

79 limit 78 to (english language and humans and yr="2010 -Current") (77)

80 60 and 71 (68)

81 60 and 75 (21)

82 limit 81 to (english language and humans and yr="2010 -Current") (9)

83 limit 82 to (english language and humans and yr="2010 -Current") (9)

84 limit 80 to (english language and humans and yr="2010 -Current") (30)

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Appendix 2: framework used for organising the included literature

Individual Barriers	**Organisational barriers**	**Technical barriers**
Staff | **Patients/users**		
Cognition Lack of skills/knowledge Ability to learn Language barriers Lack of motivation Emergent barrier	*Financial* Emergent barrier(s)	*Poor design* Poor match to working environment Emergent barrier(s)
Motivation Low value to individual Unclear benefits Prefer alternative solution	*Political* Supporting evidence	*IT infrastructure*
Accessibility Access to hardware/software Lack of accurate information Lack of time for learning/CPD Physical problems , e.g. disability	*'Buy-in'* From staff From patients/ users	Security
Lack of trust In technology In organisation	*Organisational structure* Decision-making	Support
Emergent category/uncategorised barrier	Incentives	*Standards* Patient data Data exchange
	Organisational culture	Lack of system feedback
	Education and training	Emergent category/uncategorised barrier
	New or redesigned roles	
	Work environment/broader context New ways of working	
	Other workforce-related	
	Emergent category/uncategorised barrier	