Tomorrow's tech, today

What the public think about five emerging technologies, and opportunities for future engagement





UK Research and Innovation

sciencewise

BRITISH SCIENCE ASSOCIATION

Contents

Disclaimer:

The views expressed in this report are not representitive of the views of UKRI.

Sciencewise[1], a public dialogue progamme delivered by UKRI, has conducted this research with a view to identifying areas of research and innovation and technologies where early public engagement would be useful, and welcomes further discussion with research funders, government departments, government agencies and other public bodies working on these issues.

Preface

The purpose of this report

This report aims to outline what is known about public views, values, and debate on five key emerging technologies (EmTech), and to identify gaps and areas for further exploration through public dialogue.

The report is commissioned by Sciencewise, a UKRI funded public dialogue programme that supports government departments and other public bodies to listen to and act on diverse voices, to shape policy and priorities. Important benefits of the programme include:

- **Helping decision makers to formulate policy with a deeper understanding of public views, concerns and aspirations;**
- **Supporting high quality, best practice public dialogue; and**
- **Bringing credibility and independence to government-led public dialogue projects.**

Since 2004, Sciencewise has supported almost 70 public dialogue projects on often controversial technologies and cross-cutting issues of societal change, from AI, gene editing, and climate technology to low-carbon growth and the future of food production. The Sciencewise priority themes were updated in January 2022, drawing from key government and research council priorities, and the latest research and innovation trends:

- **Climate and Environment: How can society live sustainably?**
- **Data, AI and Robotics: How should society shape our digital world?**
- **Health, Ageing and Wellbeing: How should society live healthy lives?**
- **Life Sciences and Biotechnology: How should society shape the future of life?**

Sciencewise has built a strong reputation for innovation, inclusivity, and impact and successfully implemented several major online public dialogues during the Covid-19 pandemic.

This report on public opinion about EmTech is intended to identify opportunities for anticipatory public dialogues, where members of the public are invited to share their views and values on emerging technology topics. We present results from analysing sources of public opinion on five emerging technologies. This provides a snapshot of public views at the time of writing, December 2021.

The report will be useful to those interested in public views on new and emerging areas of science and technology and is particularly targeted at those involved in science and technology policy.

Acknowledgements

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Executive summary

Emerging technologies will transform our world. We will encounter them as biological, physical, digital and virtual interventions in our lives. The impacts have potential to be felt in almost every aspect of society. It is vital that the debates that will shape the use and governance of emerging technologies involve people who will be affected by them.

An open discussion with people and communities who are representative of wider society can create new possibilities, allow policymakers to identify potential issues and build public support and trust for emerging technologies. It can also build confidence among policymakers that the public can and should be part of key policy and research decisions.

Inclusive engagement can also help to uncover the values and reasoning underlying people's views, and help policymakers understand what factors influence public opinion about science and technology.

Reactions to emerging technologies and the effects of their implementation are often hard to predict. Understanding the expectations, hopes and concerns of the public, and how they prioritise and make trade-offs, can help decision makers guide new technologies onto paths that take account of what helps and hinders their social desirability and acceptability.

The complexity of emerging technologies and the different impacts they may have on society makes it likely that individuals, groups and communities will experience or view them differently. People in historically marginalised groups have often been overlooked or even harmed by novel technologies - for example, there are many cases of discriminatory algorithms. Yet emerging technologies can be created in a way that benefits and involves all people. This is especially important given the current global focus on racial equity, and the social, economic, and health inequalities magnified by COVID-19.

This report considers five emerging technologies, identified through desk research and consultation with academics, policymakers, and technologists, that are key to the UK government's Innovation Strategy and may deliver major societal benefits, but are likely to play out in ways that cannot be totally predicted. Given their likely impacts, we wanted to find out what is already known about public opinion towards these technologies. We analysed social intelligence sources (such as dialogues, surveys, social media, mass media, opinion polls, and social research). We aimed to identify themes, possible concerns, affected communities and gaps in our knowledge around what the public think of each emerging technology.

For the technologies considered in this report we find some clear gaps in the current evidence base that we see as issues requiring urgent public engagement.

Social and ethical issues in emerging technologies

We found that several social and ethical issues appear repeatedly, regardless of which emerging technology is being considered:

Who governs the technology? How is the regulation shaped? How can people influence decisions, or control how it applies to them?

Who benefits from the technology? Are certain social groups favoured, and how might technologies widen inequality? Where are the costs and rewards felt?

Is the technology safe and secure? Are people's identities and health and wellbeing protected?

AI and automation in the workplace

AI and automation in the workplace has attracted a lot of research attention, and there have been many efforts to understand people's views and expectations for how it will affect them and where they feel the benefits are. Less research has focused on inequality at work. As the nature of workplaces change post-pandemic, there are opportunities to open up public discussions about how AI and automation could make work safer, fairer, more productive and more rewarding.

Key social and ethical issues associated with AI and automation in the workplace:

- Impact of power and bias upon workplace experience; value, innovation, and costs in terms of where jobs will increase and which sectors will benefit.
- Effectiveness, user experience and transparency, which are associated with who controls AI systems

Analysis of social intelligence of AI and automation in the workplace shows:

- People want to feel informed about AI and automation in workplaces.
- The UK public are aware of the potential implications of more automation, but are unsure what this means for them, or for the economy in general.
- Men, people in higher social grades, people with higher levels of education and younger people are more likely to feel informed, have positive views, and seek out information about AI and automation.

Data-driven technologies (DDTs)

Data, connectivity, and automated decision-making has mainly been explored with reference to the benefits and trade-offs associated with data-driven technologies, for example individuals providing their data in return for a more useful service. However, most of the sources we analysed for this report do not provide evidence about the transformative potential of data-driven technologies for people's daily lives and wellbeing.

Key social and ethical issues associated with data-driven technologies:

- Consent, control, privacy and surveillance, relating to where and how data is collected; personalisation, obtrusiveness, and individuality, around how data is used; and quality, influence, and accountability, with respect to how data-driven technology is applied.

Analysis of social intelligence on data-driven technologies shows:

- People have become used to their data being collected, but still feel uninformed and unable to influence how it is used and reused.

- There are patterns of exclusion of women, disabled people, older people, and racially minoritized groups when it comes to data collection, use, and sharing; and the systems for governance and use of data in public settings are not seen as trustworthy.

Therefore, future public engagement on data-driven technologies could focus on:

- Co-creating data-driven systems and regulation, and, in particular, involving marginalised groups in decisions about how data is collected, used, and shared.
- There is also a need for research into data in public services other than the NHS, or data collection in specific localities and communities.
- AI is relatively well-explored compared with other data-driven technologies such as 5G or internet of things (IoT) devices.

Human enhancement technologies (HETs)

Public engagement on human enhancement technologies (HET) to date has asked people about a narrow range of applications of human enhancement technologies, such as neural interfaces and "smart drugs". There are opportunities to consider how HET could impact societal inequality or physical health, and to explore a wider range of potential uses.

Key social and ethical issues associated with HETs:

- Safety and privacy of the user before, during and after HET; the impact HET could have on views of what's natural, or how diverse society "should" be; hype, costs, and dual-uses of the technology leading to unequal distribution of benefits.

Analysis of social intelligence on HETs shows:

- People are more negative than positive about life-enhancing technologies. Key concerns include commercial motives and governance of the technology.
- However, some people can see themselves using specific HET interventions like smart drugs, and would be more supportive of HET if it was used to create a fairer society.

Therefore, future public engagement on HETs could focus on:

- How HET might change ideas about physical and mental health, or prevent inequalities caused by HET.
- There are also opportunities to explore military use or dual-use implications of HET, and how to prevent misinformation about human enhancement technologies.

Augmented reality and virtual reality

Augmented reality and virtual reality (AR and VR) are largely treated as a consumer technology. There is little work looking at public views of safety and security, inequity and inclusion, or impacts on health and behaviour. With major global tech companies investing heavily in AR and VR, there is a need to involve a wider public than "early adopters" in conversations about how the technology should be used and regulated.

Key social and ethical issues associated with AR and VR:

- Efficiency, personalisation, privacy and surveillance of people's data and behaviour; the technology's role in producing empathy, therapy, connection, and isolation; safety, wellbeing, and exclusion of users in AR and VR environments; manipulation, preparedness, and advantage as a result of emending real-world events; ownership, rights, and governance of the software and platforms.

Analysis of social intelligence on AR and VR shows:

- People have a high awareness of the technologies in the UK, but that knowledge is generalised and somewhat superficial.
- However, there are indications that inequalities could arise relating to cost, digital skills and confidence, and user inclusivity.

Therefore, future public engagement on AR and VR could focus on:

- Safe and responsible use of the technology, therapeutic uses, and preventing misinformation, might involve groups such as women, older people, LBGTQ+ communities, or disabled people when developing AR and VR technology.

New gene therapies

New gene therapies are a growth industry in the UK, but very little research has been done into public views and values, especially compared with related areas such as genomics and germline gene editing.

Key social and ethical issues associated with new gene therapies:

- Protecting identity and ensuring access; diversity, decision-making, and unknown effects associated with how new gene therapies should be applied and to whom; and since new gene therapies are so resource intensive, accounting for sustainability, regulation, and costs.

Analysis of social intelligence on new gene therapies shows:

- People are most likely to favour using gene therapies for chronic health conditions, and that men, younger people, and people without a religious affiliation are most likely to be supportive of new gene therapies.

Therefore, future public engagement on new gene therapies could focus on:

- Governance frameworks and equitable distribution of accessand involve marginalised communities in conversations about how the technology can be used in treatments.

UKRI Sciencewise welcomes further discussion with government departments, and public bodies who want to understand more about the opportunities for public dialogue on Emerging Technology.

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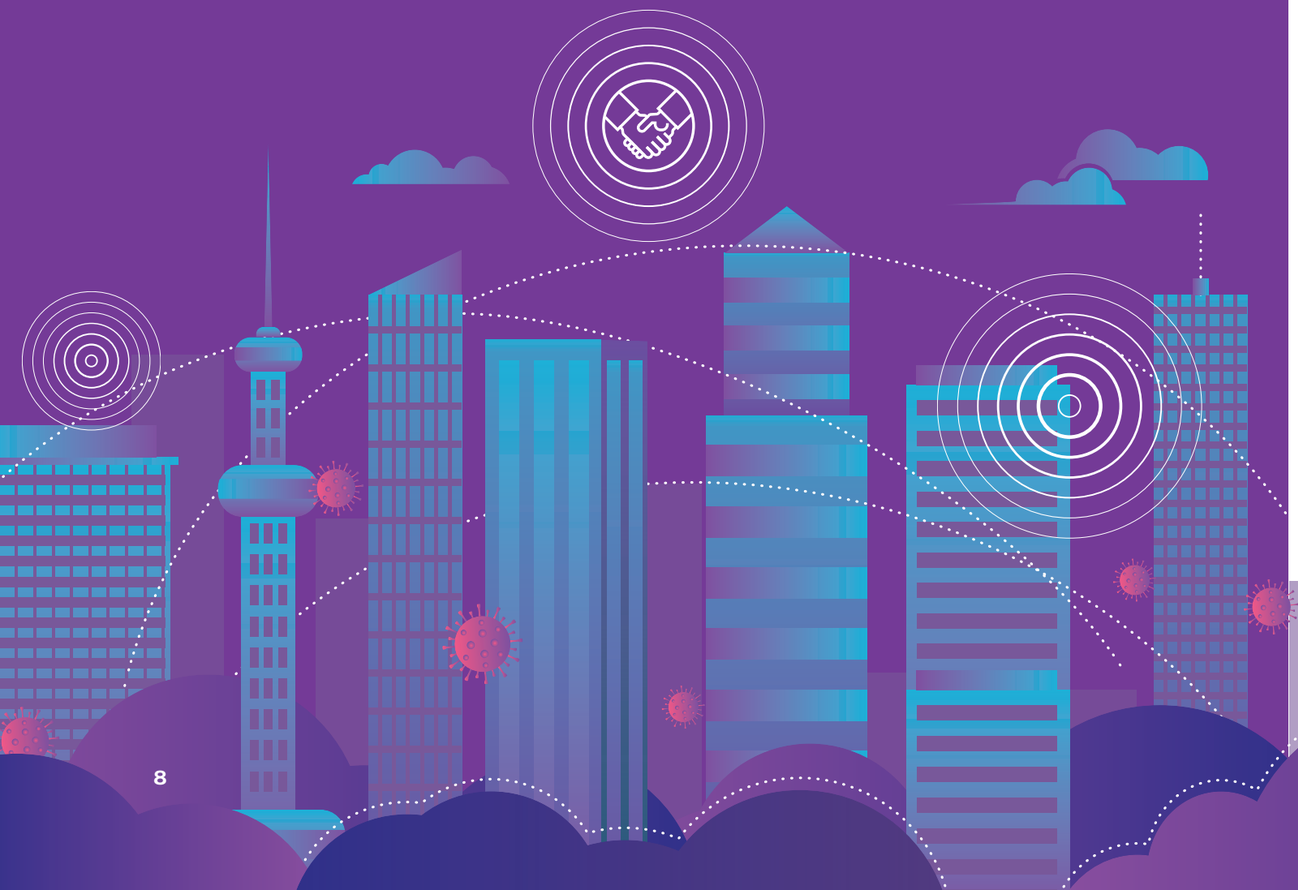
Background and methodology

Understanding the context for this report:

Societal views and values about science and technology are not fixed. It is important to understand the relevant social, cultural, economic, and political factors that might influence people's opinions and experiences of science and technology: what are these technologies being used for, to whose benefit, at what costs? It is difficult to predict how views might change and for what reasons, but the following analysis indicates some influential factors.

For the technologies considered in this report we find some clear gaps in the current evidence base that we see as issues requiring urgent public engagement.



A post-pandemic future

Much of the data included in this report was collected before the onset of the COVID-19 pandemic. Now, over 18 months after the start of the first national lockdown, people have mixed outlooks on what their lives will look like, with many facing immediate uncertainties over personal finances and mental and physical health.[2]

A British Academy evidence review identified nine areas of long-term impact of COVID-19 in the UK, including increased importance of local communities, low and unstable levels of trust, exacerbated structural inequalities, pressure on revenue streams across the economy, and renewed awareness of education and skills.[3]

Similarly, a consultation with 915 experts in technology, innovation, business, policy, and social change indicated that people's jobs, social connections, and use of crucial public services will be dependent on their relationship with and access to technology in the five years following the COVID-19 pandemic. As a result of this strengthened relationship between people and technology, economic inequality may increase, the largest technology firms may have more power, and misinformation may play a greater role in shaping public opinion. However, these experts also expect to see policy efforts made towards racial justice and social equity, enhanced quality of life, and technology that supports health, safety and community living.[4]

A survey of UK adults found that 21% thought it was likely that the world will change for the better because of COVID-19 (65% thought it was unlikely), compared to a global average of 30%. People also thought it was likely that income inequality would increase, and that it was unlikely that police would treat people equally or people become more tolerant of each other.[5]

Public trust in science, technology and policy

In 2021 the UK government made major commitments to invest in science and technology research, development, and skills as part of the Autumn Spending review. Alongside increasing Research and Development investment to £20bn by 2024-25, the National AI Strategy, the Net Zero Strategy and the Innovation Strategy promise to transform the UK into a science superpower, and a global leader on science and technology.[6]

Trust in scientists in the UK is consistently high. Pre-pandemic, levels of trust in scientists to follow professional rules and regulations was as high as 91% for university-based scientists (falling to 57% for industry scientists).[7] UK citizens generally trust scientists to tell the truth and to "do what is right". Trust in technology companies is lower, and appears to be falling as a result of mistrust of social media.[8]

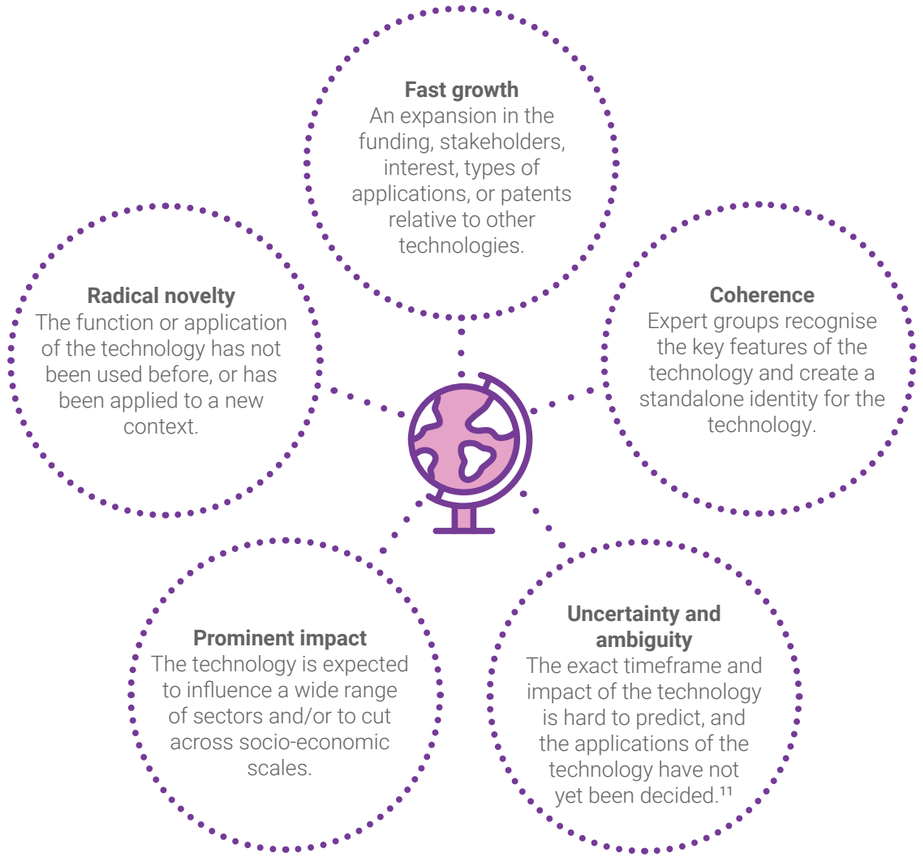
During the COVID-19 pandemic, there are indications that trust in scientists has been maintained or increased, though analysis of past pandemics indicates that public trust may fall over the coming years.[£]

By contrast, trust in government, ministers, and politicians is generally low, particularly around the issues of technology and regulation, as 72% of UK adults agree that the government does not understand emerging technologies enough to regulate them effectively (compared to 61% global average).[10] Public views on responsible regulation of science and technology are likely to be part of an ongoing conversation as the UK reviews its governance of science and technology post-Brexit.

What is emerging technology?

Emerging technology is a term used to describe a new or rapidly developing technology that is expected to be widely available within five to ten years. The use of the term is usually reserved for technologies that will facilitate or accelerate social, economic, or cultural change.

Five attributes have been used to define emerging technologies:



Technologies that are now commonplace were once considered emerging – for example wireless communication, DNA sequencing, organ transplantation, and synthetic fibres.

Across the world, society seeks to benefit from emerging technologies, whilst minimising risk and being prepared to adapt to new ways of life as a result of innovation. There are many policy considerations associated with emerging technology, including investment in research and development, regulation, and implementation. However, these considerations are complicated, since by definition **emerging technologies are fast-moving, cross-sectoral, and have uncertain or ambiguous impacts**.[12]

How were technologies chosen for this report?

There are many potential emerging technologies, and 'parent' technologies that underpin them, which promise to shape the future of society and the economy and change daily interactions. The government's Innovation Strategy recently defined seven technology "families":

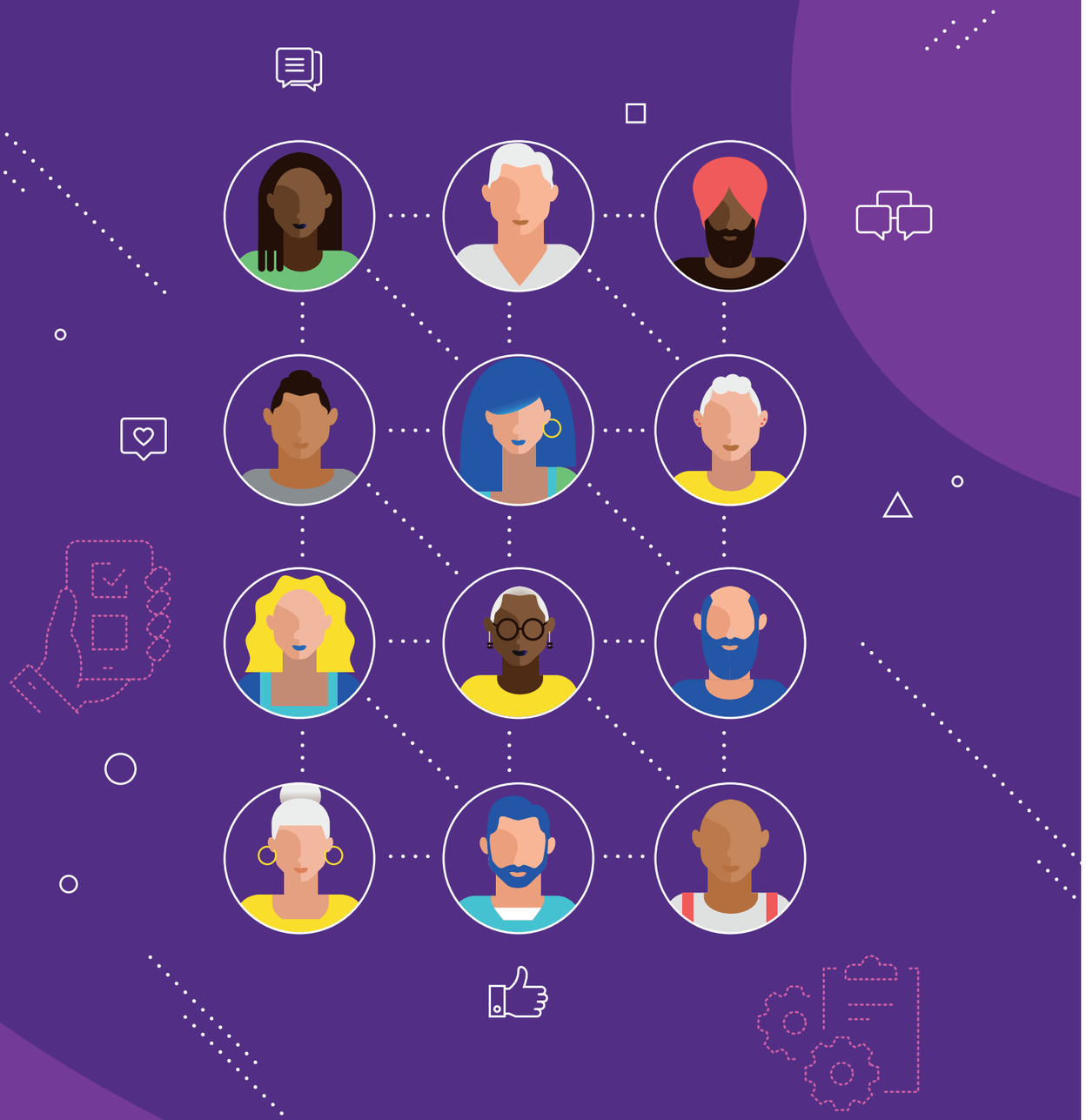
The government's Innovation Strategy recently defined seven technology "families".

1. **Advanced materials and manufacturing**
2. **AI, digital and advanced computing**
3. **Bioinformatics and genomics**
4. **Engineering biology**
5. **Electronics, photonics, and quantum technologies**
6. **Energy, environment, and climate technologies**
7. **Robotics and smart machines.**[13]

Each of these families of parent technologies encompass hundreds of potential applications and possibilities.

We followed a process of indexing, consultation, and prioritisation to identify emerging technology areas to include in this report. We scanned several lists of emerging technologies that have been compiled by UK government departments and agencies, and spoke with leaders in emerging technology, science and technology policy, ethics, and public opinion research to identify the emerging technology areas which are likely to have most societal impact, or social and ethical implications.[14] We then checked which technologies were already the subject of up-to-date, in-depth public opinion and deliberative work (for example, genomics), and focused on those where less was known about public views and values.

Among the technologies considered for inclusion were DNA synthesis, autonomous transport, digital twins and modelling technology, medical applications of nanotechnology, biomimetics, and privacy-enhancing technologies. It is possible that the technologies chosen for inclusion in this report have influenced the more general conclusions we have drawn about public perspectives on emerging technologies and what types of further research are needed. Various drafts of this report were reviewed prior to publication to ensure as far as possible that the findings and recommendations are



Why is it important to listen to diverse voices in the development of emerging technology policy?

Involving the public in discussion and decision-making around emerging technologies can ensure policies better meet the needs of a wide range of people, are easier to implement, and secure more public support. Understanding public opinion is a useful first step to opening up discussions about emerging technologies and future policy.

It is important to understand nuance of public views and attitudes, and not rely on generalisations. There are many examples where people have felt left behind, marginalised, or excluded from decision-making on science and technology, and this has implications for society as a whole. Public engagement can help, by involving people in the decision-making process. A recent example is how by listening to the views, values, and concerns of groups with lower uptake of COVID-19 vaccines, including young people, religious communities, and racially minoritized groups, the UK government, local authorities, community groups, and the NHS were able to work together take a "more culturally appropriate and sensitive approach" and develop strategies to increase vaccine uptake.[15]

Public dialogue can fulfil a number of roles in the development of science and technology, and associated policies – from testing specific policy ideas, to influencing their applications, or, from further upstream, imagining possible futures. Since 2004, the UK government has supported the Sciencewise programme (currently led and funded by UKRI), to assist policy makers in carrying out two-way conversations with the wider public on issues involving science and technology.

In the case of emerging technologies, it can be difficult to know how and when to involve the public in decisions and discussions. This is because it is hard to predict the impact of technologies when they are several years away from widespread implementation, and may seem abstract to the public; yet it is hard to change or challenge the use of a technology once it is embedded. As technology develops, our ethical frameworks and values can change too. By frequently engaging with the public and learning from people's experiences of emerging technologies as they develop, we can shape a future that responds to people's hopes and aspirations.[16]

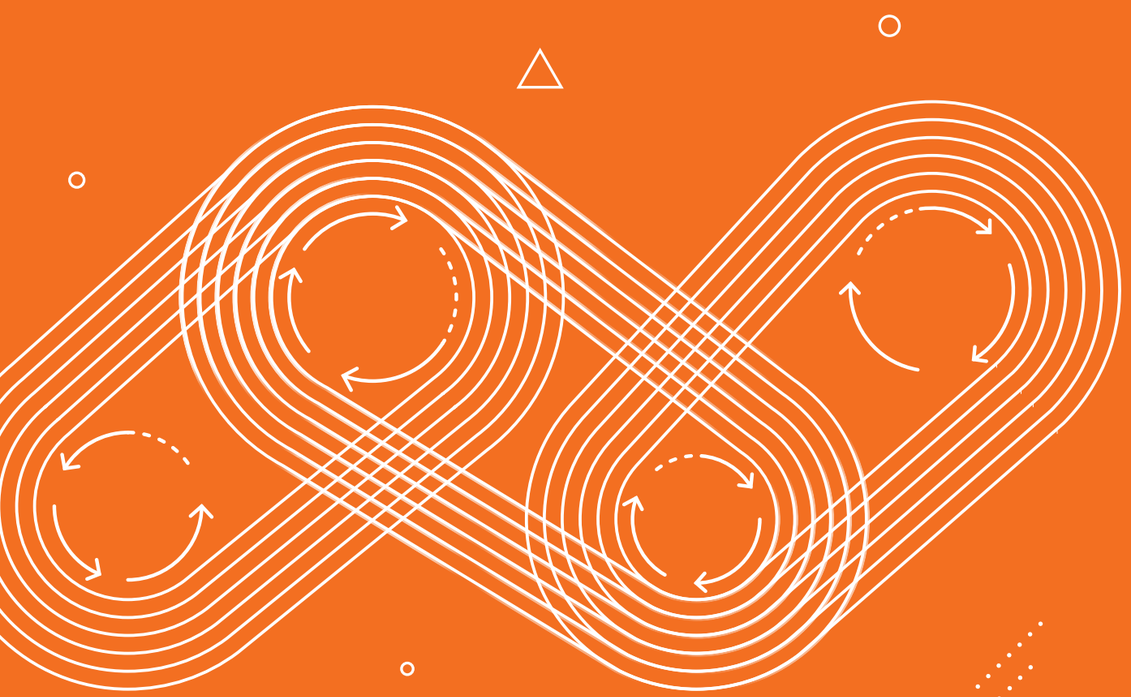
What public engagement sources were used in this report?

This report includes recent surveys, reports, polls, consultations and public dialogue initiatives on the five emerging technologies. Our inclusion criteria were

- Publicly available data;
- UK-focused, or demonstrably transferrable to UK;
- Transparent about its sampling procedure and methods;
- Analysed since 2017.

A summary of the sources considered is in the appendix.

AI and automation in the workplace



What is AI automation in the workplace?

Automation in the workplace is the use of systems that complete tasks with no involvement from humans. Typically, software or hardware will take on tasks or decisions in workplace settings to improve efficiency or generate insights based on data. AI technologies are an enabler of more complex forms of automation, because they can use previous insights and experiences to learn how to operate more efficiently without human intervention.[17]

AI can be integrated into the workplace in many different ways and involving many combinations of technologies. Current AI tools are relatively basic and cannot fully replace human labour, and any further deployment of AI requires significant technology development to address current operational failures. OECD modelling suggests that tasks and skills rather than jobs will be automated.[18]

Large-scale investment in AI technologies and the widespread disruption to workplaces caused by the COVID-19 pandemic are likely to increase the uptake of AI. For example, labour costs have increased due to protective measures, social distancing, and sick pay; risk of infection has meant minimising the numbers of human workers; and changes in consumer habits have increased online shopping, food and drink ordering, and exercise.[19] Similarly, workplace management has been extended through the use of platforms that monitor and track employees, for example ensuring social distancing at Amazon warehouses.[20]

The pandemic has also highlighted where AI tools are not fit for purpose, for example predictive algorithms failed to support medical decision-making.[21] AI is likely to be a major enabler of the efforts to mitigate climate change. It can be used in modelling to increase efficiency and reduce emissions of carbon-intensive systems and processes, in dynamic pricing to reduce waste, in monitoring the supply chain, and help reduce the need for people to travel. However AI automation is also energy intensive, as it requires high amounts of data processing and storage.[22]

Some research has suggested that UK economy could grow by as much as 10.3% by 2030 as a result of AI.[23] Government investment in the form of an "AI Sector Deal" commits £1bn of support from government, academia, and business.[24]

Social and ethical issues in AI automation in the workplace

As AI automation in workplaces becomes more widespread, questions arise over who will benefit and how we will adapt. How will we balance economic, social, cultural, and political priorities? How our do "normal" workplace practices and expectations need to change?

Potential social and ethical issues include:

- **Power, bias, and impact:** AI may shift workplace dynamics. Whilst people may spend less time on menial or repetitive tasks, AI automation might lead to a reduction in human contact, or less intuition and empathy in workplace decision-making and support systems. There could also be power imbalances caused by people having more or less agency than AI in a work context (for example, feeling their decisions are overturned by AI), or even labour attributed to AI but being supplemented by cheap human labour. Biases in AI could lead to inequality in who receives certain rewards, benefits, or penalties.
- **Value, innovation, and costs:** job losses relating to automation may lead to wider inequality, or the value attached to certain skills may decrease as a result of AI uptake. Commercial motives, while driving innovation, could lead to unbalanced economies and uncertainty over the taxation of AI systems as workers or company assets. There are also potential hidden costs, such as energy use, data sharing, or lower levels of creativity, collaboration, and lateral thinking.
- **Effectiveness, user experience, and transparency:** AI may not integrate well with existing processes, or may struggle to cope with complex situations. There may be questions about who holds responsibility for the safety and effectiveness of AI, and who has control over what data is collected, how, and for what it is used. Users may not be aware of the extent of automation or whether they are interacting with AI.[25]

Public opinion on AI in the workplace

We have drawn together existing research about public opinion AI in the workplace.

Many surveys have asked people about their general views of AI in society, their understanding of what AI is, and whether they feel it will positively or negatively impact their lives. One survey suggested that, relative to other countries, there was a lack of consensus among the UK public on AI in society, with 44% saying it has been a "bad thing" and 46% saying it has been a "good thing".[26] A study by the International Monetary Fund found that people from countries with higher levels of labour protection are more likely to hold positive views about the impact of automation on work.[27]

Positive views on AI are much more likely to be held by people who are from a higher socio-economic grade and have decision-making power. Executives in business and government, and professionals in legal, educational, medical, or engineering fields are the most likely to agree that AI will "mostly help" society, compared with construction workers, service workers, and small-scale traders.[28] 66% of UK MPs believe that automation and AI will be good for the economy, while 55% agree it will mostly affect low-skilled workers.[29] Men, people in higher social grades, people with higher levels of education and younger people are more likely to have heard of AI, have positive views, and sought out information about AI, both in general and on its use in healthcare settings.[30]

Use of AI in specific contexts

The **UK public are aware that AI may have implications for their jobs**, with 90% stating that they have heard that automation may replace some human jobs. Smaller proportions believe their job could be partially automated or fully automated within the next five years.[31] However, people are unsure how many jobs are likely to be created, or what the benefit to the economy is likely to be.[32]

Some employee surveys note optimism about the use of AI in workplaces by making their work easier, balancing their workload, or enabling fairer decision-making.[33] People expect AI to be able to help with administrative tasks.[34] However, the **UK public seem to have mixed views on whether this would lead to more job fulfilment** or allow them more time to focus on personal interests. Senior managers are three times more likely to expect more fulfilment in their future work than blue collar workers.[35]

A survey investigating AI and workplace relationships indicate that employees would value the anonymity and perceived lack of bias in AI in relation to mental health support at work.[36] **People are less supportive of AI being used in recruitment and selection**.[37]

In a study of doctors and nurses at a UK NHS hospital, only 10% of respondents were worried that their role would be replaced by AI. Although most felt AI would be useful in their job, there were high levels of concern about privacy.[38] Studies of patients have found **low awareness of AI currently being used in diagnosis and treatment of heart conditions and other diseases**. A very high proportion agree that people should be informed about the use of artificial intelligence in healthcare, and would prefer AI to work alongside a human doctor (80% agreement) than instead of a doctor (81% disagreement).[39]

The UK public can see how AI might drastically impact service industries, but believe this will lead to people having less contact with each other.[40] Although personalisation of products and services is usually positioned as a benefit of AI, **people have concerns that AI will make broad generalisations and not treat people as individuals**.[41] People also feel that service related AI should be treated with respect and fairness, with 64% of people agreeing "we should be polite" when interacting with AI.[42]

A survey of UK adults found that people expect AI to be most applicable to urban planning, climate and weather modelling, assembly lines, and healthcare diagnostics. People think it will be least applicable to determining legal cases, helping governments decide what to invest in and suggesting work rotas based on previous performance.[43]

Governance of AI

When asked about workplace ethics and company policy on AI, 26% of employers claim to have a written statement on ethical considerations associated with use of AI or bots, with 29% having concerns

about future liability. **More than half of the employees included in a survey by Genesys were not worried that their companies might misuse AI**.[44]

A 2019 survey by the Department for Business, Energy, and Industrial Strategy, found that people believe it is more appropriate for an independent regulator than for the government, or companies that make and sell AI technology, to be responsible for the safe use of automation and AI.[45]

Transition to AI – future of work

An International Monetary Fund working paper found that over half of UK adults feel personal responsibility for preparing themselves for future workplaces. A positive view towards reskilling and retraining is associated with higher levels of education, income, job satisfaction, and perception that AI will have a positive impact overall. Women and workers who have experienced career disruption are more likely to expect government protection for jobs that are most at risk of being replaced by AI.[46] There are also concerns about AI deskilling the workforce as people will rely more on technology to complete tasks such as basic calculations or remembering information.[47] A survey of workers in the UK found that 62% are ready to learn new skills to ensure their continued employability.[48]

Social intelligence trends and gaps

AI automation has attracted a lot of research, and there have been many efforts made to understand people's views and expectations for how it will affect them and where they feel the benefits are.

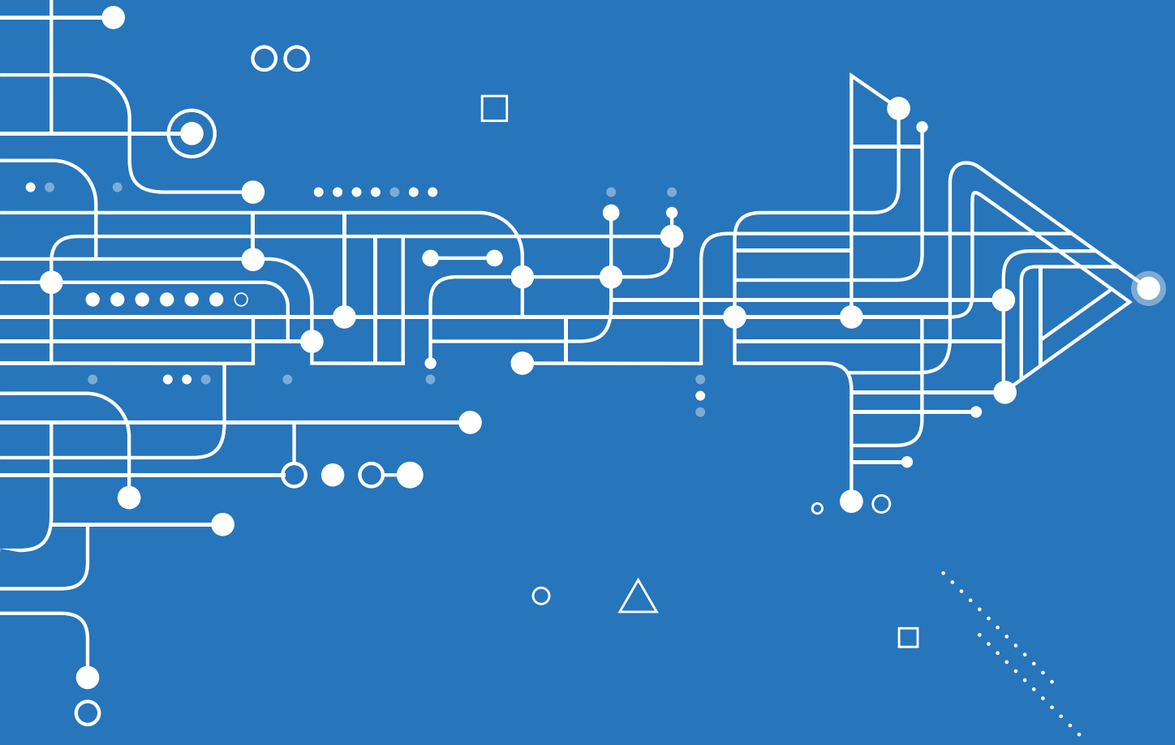
Trends in social intelligence:

- **People want to feel informed about AI automation** in workplaces, especially the impact on them personally, potential benefits, and ways they can prepare themselves for the future.
- There are **clear demographic trends around who feels informed**, has positive views, and seeks out information about AI automation. Men, people in higher social grades, people with higher levels of education and younger people are more likely to feel part of societal discussions on workplace AI.
- The COVID-19 pandemic has led to fundamental changes to jobs and workplaces, and it's likely that peoples' views about employment and the future of work have changed. We **did not find any research that asked whether people's views on AI automation in the workplace have been affected by the pandemic.**

Opportunities for new public engagement on AI and automation in the workplace:

- What are the opportunities for engagement with people who feel less informed excluded from conversations on AI automation? For example, exploring the underlying values that shape people's engagement with AI.
- How might AI automation improve people's experience of work? For example, talking about automation and productivity in the context of under-represented groups in particular professions, good employment practices, or power dynamics.
- How might education be transformed by or for AI automation? Our analysis shows that people are aware of the need to build skills to adapt to new workplaces and job requirements. However, much less work has been done to understand which skills people think will be important, and how UK education should change.
- Are there opportunities for AI automation to support a net zero economy?

Data-driven technologies



Summary

Data-driven technologies are likely to become more commonplace as capacity for processing and storing information increases. Data could be combined or shared to provide personalised services and experiences, but as a result it could lead to increased surveillance or profiling of individuals. Social intelligence research has focused on people's views on data collection and governance, particularly in healthcare settings.

Our analysis shows that although people are more comfortable with sharing personal data than they were a decade ago, there are still many people who feel uncertain about how their data might be used, particularly older people and people in lower social grades. People are concerned about data being used for profit, and would like more control over their data.

What are data-driven technologies?[49]

Rather than focusing on one technology, or application of a technology, **this section considers a combination of several emerging technology areas**. When looked at together, the connectivity and processing power of 5G; the volumes of data collected on our whereabouts, health, and social interactions; and artificial intelligence (AI) to make sense of it all and use it for predictions or decision-making, have the potential to transform everyday interactions and services.

Much of the underlying data is collected passively by social media, website cookies, applications, health records, and Internet of Things (IoT) devices. There are multiple types of data collected, analysed and combined in these systems. Structured data, such as personal information and location, can be shared alongside unstructured data (images, recordings, multimedia), "content-free" data (reaction time, or amount of scrolling on a page), and biometric data to build a complex picture of people's lives and interactions. Digital twinning and synthetic data completely remove data from their original source and context to construct alternative worlds. In many cases, the result of a data-driven future is the use of this data for decision-making, on individual, community, system-wide, national, or international scales. This will become more widespread as both processing power and the volume of data increase and interlink.

For example:

- In **health and healthcare**, data collection and combination may enable artificial intelligence to identify an individual's risk of for a particular disease, predict outcomes, diagnose conditions, search for treatments, or suggest care provision;
- In **roads, rail, infrastructure, and public services** data may determine which public services people have access to and how much they cost (for example risk scoring);
- In **consumer goods, advertising, and media**, people may be offered different prices, benefits, or personalisation of products based on their personal information; linked data could be used for targeting and influencing people to change their views or behaviour;
- In **security systems**, predictions could be made about the likelihood of crime in particular areas; biometric data could be used for identity verification or monitoring; adoption and use of data driven technologies may be identified as a means to 'nudge' citizens and consumers towards socially preferred outcomes.

There are signs that **the COVID-19 pandemic has accelerated implementation of data-driven technologies**. Citizens have been asked to input health and location data (or give permission for this data to be collected digitally) as part of symptom tracking and health data provision; or have been subject to non-voluntarily thermal imaging, location tracking, or types of profiling to help prevent the spread of the virus.[50]

The UK government has given full support to 5G infrastructure in the UK and expects the majority of the population to have 5G access by 2027.[51] It has also invested £70 million in improving security of digital devices and online services.[52] In September 2021 the UK government launched a consultation on reforming UK data protection regulation to maintain high standards of responsible data collection and use, whilst supporting innovation and data-driven industries.[53]

Social and ethical issues in data-driven futures

As we move towards a data-driven future there are questions about how, by whom and in what circumstances data is used. How can data, AI, and connectivity combine to improve our lives, whilst preserving privacy and security?

Specific social and ethical risks that have been identified include:[54]

- **Consent, control, privacy and surveillance:** if users find the terms of data collection difficult to access or understand they may unintentionally give consent for data to be used for purposes that they do not agree with.. Those purposes could include monitoring using location tracking, social media data, location data, or facial recognition but purposes may change as new technical possibilities are found. If data is transferred or reused there may be increased risks of breaches.
- **Personalisation, obtrusiveness, and individuality:** devices or services could interrupt or intrude on peoples' lives, or shift responsibility for supporting decisions (such as exercise or eating habits) away from health experts and towards non-experts who have access to the data. As well as hyper-personalisation based on previous choices and behaviours, data could alternatively be decontextualised so that people are treated less as individuals, or are profiled based on a few broad characteristics.
- **Quality, influence, and accountability** there might be a lack of clarity over who decides on what level of improved efficiency or effectiveness provides enough benefit to warrant data collection, use, or sharing, particularly if only a few companies dominate the market for data-driven technologies,. There are questions of oversight on how data is controlled, used, or deleted, and how benefits are distributed (for example community transformation based on data that may not represent all the people who will be affected). Similarly, actions in digital spaces may start to influence actions and experiences of physical spaces and vice versa (for example, someone's social media habits determining their level of service in a shop).

Public opinion on data-driven futures

We found some broad similarities in US and UK citizens' attitudes to data privacy issues in some surveys, so have included selected US data in our analysis.[55] Most of the sources of public opinion included in this analysis asked about **data sharing in consumer and health contexts**, and aimed to understand **awareness and attitudes among members of the public to the organisations that may use their data**. We concentrate less on AI as a general data-driven technology, since it is explored in the previous section of this report, in workplace contexts.

There have been **clear shifts in public opinion and attitudes to data sharing and security over the past decade**. People report **more comfort with data sharing, and fewer concerns about privacy, albeit from high levels.** 75% list this as a concern in 2018 compared to 87% in 2012.[56] To some extent, the COVID-19 pandemic has increased public engagement and knowledge about data sharing, with 54% of people more aware of how organisations use their data.[57]

Doteveryone's 2018 People, Power, and Technology report found **mixed awareness of exactly how data**

is collected from websites and social media, what data is gathered, and what it is used for. People know that data is collected for advertising purposes, but are less aware that data could be sold or shared between organisations, or used for decisions about pricing or prioritisation. Very few surveys ask about data mining or background data collection. Many people want greater control and understanding of how their data is used, and point to transparency as important. But 43% of people feel they have no power to address these issues as companies will "do what they want".[58]

Two UK-based surveys asked about awareness and intended uptake of 5G. In general, **people have limited knowledge about potential benefits, risks, and users of 5G technology**, and see it as being more relevant for being "ready for the future" than impacting their lives now.[59] There are some concerns around health risks of 5G, but the public have not been asked about 5G in relation to privacy.[60]

Our analysis suggests that **people with lower incomes consistently feel as though they cannot access the benefits from data-driven technologies**. There are signs that women and young people have concerns about types of data collected and potential security breaches. But it was difficult to extend our analysis beyond age and gender, given the small samples typically used in national surveys, and the underpinning values and emotions that drive those concerns have not been explored in detail.

People aged under 40 are more likely to understand why their data is collected and to see benefits to them than in older age groups.[61] A small focus group study found that **older people can feel that the personalisation benefits from data collection are irrelevant to them**, and expressed suspicion about why their personal information would be useful. Similarly, young people with mild learning disabilities had negative feelings about sharing personal data and expressed anxiety about potential security breaches in which this data might become public.[62]

Age is not the only demographic that is relevant to attitudes to data-driven futures. **Wealthier people are more likely to see benefits to their lives from data collection, compared with the poorest communities** and focus groups of vulnerable adults feel most concerned that data could be "used against them".[63] Women tend to be more protective of unstructured data such as photographs and video than men.[64] People are aware of the cost of technology increasing inequality in society, with 79% agreeing that technology companies should make technology pricing accessible so less well-off people aren't excluded.[65] A survey looking specifically at data and inequity during the COVID-19 pandemic found that 19% of respondents did not have access to a smartphone and 14% did not have access to broadband internet. Disabled people and those with lower household incomes were least likely to have access to digital technologies.[66]

Use of data in specific contexts

A Royal Society review of public engagement and data governance found that if people know about a specific data use, they have more appreciation for the benefits and risks involved.[67] A subsequent dialogue on machine learning emphasised that people's views of benefits and risks of data collection and analysis are highly context-specific.[68]

- In **health and healthcare** settings people would be prepared to share information with the National Health Service (NHS) and in health research more broadly if it helped develop new understanding, medicines and treatments (upwards of 70% agreement in all surveys identified). Across surveys and focus groups of various sizes, the public consistently have **major concerns about sharing anonymised health data with private companies.**[69] A public dialogue by the National Data Guardian's Office, Understanding Patient Data and Sciencewise found that transparency throughout the data lifecycle was essential for gaining public support, that public benefit must outweigh profit, that benefits must be distributed equitably, and that safeguards should be in place to protect people from data manipulation. The scale of benefit, and the data being used for different purposes than first intended were less of a concern.[70]
- **In consumer settings** such as online purchasing, there are mixed views on sharing data in return for specific benefits such as a reduction in price, better recommendations, or a more personalised service (35% support this and 34% oppose this). In general, **people are more accepting of personalised services than of the data collection and analysis that is required to enable them.**[71]

However people see this as a one-off "data transaction" and are largely unaware and unsupportive of data being stored and shared with third parties. This means that there is often a mismatch between consumer behaviours and consumers' underlying attitudes.[72] Similarly, another public dialogue report shows there is mixed awareness of the use of data for online targeting, and that people generally overestimate data collection but underestimate the level of sophistication in the predictions that decision-making algorithms can achieve.[73]

- **In security and surveillance settings**, there is scepticism about data such as online activity being used to monitor crime or prevent people from harm, with less than 30% of the public likely to support this. Research into biometric data collection such as facial recognition found that people are wary of the "normalisation" of surveillance, and a particular distrust of private sector use of the technology. Younger people feel more concerned about bulk data collection and potential state surveillance than older people.[74] A large proportion of people (65%) worry about smart devices being used for surveillance, and that their data will be used against them in some way without their knowledge.[75] People are wary in general of location tracking, citing concerns that it may infringe on people's rights, or will lead to people being constantly tracked, taking away rights to privacy. Lower numbers of people agree that tracking will improve public safety (46% agree).[76]

Views of data linkage

The key aspect of data-driven futures is the linking of data across services, institutions, and contexts. A focus group study found that key factors influencing people's views on data linkage include: societal benefits and the motives of the organisations that collect data; timeframe associated with data linkage, and how long data should be kept before permission has to be sought for re-use; transparency over how data is collected and shared.[77]

Attitudes to governance models

Across all contexts, the ability to control what data is gathered and how it is used is key to public trust. When asked about how data should be collected, stored, used, and shared as part of a data-driven future, the public are **in favour of systems where they can control their data, or rely on an independent regulatory body to monitor good data practices**.[78] One survey indicated that people support government regulation on data use.[79] People are generally distrustful of UK data protection regulation to ensure that their data is not shared without permission, with 55% saying they "do not trust" the current laws. Trust is higher for younger people and for people educated to degree level.[80]

Most studies look at **current or near-term uses of data rather than asking about the longer-term future**, or the way people want society to be shaped by data. This gap was identified by the Royal Society and British Academy in 2017 and there are still very few instances of the public being involved in designing future scenarios for beneficial and equitable systems based on data collection and sharing.[81]

Impact of COVID-19

Several data-driven technologies were introduced or expanded to monitor and mitigate the spread of COVID-19, and there are signs that this has influenced public views and behaviour to be more accepting of data collection. In April 2020, around 65% of **UK adults supported tracking people who had been diagnosed with coronavirus and their contacts**, whereas six months before the first COVID-19 lockdown, 67% were concerned about how information about them would be used by the government.[82]

In the area of health and care data, 63% of UK adults agreed that the **pandemic had made them more accepting of the need to share data**, yet 70% agreed that after the pandemic data sharing rules should return to what they were before.[83] People who believed that digital technology had the potential for benefit in the COVID-19 pandemic were more likely to be male, university educated, worried about COVID-19, and trusting that rules and regulations are in place (the strongest predictor).[84] People from racially minoritized groups were 18% more likely than white people to be concerned about facing discrimination as a result of vaccine passports.[85]

Additionally, links with COVID-19 may have influenced awareness and views on 5G, since misinformation about 5G masts spread rapidly in the early stages of the pandemic.

Social intelligence trends and gaps

There is a wealth of research that asks people about the benefits and trade-offs associated with data-driven technologies. However, most of the sources we analysed for this report do not ask about the transformative potential of data-driven technologies for people's daily lives and wellbeing.

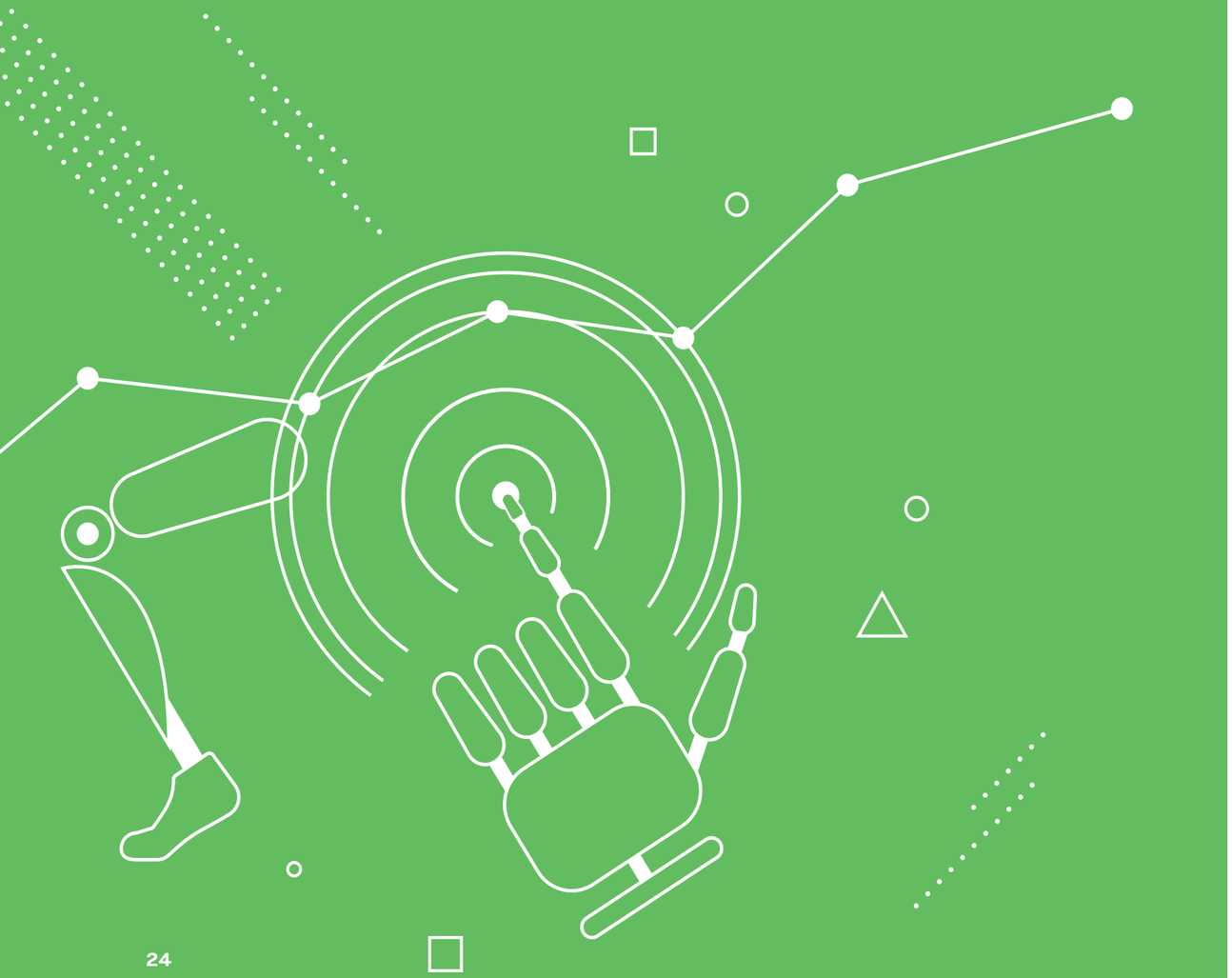
Trends in social intelligence

- AI is a relatively well-explored compared with other data-driven technologies such as 5G or internet of things (IoT) devices.
- There are signs that people are more used to their data being collected, but still feel uninformed and unable to influence how it is used and reused.
- There are patterns of exclusion of women, disabled people, older people, and racially minoritized groups when it comes to data collection, use, and sharing, but these are complex and could be explored further.
- The systems for governance and use of data in public settings are not seen as trustworthy.

Opportunities for new public engagement on data-driven technologies:

- What are the opportunities to co-create a society that includes data-driven technologies? For example, a shared vision for a future in which people feel in control of their data, and trust the effectiveness of regulation.
- How should marginalised groups be involved in decisions about data driven systems and sectors? For example, involving people with lived experience of exclusion as a result of accessibility of technology; which datasets are used; oversurveillance; the impact of data use; who has access to the benefits.
- What could be put in place to minimise the harms and maximise the benefits of data-driven services, and systems? For example, there is relatively little research looking into employer use of data, data in public services other than the NHS, or data collection in geographically localised spaces and communities.

Human enhancement technologies (HETs)



Summary

Advances in precision medicine, nanotechnology, and drug development are beginning to open up opportunities for novel interventions on the human body and performance. Social intelligence research has looked at people's comfort with human enhancement as therapy, as a life-extending tool, and as a route to personal gain.

Our analysis shows that people can see themselves using specific human enhancement technologies to make their lives easier – for example, to improve cognitive function. However, people have concerns around the safety and commercialisation of the technology, and the implications for a diverse society.

What are human enhancement technologies?[86]

Human enhancement technologies (HET) are a range of technological interventions on the human body, which aim to make people "better than well", either by restoring or extending human performance. HET aims to extend human abilities beyond biological expectation, and could even create new kinds of human function, distinguishing HET from medical technologies or health-improvement therapies.

HET links several fields across science and technology, especially within engineering and medicine, and includes **improvements to both physical and cognitive function**. Technologies that act on human cognitive systems aim improve memory, alertness, or mental capacity. Examples include smart drugs and brain-computer interfaces. HET that act on physical ability are designed to improve strength, sensory perception, immune function, or ageing. Examples include bionic limbs and sensory implants. HET could also be used to alter emotional or moral behaviours and capacities, or for cosmetic purposes.

Human enhancement technologies could have a **major impact on societal norms and economies**. People might live much longer, and have different healthcare, insurance, and pension needs. People might choose to have children at different life stages. Leisure and social habits may change.

Human enhancement technologies are beginning to **attract high levels of investment in the UK** for the manufacture of devices and development of medicines. The firm Galvani Electronics, a collaboration between Glaxo Smith Kline and Google's parent company Alphabet, launched with a £540 million investment.[87]

Social and ethical issues in human enhancement technologies

As human enhancement technologies attract more investment and become more sophisticated, questions arise over their objectives and the governance. How do we define the limits of how far enhancement should go? How will HET change our definition of wellbeing or our definition of being human? Specific social and ethical issues that have been identified include:[88]

- Safety and privacy: many HET interventions involve collecting data from the user (for example, height, weight, brain activity) which may be available to the HET manufacturers or could put the user's technology at risk of being hacked. HET interventions or devices could malfunction and cause permanent physical harm to the user, or could put more at risk of body dysphoria or other psychological harms.
- Nature and diversity: people will have different ideas and values about how far HET should go. As a result it could reduce society's capacity to support difference, or reopen complex and harmful debates about "perfection" (for example, links with eugenics). HET might also increase or decrease

the control people have over their health, which has previously been largely determined by genetics, life circumstances, and access to care. It could also cause people to reevaluate their identities and sense of self. HET might limit understanding of natural processes, or provide a "quick fix" rather than treating the cause of a condition.

- Hype, costs, and dual-uses: HET might only be available to limited users because of cost, eligibility requirements, or different national regulations. Similarly, companies might use HET to define societal norms or position the technology as desirable and aspirational. HET might not live up to its promise, which could lead to a backlash or frustration from the people who were hoping to benefit from the technology. HET is likely to be used for conflict, defense and security, and could be used to cause harm, or disrupt global diplomacy.

Public opinion on human enhancement technologies

Our research indicates that views on human enhancement technologies vary greatly between nations.[89] Therefore we have focused on UK-based studies and not attempted to draw conclusions from international research, except where stated.

Public attitudes on HET can be seen in the context of general public views about ageing and prolonging life. **UK adults generally prefer quality of life over length of life**, with 84% saying they would like to live as long as possible if quality of life was ensured, compared with 15% choosing a long life with limited health. When asked about the role of technology in prolonging human life, people are **more negative than positive on the impact that life extending technology will have on society**. These negative views are linked to beliefs that the technology will lead to higher taxation, strain on public services, and the technology being fundamentally unnatural.[90] Men, younger people, and people who describe themselves as in "very good health" are more likely to be interested in taking up life extending technology.[91]

When asked about specific HET interventions, **80% of people think they are likely to take up drugs that enhance memory and concentration in later life**; 59% think they are likely to use wearable enhancements such as clothes which improve muscular performance; and 24% think they are likely to have a brain chip that improves memory and intelligence. Men, White people, young people, and more affluent people are more likely to agree with enhancement interventions than women, racially minoritized people, older people, and less affluent people.[92]

UK adults are generally **not optimistic that enhancement could level the playing field and encourage societal equality** and over half believe it is a danger to society. The UK is broadly in favour of government intervention or regulation of enhancement.[93]

UK and international views compared

A recent literature review of national academic and popular media debates around the ethics of HET found that **most debate in the UK did not focus specifically on the UK context**, as many influential people involved in HET ethics in the UK focus their work internationally. Most academic work and media coverage focuses on use of pharmaceutical cognitive enhancing drugs (PCEDs) by students and young men.[94]

Two European surveys asked about attitudes to augmented people, and found that there was general acceptance of HET to add to the diversity within society: 49% of Europeans are "excited" or "optimistic" about a future that includes augmented and non-augmented people. However, both surveys indicated that **UK adults are more hesitant about HET than southern European and north African nations** such as Morocco, Italy, Spain and Portugal.[95]

HET in specific contexts

A focus group study on pharmaceutical cognitive enhancing drugs (PCEDs) asked members of the public to imagine future scenarios for use of PCEDs. People positioned the technology as a **way for**

individuals to overcome structural disadvantage in society, or as a tool for doing ones' best. These uses were seen as socially acceptable, compared with using PCEDs for personal gain.[97]

People's concerns around HET are mostly linked to safety and security fears, for example that a device could be hacked or cause permanent damage. People are also aware that potential commercialisation of the technology might lead to it becoming controlled by a few companies or only available to the wealthy.

A public dialogue on neural interfaces (NIs) found strong support for use of this type of HET to **create a more equitable future, where disabled people might be less marginalized and society could better understand and support difference**. Experiencing environments and supporting creativity were also seen as potential benefits. The key considerations for societal support are equality of access, ease of use, restorative potential, transparency and individual choice, enhancing quality of life rather than just length of life, and safety and ethical regulations.

People identified **societal trade-offs around the economics of an ageing workforce**, but that NI-enabled people may be more efficient and fit for work for longer, reducing their reliance on the state. Participants also raised the issue of NIs becoming a "quick fix" for certain conditions, that would take attention away from identifying the underlying causes.[98]

Social intelligence trends and gaps

We found that current studies ask about a narrow range of human enhancement technologies and potential concerns.

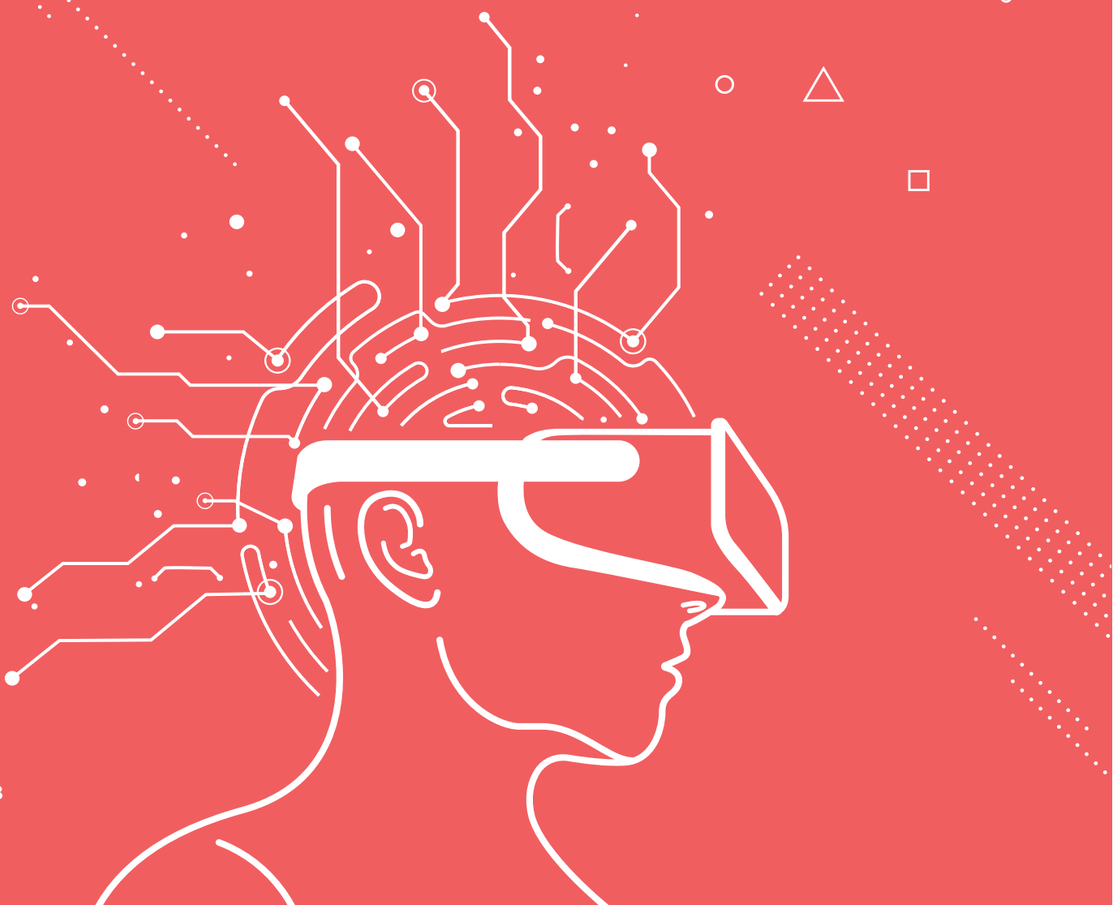
Trends in social intelligence

- People are more negative than positive about life-enhancing technologies, but can see themselves using specific HET interventions such as smart drugs.
- People are supportive of HET if used to create a fairer society, but have concerns about commercial motives and governance.

Opportunities for new public engagement on human enhancement technologies:

- What are the opportunities to collectively explore the possibilities of human enhancement technologies, and discuss how HET could change our ideas of physical and mental health? For example, although in-depth public consultation work has been done around neural interfaces, there is no other research that asks people about the full breadth of potential HET uses and users.
- How should potential societal inequalities caused by HET be prevented, such as who has access, and how widespread use of HET could reshape society?[99] For example, by listening to the views of people who are most affected by conditions such as body dysphoria, and when consulting with disabled people to consider the full range of disability and neurodiversity.
- How could information about and benefits of military use of human enhancement technologies be shared, and dual-use implications of HET be explored transparently? For example, development of HET is likely to be a priority for UK defence and security. There is not currently any research about people's views of HET in military contexts, and if or how the benefits of technology developed for warfare should be shared with wider society.
- Are there ways to prevent misinformation about HET? For example, people's relationship with health and technology is likely to have shifted as a result of the COVID-19 pandemic. There was widespread misinformation about the COVID-19 vaccines containing "brain chips" or other hidden technologies that would augment the human body, which could influence future views on HET.

Augmented Reality and Virtual Reality (AR and VR)



Summary

There is increasing attention on the "metaverse", through which people could spend much of their lives in virtual or augmented reality environments. Social intelligence research has examined the consumer relationship and understanding of AR and VR, and how to improve user experience.

Our analysis shows that people with a commercial interest in AR and VR are likely to be more optimistic and informed about the technology. Whilst a large proportion of the general public are aware of AR and VR, this understanding appears to be superficial, and does not include the full range of potential applications of the technology.

What is AR and VR?[100]

In technical terms, virtual reality (VR) is a computer generated, three-dimensional environment that people can fully inhabit and interact with. Augmented reality (AR) is a digital change or enhancement to the physical (real) environment, such that people experience the two environments blended together. **Immersive VR and AR (sometimes collectively known as extended reality, or XR)** rely on the technology being sophisticated enough to blend with human senses of touch, sight (including peripheral vision), hearing, smell and taste, but also the senses of balance and presence in space.

AR and VR have uses in immersive entertainment; gaming; data visualisation; virtual workplaces; and training and skills development. VR technology has medical applications in therapy, pain management, rehabilitation, or assessment of symptoms. AR is commonly used as a consumer or educational experience – for example experiencing a historic environment, or trying on a product before purchase.

AR and VR are expected to have positive impacts on the UK economy, including a 2.4% boost to GDP (£62.5 billion), and to be used in 1.19% of jobs (400,663 workers) by 2030.[101] In 2021, Facebook announced that they would bring their brands together under a new corporate identity 'Meta', referring to the immersive metaverse enabled by VR and AR.

Social and ethical issues in AR and VR

As AR and VR technology becomes more widespread, questions arise over responsible and safe use. How interlinked will virtual and physical worlds become? How do we assign rules, morals, or behavioural expectations in a medium that is designed for escapism?

Specific social and ethical issues that have been identified include:[102]

- **Efficiency, personalisation, privacy and surveillance:** Users may share personal data to gain a personalised experience, yet risk their identities being mimicked, or have their virtual actions scrutinised by governments and authorities, or targeted for advertising. The spaces users inhabit in AR and VR could be considered both public and private, so it is difficult to set expectations for how behaviour is monitored.
- **Empathy, therapy, connection, and isolation:** Users may be able to empathise and connect with people in different circumstances to them, yet may absorb themselves in virtual experiences for prolonged periods, and begin to isolate themselves from other social interaction. Additionally, it could promise access to worlds that were previously sacred or private.
- **Safety, wellbeing, and exclusion:** There are risks to safety if users lose ability to identify hazards in their physical environment, or are injured through repeated gestures or motions; similarly users may be exposed to situations that they find traumatic or stressful. This is particularly relevant when thinking about children and vulnerable adults who may be less able to distinguish the boundary between reality and XR**.** Finally, upon returning to the unaltered world, users might be more tolerant

of extreme behaviour or violence. Whilst it can be used as therapy for disabled people, the technology has not been developed or tested with people of all abilities (for example, visually impaired people).

- **Manipulation, preparedness, and advantage:** The technology could be used to generate fake news or propaganda in the form of amended footage of real-world events, or artificially constructed events. AR and VR also have military uses for capturing information about an environment, or for training and testing, or for use as an invasive technology in warfare.
- **Ownership, rights, and governance:** There are various questions about the inclusivity and economics of XR. Few companies may dominate the market and control the governance of the technology (for example, Facebook acquired Oculus and is expanding into the 'metaverse'), which brings up issues around rights to the software and platforms, or monetisation of virtual environments. The economic cost to users could worsen the "digital divide" in society if AR and VR become the norm.

Public opinion on AR and VR

Almost all the sources of public opinion on AR and VR we found were from international contexts (non-UK, or global samples). We found two surveys, consultations, or public dialogue activities that specifically looked at the UK context.

Two UK-based surveys asked about general awareness and understanding of AR and VR. A Royal Society survey on digital technologies found that **78% of people had heard of, and understood a little about, VR.**[103]

A survey by the software support company GetApp limited their questions to consumer applications, for example how AR fits in to entertainment or shopping habits. They found that 39% of consumers had tried AR and 38% had tried VR to test or view a product.[104] However, **access to and ownership of VR headsets is declining year-on-year from 12% in 2018 to 9% last year**.[105] A Swedish study showed positive attitudes towards VR marketing, and its ability to influence customers, yet it highlighted public concerns around personalisation based on factors such as economic preferences or relationship status.[106]

Very little research has looked at public views on AR and VR in medical settings, particularly for mental health. Small studies have looked at the use of AR and VR in treatment of anxiety, post-traumatic stress disorder, and pain relief. These found that users typically had limited knowledge of the use of AR and VR in health, but reported positive experiences and optimism following their involvement in trials.

Users of AR and VR in education settings reported that VR increased interest in and motivation to learn about the content, and consequently may contribute to longer-lasting proficiency. Disadvantages are mostly related to costs, lack of analysis, the time required to learn to use hardware and software, possible health and safety effects on the user, and slow integration of technology into the curriculum.[107]

We found some instances where **public opinion indicated awareness of inequality in AR and VR**. For example, older people report lower confidence using digital tools, or setting up new devices and digital literacy gaps exist for many of the vulnerable and marginalized communities that might benefit from AR and VR technologies.[108] However, a survey by US-based Touchstone Research found **higher interest in AR and VR in racially minoritized groups, compared with white respondents**. They suggest this could be because older age groups, which had less interest on the whole than younger generations of Americans, tend to be more White, while younger Americans are more ethnically diverse.[109]

Regular users of social VR **reported experiences of sexual, verbal and sometimes physical harassment towards their avatar targeting their gender, race, or sexuality.**[110] This mirrors public experiences about video games in general, which 9% of UK adults would describe as "inclusive".[111]

By contrast to the general public, **in investment, start-up and technology sectors, awareness and optimism around AR and VR is high.** For example, 86% of respondents to one survey expect AR and VR to be "as ubiquitous as mobile devices" by 2025. A survey of the business community ranked it as

"most disruptive" technology, ahead of AI and internet of things, and 58% of that group had grown "more positive" towards the technology over the past 12 months.[112]

Businesses are also better informed around legal risks, particularly consumer privacy and data security, product liability/health and safety issues, difficulty in licensing technology and IP, potential infringement of third party–owned IP, and compliance with platform requirements in publishing content.[113]

Social intelligence trends and gaps

We found very little research that asks members of the UK public about their views, values, and experiences of augmented reality and virtual reality.

Trends in social intelligence

- Generalised and somewhat superficial awareness around the concepts of augmented and virtual reality is high amongst the UK public
- Engagement and opinion research has involved groups who have a commercial interest in VR and AR, for example surveys of business leaders or early adopters. Those groups are likely to have more awareness of risks and benefits, and their policy implications.
- Engagement has happened on a whole-population level, so it is not possible to analyse impacts or views on marginalised groups. However, there are indications that inequalities could arise relating to cost, digital skills and confidence, and user demographics.

Opportunities for new public engagement on AR and VR:

- What defines safe and responsible use of AR and VR? For example, by ensuring discussions around personal information, privacy, user data, targeted advertising, fake news, risks of identity theft, or tracking and monitoring are applied to the metaverse.
- What are the opportunities of therapeutic use of AR and VR to benefit health and wellbeing? For example, by involving people in designing and monitoring medical interventions, or by opening up dialogue about potential mental health risks.
- How can virtual worlds be inclusive to all? For example, by ensuring groups such as women, older people, LBGTQ+ communities, or disabled people are listened to when developing AR and VR technology.

New gene therapies

Summary

Whilst the cost and resource associated with new gene therapies is high, the capacity and technology to treat chronic diseases is growing and is likely to become more widely available. Very little recent social intelligence has focused directly on new gene therapies.

Our analysis shows that people are cautiously optimistic about new gene therapies as a treatment, but have potential concerns over commercialisation, access, and safety. Very little work has been done to involve communities who stand to be most impacted by new gene therapies, for example people living with, or at risk of, chronic disease.

What are new gene therapies?[114]

Gene therapy is the introduction, removal, or change in genetic material (DNA or RNA), often as a treatment for a condition caused by a misfunctioning, or missing gene. There are two types of gene therapies:

- Somatic gene therapy: the introduction of a section of DNA/ RNA to non-reproductive cells of the body that does not affect reproduction and will not be inherited by future generations.
- Germline gene therapy: the introduction of a section of DNA to reproductive cells that impact reproduction and will inherited by subsequent generations. Current UK regulation states that gene therapies cannot be carried out on germline cells. However, outside the UK, gene edited babies were born in China in 2018 and the scientists responsible for leading the procedure was subsequently jailed.

Gene therapy can be used to **treat single gene disorders or chronic diseases** such as cystic fibrosis.[115] Gene therapies may be longer lasting than other medical interventions, and could be used to treat complex or rare conditions (over 80% of rare diseases have a genetic component)[116], or to improve the body's ability to fight off disease in future.

Gene therapy is one of a range of 'gene technologies'. The Royal Society defines genetic technologies as, "…anything to do with understanding, making or adapting genetic material". In this report, we look at gene therapy where a disease is treated by the introduction of pre-modified genes into target cells, and therapies where DNA is edited within the cell.

Gene therapies can be **highly personalised, and involve many different components and manufacturing processes**. They usually cannot be produced at scale, and require an experienced clinician to deliver them to patients and track their effectiveness. Gene therapies have received a lot of investment and commercial attention, yet at present they are specialised, expensive, and not widely available. However, new advances are improving the efficiency and availability of their design, manufacture, and administration.

The UK Cell and Gene Therapy Catapult reported that **the UK accounts for 12% of global clinical trials using cell and gene therapy**. As of 2020, the sector had over 90 advanced therapy creators in the UK which helped create a £300 million turnover and created over 3,000 jobs.[117] In 2018, Innovate UK suggested that by 2035 the UK could have a 15% share of cell and gene therapy global activity, secured revenue in excess of £10 billion and generated 18,000 high-skilled jobs.[118]

Social and ethical issues in new gene therapies

The concept of introducing new genetic material as a treatment differs from more traditional medical interventions like surgery and pharmaceuticals, and raises questions around justice, ethics and safety. How will we see our health in the future – as chance, or as choice?

Specific social and ethical issues that have been identified include:

Identity and access: it could be difficult to know the effectiveness of gene therapy without compromising individual identities, since in some cases it is so personalised and user groups are so small. Gene therapy might only be available to limited users because of cost, eligibility requirements, or different national regulations. There would need to be a decision on what criteria should be met in order to establish that an experimental therapy in humans is safe and ethical.

Diversity, decision-making, and unknown effects: technology behind gene therapies could ultimately be used to alter germ-line (inheritable) traits to improve height, intelligence or athletic ability. Linked to this, people will have different ideas and values about human "normality", "naturalness", and which conditions should be treated with gene therapy.[119] Therefore, gene therapy could reduce society's capacity to support difference, or reopen complex and harmful debates about "perfection" (for example, links with eugenics). There are risks associated with changing processes we don't yet understand (e.g. ageing). Gene therapy might limit understanding of natural processes, or mask the underlying cause of a condition, or create unforeseen changes that only become apparent long after the procedure.

Sustainability, regulation, and costs: views and attitudes to gene therapy could define jurisdiction governance or allocation of resources, similarly, regulation could happen on sectoral, national or international scales. In the UK, the resource and material costs may be too expensive for the NHS to offer gene therapy to all citizens. There is also a question over the sustainability of a therapy that can be so resource and cost intensive.

Public opinion on new gene therapies

There has been a proliferation of studies looking at gene editing and genomics. These studies bring up many ethical issues, but these are usually not relevant to the debates around new gene therapies, since they focus on inheritable changes, or on the data associated with genetic technologies.

Between the mid-1990s and 2000s there were many UK and international studies that looked at public attitudes towards gene therapies. These studies helped inform the industry we have today, but we found only **one survey, consultation, or public dialogue activity that specifically looked at the UK context, and none from a UK perspective** after 2017.

In 2017 the Royal Society reported that **the UK public is cautiously optimistic about the use of technologies such as DNA sequencing, gene therapy and genome editing** to help tackle global challenges like improving human health, reducing inequality and responding to the impacts of climate change. People believe genetic technologies should be low cost, accessible to all, promote collective welfare, and use transparent processes. People are most concerned about editing out difference in society, use for individual or corporate gain, draining NHS resource, or the technology being unsafe.[120]

A systematic review of public acceptability of gene therapy and gene editing for human use provides a useful insight into international public opinion of gene therapies between 1992-2019.[121] The review included 25 quantitative, 2 qualitative, and 14 mixed-method studies which were conducted in mainly Western countries. The UK (11), the US (10), Australia (6) and Japan (6) were the most studied.

The review provides some useful insights across a 27-year period. However, the different methods used in the original studies and the large time period only make this a useful reflection piece, rather than a representation of current UK public opinion.

The key findings of this systematic review were:

Demographics:

- The majority of the studies that looked at gender differences found that women are less likely to approve of gene therapy.
- Those who have a stated religious affiliation are less likely to support gene therapy compared to those with no affiliation.

- The studies that looked at age found that younger participants were likely to be more accepting of gene therapy than those from older cohorts.

Medical intervention:

- In most studies there was considerably less support for gene therapy used for non-medical purposes compared to medical interventions.
- Most studies found the majority of respondents were uncomfortable with genetic enhancement but were supportive of using gene therapy for treating conditions such as blindness in birth or fatal diseases.
- The majority of studies found that disease severity, e.g. whether these were fatal or debilitating diseases such as Alzheimer's, Parkinson's and cancer, had a large impact on approval of gene therapies as treatment.

Public views:

- There was widespread support for somatic gene therapy, but the use of germline treatments was far more divisive.
- Most studies found there was widespread approval for gene therapy for medical use in humans, although there were potential risks.
- There was some concern around the misuse of both somatic and germline technologies. Other concerns included negative health outcomes, medical side effects and the unknown long-term outcomes of these therapies.

Social intelligence trends and gaps

There were no studies that asked members of the UK public about their views, values, and experiences about new gene therapies in the last four years. As a result, the evidence presented in this section is out of date and is from a range of different countries. Investment and development of the technology has increased rapidly since the last major research was conducted into public views.

Trends in social intelligence

- There are indications that men, younger people, and people without a religious affiliation are most likely to be supportive of new gene therapies.
- People are more likely to favour using gene therapies for chronic health conditions than for enhancement purposes.
- Much more attention has been paid to understanding public views on germline gene editing than on other genetic technologies. We are therefore unable to assess how people's views might or might not change in relation to different genetic technologies.

Opportunities for public engagement on new gene therapies

- What are the right mechanisms to understand the general public's priorities and concerns about new gene therapies? For example, involving people in the governance and messaging as treatments become more widely available.
- How could marginalised communities be more involved in conversations about new gene therapies? For example, new gene therapies have the potential to provide treatment for conditions that are more likely to be experienced by minoritized groups – for example, sickle cell disease and HIV. The technology could also have associations with harmful and discriminatory ideas such as eugenics.

Appendix

Analysis of current public opinion research

When compiling this report, we encountered the following challenges and limitations when analysing public opinion, especially in the case of surveys and polls:

- **Lack of transferability** between contexts and communities limits the conclusions we are able to draw from international, or specific user-group data;
- **Aggregation** of data from multiple contexts and communities so it is difficult to see detail;
- **Sample sizes** are generally not large enough to understand the views of traditionally marginalised groups, such as disabled people or racially minoritized communities; and
- **Inconsistency** in how terms and technologies are defined, and lack of specificity around which technology is being referred to (for example, people being asked about "AI and robotics" as one question).

Trends in social intelligence on emerging technologies

We found that public engagement on emerging technologies tends to:

- **Ask people about emerging technologies in the context of their lives at the time**, not what they hope for in future years;
- **Use samples of 1,000 – 3,000 adults** where demographics are representative of the UK. However, this means that quantitative surveys do not provide usable data from historically marginalised and minoritized communities, since the typical sample sizes are too small to be able to infer views from those populations;
- **Rarely be regular, or global.** A lot of public opinion research is happening across several nations, which sometimes included the UK (for example Eurobarometer). However, both UK-based public opinion research on emerging technology (aside from the regular Public Attitudes to Science surveys published by the Department for Business, Energy and Industrial Strategy, and recent work by the Ada Lovelace Institute) and truly global research (such as Wellcome's Monitor and the Lloyd's Register Foundation World Risk Poll) is less common, and is often limited to a few topics; and
- **Show relatively consistent views.** Although we cannot know the long-term effects, our analysis indicates that trust in science and technology has remained stable throughout the COVID-19 pandemic. However, there are indications that attitudes to health and wellbeing, and digital behaviours have changed as a result of measures to reduce the spread of COVID-19, and could continue to shift.

Recommendations for public engagement on emerging technologies (EmTech)

We recommend that funders and commissioners of social intelligence and public engagement on emerging technologies should:

- **Address a gap in research on the future implications** of emerging technologies, and support engagement that presents multiple options for people to consider and help to shape such EmTech.

- **Boost population samples of minoritized communities** to go beyond regional, age and gender segments. Reporting should highlight data on the views of racially minoritized communities, disabled people, and should be as intersectional as possible.
- **Build capacity for all kinds of public engagement and involvement**, including surveys and dialogues in the UK and globally – for example, longitudinal public research that compares the views of both UK and global attitudes on emerging technologies and scientific advancements.
- **Closely monitor public attitudes and behaviours throughout the COVID-19 pandemic**, and do not assume they have remained static. The period researched for this report (2017-2021) needs to be carefully interpreted due to the societal and social changes during this period, and there should be ongoing tracking of key science and technology questions.

How were technologies chosen for this report?

There are many potential emerging technologies, and 'parent' technologies that underpin them, that promise to shape the future of society and the economy. UK Research and Innovation recently categorised them into seven "families": Advanced materials and manufacturing; AI, digital and advanced computing; Bioinformatics and genomics; Engineering biology; Electronics, photonics, and quantum technologies; Energy, environment, and climate technologies; and Robotics and smart machines.[122] Each of these families of parent technologies encompass hundreds of potential applications and possibilities.

We followed a three-step process to identify emerging technology areas to include in this report:

- **Indexing:** we scanned several lists of emerging technologies that have been compiled by UK government departments and agencies (including the tech families referenced above, National Physical Laboratory[123], and Government Office for Science [124]) and identified emerging technology areas that appeared across multiple lists;
- **Consultation:** we discussed the index with leaders in emerging technology, science and technology policy, and in the ethics and social impacts of science and technology and public opinion research to identify the emerging technology areas which are likely to have the most societal impact or social and ethical implications; and
- **Prioritisation:** we checked which technologies were already the subject of up-to-date, in-depth public opinion and dialogue work (for example, genomics), and focused on those where less was known about public views and values.

Among the technologies considered for inclusion were DNA synthesis, Autonomous transport, Digital twins and modelling technology, Medical applications of nanotechnology, Biomimetics, and Privacy-enhancing technologies. It is possible that the technologies chosen for inclusion in this report have influenced the more general conclusions we have drawn – about public perspectives on emerging technologies and what types of further research is needed. Various drafts of this report were reviewed prior to publication to ensure the findings and recommendations are transferable.

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