Digital technologies and human transformations

Workshop report

THE ROYAL SOCIETY

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Executive summary

The use of tools has always conditioned and been conditioned by humans and their societies. From stone-age implements, to writing and printing, to the mechanisation of manufacturing, technology design and use have always been entwined with the evolution of human capabilities. Digital technologies are transforming human experiences, and significant questions about how individuals interact with digital technologies, and how these technologies mediate interactions between people, follow. To explore the implications of this wave of technological change, the Royal Society convened a series of workshops in 2019.

Digital technologies are creating new ways of experiencing the world. New applications of virtual reality technologies are emerging across a range of research domains. As these become more sophisticated – with more senses integrated and with more convincing simulations of the physical environment – the more likely it will be that the line between virtual and physical worlds becomes blurred for their users. As the virtual world becomes more accessible, it becomes part of the 'real world', with consequences for how individuals interact with it.

Interactions between individuals and the online environment are also changing, with intensive targeting of news, products or services, and the use of sophisticated fake images and videos. These online interactions, however, are embedded in broader social relationships: both technological and social factors influence who interacts with whom, and filtering effects influence how people respond to the information they see. These are not yet well-understood.

Digital technology also affects the physical environment. As concerns about the impact of climate change grow, so too does awareness of the environmental impact of systems that can be both resource and energy-intensive in their manufacture and use. Research is offering ways of creating more energy-efficient technologies, as well as opportunities to deploy digital technologies to optimise patterns of energy use in ways that reduce overall carbon emissions. Further action is required to develop and deploy such responses in order to reduce the impact of digital technologies on the environment.

The early days of digital technology brought much excitement about their potential to build new bridges between individuals. Digital platforms have offered a forum in which to develop new connections: individuals have an opportunity to communicate to and with much broader – or much narrower – groups in ways that were not previously possible. However, there are also harmful consequences, for example, the effect of the content of on-line material on vulnerable groups, the formation of extreme groups and polarisation.

Interactions between individuals and digital technologies are developing across all spheres of daily life: automation and increasingly sophisticated remote working are transforming the workplace; digital technologies are transforming the classroom by giving teachers and students new tools for learning; in the home, assistive robots can help those in need of care to live independently for longer. These technologies are economically disruptive, displacing existing modes of production with more efficient ways of working and boosting productivity across all sectors and industries, with potentially profound implications for employment.

While it seems clear that digital technologies will transform human lives and experiences, the nature of these changes is less clear: do digital tools provide a temporary extension? Or are there longer-term changes to human capabilities that have not yet been uncovered? The political and social challenge is to manage such changes to minimise short-term social disruption and to maximise longer term social benefit.

The potential for digital technology to foster new forms of over-dependence or over-reliance is an emerging ethical concern. Responsible design is important to ensure that technologies empower users and help them build capabilities rather than lose them. From computer science to sociology, interdisciplinary insights can help to understand better the types of disruption that can arise when individuals interact with technology, and how, as a result, they interact with each other.

People and technology co-adapt, and the boundaries of what is technologically feasible and socially acceptable are in flux. As digital technologies advance and their role in daily life changes, new understandings of their harms and benefits will be needed, and further dialogues about the nature of the transformations to human lives, capabilities, and experiences that they may bring.

Introduction

From writing and printing to the mechanisation of manufacturing, technology design and use has long been entwined with the evolution of human capabilities. Data-enabled technologies are creating new opportunities to expand and shape human experience: digitally-connected devices and platforms enable new forms of connection and interaction; artificial intelligence (AI)-enabled technologies are automating tasks and processes, changing the nature of work; education technologies are supporting new approaches to learning and remembering; and augmented reality and prosthetic technologies are shaping how their users move through and sense the environment around them.

Significant questions about how individuals interact with digital technologies, and how these technologies mediate interactions between people, follow. Society could stand on the edge of a new age of digital enlightenment, with digital technologies democratising access to information and global networks fostering new connections between individuals and communities. In parallel, there is a risk that these technologies could entrench existing social inequalities and biases, with the benefits of technological change concentrated amongst the few.

In 2012, a joint project between the Royal Society, Academy of Medical Sciences, British Academy, and Royal Academy of Engineering explored how advances in science and engineering could enhance human abilities, and the implications of these enhancements for the future of work. Since this study, advances in digital technologies have progressed at pace: AI technologies are achieving or surpassing human-level performance at some tasks; platform-based services are fuelling the digital economy; and a range of new device or robotics-based tools have entered the home and workplace.

To explore the implications of this wave of technological progress – from cloud computing to virtual reality, and home robotics to global platforms – the Royal Society convened a series of workshops in 2019 on the topic of 'Digital Technologies and Human Transformations'. These workshops set out to explore the ways in which digital technologies are shaping human lives, experiences, and capabilities. They considered:

- Moving and sensing: in what ways are technologies influencing how individuals move through and sense the world around them?
- Remembering and learning: how can digital technology support learning, and human cognitive functions?
- Working and earning: what are the implications of digital technologies for patterns of working, earning, and economic activity?
- Connecting and depending: what forms of connection and interaction are digital technologies enabling, and what dependencies potentially follow?

The report that follows summarises the key themes from these discussions, and their implications for human lives and capabilities. It considers:

- How technologies are enabling new forms of interaction between individuals and their environments;
- The ways in which interactions between individuals are mediated by digital technologies; and
- Interactions between individuals and technology, and their implications for human capabilities.

This note summarises discussions at these workshops. It is not intended as a verbatim record and does not reflect an agreed position by workshop participants or the Royal Society.

Patterns of interactions between digital technologies, individuals, and groups

Interacting with the environment

The intersection of virtual and physical worlds

Technologies can interact with human senses in different ways: they can restore or provide a substitute for an absent sense; they can extend existing senses, making them more acute; or they can alter or augment the senses. A range of technologies today offer new ways for people to perceive and move through their surroundings, in many cases opening windows into phenomena that were previously imperceptible. In so doing, these technologies change the interfaces between individuals their environment, offering new perspectives on the world, and new forms of reality.

Advances in virtual and augmented reality (VR and AR) technologies offer new ways of perceiving and interacting with the world. As hardware costs fall, compute power increases, and research advances, VR and AR technologies are becoming more accessible, with new applications emerging across a range of research domains.

Applications in healthcare, for example, offer particular promise. VR and AR technologies can help clinicians to simulate 'real life' experiences within the safe environment of the consulting room, for a range of purposes. For patients with severe anxiety, these technologies allow exploration of stressful environments, with clinicians providing support as they encounter potentially difficult experiences. Virtual environments can also help prosthetics users to practice interacting with a prosthesis before it is fitted, helping ensure that the user and the physical device are subsequently able to interact more effectively.

Simulated environments also open opportunities for new scientific research, for example creating representations of molecules with which researchers can interact, with the aim of better understanding their structure and function, and aiding nanoscale engineering and design (Box 1).

Challenges in implementing these technologies remain. While simulations can produce compelling representations of well-characterised environments, it is more difficult to create good representations of environments that are poorly understood – the conditions on other planets, for example. It also remains challenging to integrate inputs in ways that allow users to interact with these virtual environments using multiple senses – combining sound, vision, and touch, for example. Such sensory integration plays an important role in replicating the nature of human experiences in the physical world, and will be necessary to create natural-seeming virtual experiences. Even in areas where there have been research advances in recent years – such as the ability to manage motion sickness in VR systems – further work remains to translate these insights into design principles that are widely implemented.

As they enter more areas of life, these technologies could disrupt distinctions between the 'real' and 'digital' worlds. The more effective they become – with more senses integrated, with more convincing simulations of the physical environment, and with AR more integrated into day-to-day tools – the more likely it will be that the line between virtual and physical worlds becomes blurred for their users. As the virtual world becomes more accessible, it potentially becomes part of the 'real world', with consequences for those that move through it.

78% of people report having heard of, and understanding a little about, virtual reality technologies.

61% of people think digital technologies could be 'very useful' in healthcare over the next 10 years.

1. The statistics in this document refer to polling carried out online by YouGov on behalf of the Royal Society. Details are in Annex 1.
2. See, for example: Valmaggia, L., Latif, L., Kempton, M. and Rus-Calafell, M. (2016) Virtual reality in the psychological treatment for mental health problems: A systematic review of recent evidence. Psychiatry Research 236, 189-195
3. See, for example: BBC (2016) Virtual reality to help prosthetic limb use, available at: https://www.bbc.co.uk/news/av/uk-england-south-yorkshire-37766373/virtual-reality-to-help-prosthetic-limb-use

BOX 1

Designing multi-sensory environments for nanoscale engineering and design

Molecules are imperceptible to human senses – they exist in the nanoscale – meaning that researchers typically relate to them at an abstract level, using mathematical representations or simulations to build models of how they fit together and function. These models play an important role in research: the structure of molecules affects how they function, and understanding this structure has implications for their use across a range of areas – including materials, medicines, and energy. Better understanding how and why molecules behave the way they do could make nanoscale engineering and design more effective.

One approach to developing this understanding is to create virtual environments for nanoscale engineering. The Intangible Realities Laboratory at the University of Bristol, for example, has created a VR environment in which researchers can interact with simulations of how molecules behave, based on their known physical properties. These simulations allow researchers to interact with representations of molecules – moving them, twisting them, tying them in knots – to test how they respond to different manipulations. This type of environment allows complex modelling tasks to be carried out in a more intuitive way, helping researchers generate new insights into the structure and characteristics of different molecules.

Extending this work, the lab is exploring new ways of making nanoscale phenomena perceptible across multiple senses, for example through adding sound effects to the simulation that illustrate changes to molecular energy states, or using e-textile gloves that add a sense of touch to these interactions.

Alternative realities and the information environment

Other interactions between digital technologies and their users are constructing alternative realities in more subtle ways, through changes to the information environment that contributes to how an individual understands the world.

The development of AI technologies that personalise recommendations for news, products or services, coupled with the dominance of advertising as a source of business revenue for some digital companies, has opened new debates about how technology is changing the information to which individuals are exposed on a daily basis. These changes have led to concerns about the extent to which individuals are targeted with a limited range of online information as a result of the development of so-called filter bubbles.

The term 'filter bubbles' describes a mechanism by which algorithmic tailoring of online information results in individuals being exposed only to content that is tailored to their anticipated pre-existing preferences or beliefs. These bubbles could enhance connections between members of a community and allow new connections. They could, however, also contribute to the spread of misinformation, the narrowing of political debate, or hardening of particular worldviews. Individuals are brought together, but in ways that potentially deepen social divisions by reinforcing existing beliefs and reducing the extent to which they have the opportunity to interact with others that hold different views – essentially reducing the diversity of views to which they are exposed.

12% of people think that the benefits of social media as a news source outweigh the risks; **37%** think that the risks outweigh the benefits.

4. O'Connor, M, Deeks, H, Dawn, E, Metatla, O, Roudaut, A, Sutton, M, Thomas, LMM, Glowacki, BR, Sage, R, Tew, P, Wonnacott, M, Bates, P, Mulholland, A & Glowacki, D, 2018, Sampling molecular conformations and dynamics in a multiuser virtual reality framework, Science Advances, vol 4.
5. O'Connor, M., Bennie, S., Deeks, H., Jamieson-Binnie, A., Jones, A., Shannon, R., Walters, R., Mitchell, T., Mulholland, A. & Glowacki, D. (2019) Interactive molecular dynamics from quantum chemistry to drug binding: an open-source multi-person virtual reality framework. J. Chemical Physics 150, 224703
6. Glowacki, D. (2019) Perceptions at the nanoscale. Nature Nanotechnology, 14, 403

Grouping of individuals around content and messaging on a particular issue, theme or political position – forming information echo chambers in the process – is not new: individuals have long chosen the lens through which they engage with the world by selecting specific newspapers, for example. However, the information environment is changing: people increasingly access information about news, current affairs, and science through social media; AI tools are enabling the creation of more convincing fake images, text, and audio, and these tools are becoming more widely accessible; meanwhile media industry consolidation potentially plays a role in influencing the number of different sources to which individuals are exposed; and malicious actors are seeking to influence online debates via misinformation or disinformation campaigns for political or economic gain.

These patterns of digital information consumption interact with existing human cognitive biases, such as the processes by which the human brain stores memories. Memories are moulded by patterns of information retrieval and use; these patterns of use attach different retrieval cues to different memories, which influence how and when that memory is recalled (see Box 2). Memories with stronger retrieval cues are more likely to surface, and information that is more frequently or recently accessed becomes more accessible, while other memories are supressed or forgotten.

BOX 2

Cognitive neuroscience and the mechanisms of memory

Forgetting is not simply a passive process – a by-product of the passage of time or cognitive decline – but one shaped by active mechanisms that determine the accessibility of memories and knowledge. Research at the Memory Control Laboratory at the University of Cambridge's MRC Cognition and Brain Sciences Unit has shown some of the ways in which people remember – or forget – information.

The brain processes vast amounts of information every day, and for every important piece of information there will often be competing, less salient memories. These competing memories are associated with different signals that influence how they are stored: information associated with strong retrieval cues – for example, relating to recent events – is more readily accessed by the brain. Selectivity in the frequency with which information is accessed and used foregrounds some memories and diminishes others. This process is known as adaptive forgetting: over time, the brain gradually tunes the state of memory, keeping information that is more likely to be needed in a state of activity, and the things that would otherwise distract from relevant information in a state of suppression until they are ultimately forgotten.

This type of retrieval-induced forgetting has been demonstrated in a wide range of circumstances and for different types of memories. When police interview an eye-witness to a crime, for example, and selectively ask about only a few features of an event, that witness is more likely to forget the things that they are not asked about.

In groups, these processes can result in a phenomenon called socially-shared retrieval-induced forgetting: individuals can induce forgetting in each other through selectivity in the way that they communicate their experiences. By discussing some information more readily – and backgrounding other information – the memories of individuals in a group can become aligned; they tend to remember the same things, and forget the same things.

7. See, for example: Coman, A. and Hirst, W. (2015). Social Identity and Socially Shared Retrieval-Induced Forgetting: The Effects of Group Membership. Journal of experimental psychology. 144

Such processes have implications for both how individuals remember events, and also how groups share experiences. By recalling only certain aspects of a shared experience, groups begin to selectively retrieve information relating to that experience, with some memories being gradually sculpted away and dominant framings emerging: as a result, over time, the memories of individuals in the group become more alike.

While the factors that produce and shape human memories are well-studied in neuroscience, the interactions between these cognitive processes and the ways in which information is shared, amplified or suppressed in the online environment remains relatively unexplored. The social and political consequences, too, are not yet clear, and there may be significant implications for political polarisation and social cohesion.

Digital technologies and the environment

Many of the impressive advances in the capabilities of digital technologies in recent years are due to their ability to leverage growing computing power to rapidly analyse vast amounts of data. However, as society's concerns about the impact of climate change grow, so too does debate about the environmental impact of digital technologies that can be both natural resource and energy-intensive to develop and use.

New research is pointing to ways of creating more energy-efficient technologies, as well as opportunities to deploy digital technologies to optimise patterns of energy use in ways that reduce overall carbon emissions. Further action is required to develop and deploy such responses, in order to reduce the impact of digital technologies on the environment.

50% of people aged 55+ report having a good understanding of social media platforms, compared to **82%** of 18 – 24 year olds.

Interacting with each other

The early days of digital technology development brought much excitement about their potential to generate new connections, building new bridges between individuals and helping form new communities.

Digital platforms offer a forum in which to develop new connections. However, the processes by which these develop are embedded in broader social interactions: ranking effects from technology and existing social relationships shape who interacts with whom, and filtering effects that shape how people respond to the information they see. These technological and social factors can affect how individuals interact with each other in complex ways across different environments. For example:

- At work, organisations are able to standardise tasks and workflows in ways that allow them to be administered by automated systems. As a result, in some workplaces, interactions with human managers can be replaced by digital interfaces with standardised performance measures, and workers can be monitored more extensively, facing new pressures to optimise their performance in order to be able to attract new work.
- At home, individuals are potentially exposed to new forms of harmful material or forms of abuse, with implications for the health and welfare of vulnerable groups. It is now possible, for example, for groups with extreme political views to connect and raise the profile of their cause in ways that previously would have required centralisation of resources.

Technologies create the opportunity to communicate to and with much broader audiences, as well as to target much more specific groups, in ways that were not previously possible. However, these interactions tend to support connection without the means to collectivise – users are highly connected, frequently interacting with platforms or online services, but in ways that do not necessarily lead to connections between users.

8. Coman, A., Momennejad, I., Drach, R. and Geana, A. (2016) Mnemonic convergence in social networks: the emergent properties of cognition at a collective level. PNAS 113 (29) 8171 – 8176

In some ways, digital technologies are therefore reinforcing the need for new spaces for civic interactions offline. Such spaces might:

- Offer access to reliable, accurate information;
- Allow people to collaboratively design and develop technologies for civic purposes;
- Open up further opportunities for democratic debates about the development of digital technologies as a form of civic architecture.

Interacting with technology

Digital technologies are shaping all spheres of daily life.

Technology-enabled changes might be encountered in the workplace, for example through

- new tools to support customer service, for example, or systems that automate routine tasks; or
- new ways of working, with more advanced technologies to enable remote working.

Employees might also experience wider changes to their relationship with work, drawing from multiple sources of income that include both regular jobs and gig working. These portfolio careers pose a challenge to current notions of 'working life', with implications for professional identities, the connections between workers and employers, and how work relates to an individual's sense of personal identity and self-esteem.

Organisations, meanwhile, may need to develop alternative business models or reorganise their means of production in order to make best use of the transformative potential of data and digital technology. They may need to build teams with different mixes of skills, and develop alternative approaches to managing those teams. As people work for longer and younger generations enter the workforce, teams might also have different demographic profiles, with five generations working together.

5% of people report having a good understanding of 'co-bots', robots that work alongside people to carry out a task in the workplace.

The tools of the digital transformation comprise a 'general purpose technology', which are rare in history. It is a technology that continually transforms itself, progressively penetrating new domains, boosting productivity across all sectors and industries because of its cost effectiveness, and with profound economic and social implications. It is economically disruptive, rapidly displacing existing modes of production with more efficient ways of working, with implications for employment. The political and social challenge is to manage such changes to minimise short-term social disruption and to maximise longer term social benefit.

In the classroom, digital technologies are giving teachers and students new tools for learning. These might include, for example, tools to give personalised feedback to students, or platforms for collaboration between students and teachers. The most effective of these take insights from neuroscience about how individuals learn, and combine them with innovative approaches to education delivery, boosting both learning outcomes in the near-term and the ability of students to learn in the longer term. Creating these systems will require new collaborations to design tools that work well in different learning environments, and to support teachers in their application. They will also require approaches to data governance that manage tensions between individual and group benefits, and between concerns about privacy and the benefits of data use.

57% of people think digital technologies could be very useful in education in the next 10 years.

9. See, for example: Linn, M., Eylon, B., Kidron, A., Gerard, L., Toutkoushian, E., Ryoo, K., Bedell K, Swearingen A, Clark DB, Virk S, Barnes J, Adams D, Acosta A, Slotta J, Matuk C, Hovey C, Hurwich T, Sarmiento JP, Chiu JL, Bywater J, Hong J, Ben-Horin H, Kali Y, Sagy O, Tal T, Osborne J, and Laurillard, D. (2018). Knowledge integration in the digital age: Trajectories, opportunities and future directions. Proceedings of International Conference of the Learning Sciences, ICLS, 2 (2018-June), 1259-1266.
10. There is evidence, for example, that giving feedback, developing metacognition, practising recall, using spaced repetition, and deliberative practice support effective learning.

In the home, the development of assistive robots offers ways of supporting individuals to live independently for longer. Such technologies can offer support for memory or cognitive decline, such as guidance in taking medication; for sensory or physical impairments, for example offering mobility support; or for rehabilitation, by helping with exercise plans and individual motivation. A range of such tools already exist, from telepresence robots that provide remote access to medical advice to emotional support robots that can help calm patients (Box 3). As these begin to enter wider usage, there will be important questions about the ethics of their deployment, including the ways in which they collect data from the home, and their implications for the privacy, autonomy, and dignity of their users.

Across these areas, it seems likely that new or unexpected forms of interaction between individuals and technologies will emerge. This might include different forms of coordination – for example, as human drivers and autonomous vehicles encounter each other on the roads – or incidents in which human behaviours do not follow expected patterns (Box 4). Technologies will need to be resilient in the face of such shifting patterns of interaction, with their design taking into account the broader context and consequences of their use (or mis-use).

59% of people think that the benefits of technology that helps people with dementia and memory loss outweigh the risks.

BOX 3

Examples of assistive robots

Different forms of robotic support for care at home already exist. These include:

- Robotic beds, which can convert from a bed to a wheelchair, meaning users can become mobile more easily.
- Robotic arms to help people with paraplegia move their wheelchair using head control, eye movement, or limited hand movements.
- Exoskeletons that provide physical support to care workers in lifting and moving the people for whom they care, and that could help those with spinal injuries walk.
- Emotional support robots, which are believed to help calm patients who are distressed or dealing with anxiety.
- Home care assistants that can provide meal preparation assistance or support dressing.

11. See, for example: CNET (2009) Panasonic's robotic bed transforms into a wheelchair, available at: https://www.cnet.com/news/panasonics-robotic-bed-transforms-into-wheelchair/
12. See, for example: IEEE Spectrum (2019) Jaco is a low-power robotic arm that hooks to your wheelchair, available at: https://spectrum.ieee.org/the-human-os/robotics/medical-robots/robot-arm-helps-disabled-11-year-old-girl-show-horse-in-competition
13. See, for example: IEEE (2019) Cyberdyne's HAL exoskeleton helps patients walk again in first treatments at US Facility, available at: https://spectrum.ieee.org/the-human-os/biomedical/bionics/cyberdynes-hal-medical-exoskeleton-helps-patients-walk-again-at-first-us-facility
14. See, for example: The Guardian (2014) How Paro the robot seal is being used to help UK dementia patients, available at: https://www.theguardian.com/society/2014/jul/08/paro-robot-seal-dementia-patients-nhs-japan
15. Chance, G., Camilleri, A., Winstone, B., Caleb-Solly, P. and Dogramadzi, S. (2016) An assistive robot to support dressing – strategies for planning and error handling. In: 2016 6th IEEE International Conference on Biomedical Robotics and Biomechatronics (BioRob), Singapore, 26-29 June 2016., pp. 774-780

BOX 4

Cooperation and competition between humans and digital technologies

Travelling on the road requires negotiations between a range of different actors – vehicle drivers, pedestrians, cyclists – as each tries to optimise their journey. These behaviours create a variety of coordination challenges, in which these actors judge the intent of other road users, and take action accordingly – at junctions, road crossings, or roadworks, for example.

Behavioural sciences have long used game theory to understand how individuals are likely to act in situations where there are opportunities to cooperate or compete to achieve different outcomes. As a result, individual behaviour in these circumstances is now relatively well-understood: human road users do not give way to all threats, but make judgements about how others are likely to behave as they compete for space on the roads.

It is not clear, however, that these behaviours still hold when human road users interact with autonomous vehicles and AI-enabled systems. Will a human still opt for a mutually beneficial compromise with a self-driving car? Findings from emerging, unpublished research at LMU's Cognition, Valuation and Behaviour (CVBE) and Crowd Cognition (http://crowdcognition.net) groups suggest not; that people are less likely to cooperate spontaneously with an AI agent in the same circumstances as they would with another human.

There are already examples of these unexpected patterns of interaction developing as humans and autonomous vehicles interact on the road. In a 2018 incident, for example, a collision between an autonomous car and a municipal bus was attributed in part to a prediction made by the autonomous vehicle that the bus would slow or allow it to pass.

These interactions raise questions for further research, for example: what game theory paradigms would best describe likely human-AI interactions? And in what circumstances might these coordination problems arise?

People and technology co-adapt, and the boundaries of what is technologically feasible and socially acceptable are in flux. Across a range of different tools and applications, however, emerging patterns of interaction between individuals and digital technologies point to new ethical challenges, such as the negative effects of dependency on technology.

For some, digital technology is an empowering force. A task-based work platform might, for example, offer an opportunity for additional casual income to someone who was not previously able to participate in the labour market. However, in other cases their impact might be de-skilling. There are indications, for example, that people remember information that is digitally-mediated less effectively than that received by other means, with implications for how individuals store and understand different forms of knowledge.

Careful design of the points of interaction between individuals and technology is important in shaping the extent to which technologies support individual autonomy or foster undesirable dependencies. If digital technologies could be developed in ways that help build the metacognitive ability of their users, they could both support daily tasks, while also helping people build stronger capabilities in the longer-term. Creating this switch will require investment in understanding user needs, as well as research advances that help develop more effective systems (Box 5).

16. Camara, F., Romano, R., Markkula, G., Madigan, R., Merat, N. and Fox, C. (2018) Empirical game theory of pedestrian interaction for autonomous vehicles. In: Grant, R, Allen, T, Spink, A and Sullivan, M, (eds.) Proceedings of Measuring Behaviour 2018. Measuring Behaviour 2018: 11th International Conference on Methods and Techniques in Behavioural Research
17. Scientific American (2018) Google says it bears "some responsibility" after self-driving car hits bus, available at: https://www.scientificamerican.com/article/google-says-it-bears-some-responsibility-after-self-driving-car-hit-bus/
18. See, for example: Tamir, D., Templeton, E., Ward, A., and Zaki, J. (2018) Media usage diminishes memory for experiences, Journal of Experimental Social Psychology, 76, 161 – 168
19. The term 'metacognition' typically refers to 'thinking about thinking' or an individual's ability to understand and control their cognitive abilities.

BOX 5

Technology and cognition

Studies of human memory have shown that the brain responds in different ways to different types of training or learning behaviours. London taxi drivers, for example, who memorise over 85,000 streets as part of their licensing requirements, have been found to have increased the size of their posterior hippocampus, the part of the brain responsible for spatial memory.

Recent research from UCL's Spatial Cognition Laboratory suggest that mapping applications may have changed how people engage their brain to navigate, with implications for how the brain perceives and remembers the world. For example, in one study, researchers investigated activity in areas of the brain responsible for memory and navigation (hippocampus) and planning and decision-making (prefrontal cortex) in people navigating London's Soho district. They found these brain regions were tracking spatial information when they were using their memory, but not when they followed GPS-guided instructions on a screen. This may underpin why memory for environments is often much worse after using GPS-guided navigation.

Other studies also suggest that human cognitive capabilities could be influenced by interactions with technologies. For example:

- In a study of the impact of search engine use on memory, researchers investigated the cognitive consequences of having a digital 'memory' readily available, finding that users were less likely to remember content for which they had searched online.
- A study of how people viewed a painting found that smartphone use influenced memory production: users that took a photo of the picture were less likely to remember its detail than those who studied it directly for a short period, and this held true even when an individual both studied the picture and took a digital record.

20. Maguire, E., Woollett, K. and Spiers, H. (2006) London taxi drivers and bus drivers: a structural MRI and neuropsychological analysis, Hippocampus, 16 (12) 1091 - 1101
21. Javadi, A., Emo, B., Howard, L., Zisch, F., Yu, Y., Knight, R., Silva J., and Spiers, H. (2017) Hippocampal and prefrontal processing of network topology to simulate the future. Nature Communications 8, 14652
22. Hejtmánek, L., Oravcová, I., Motýl, J., Horáček, J., & Fajnerová, I. (2018). Spatial knowledge impairment after GPS guided navigation: Eye-tracking study in a virtual town. International Journal of Human-Computer Studies, 116, 15-24.
23. See, for example: Sparrow, B., Liu, J. and Wegner, D. (2011) Google effects on memory: cognitive consequences of having information at our fingertips. Science, 333 (6043), 776 – 778
24. Soares, J. and Storm, B. (2018) Forget in a Flash: A Further Investigation of the Photo-Taking-Impairment Effect. Journal of Applied Research in Memory and Cognition, 7 (1) 154 – 160

Digital technologies and human transformations

Interactions between technology and the wider social, political, and cultural context

Technology is not a unique or overwhelming force, but one subject to wider social, political, and cultural factors.

Online information sharing, for example, is shaped by factors including the economics of the media information environment, patterns of social interactions and social divisions between users offline, and cognitive biases towards – or against – different types of information. Wider influences over who or what is considered a trustworthy information source also play a role in this environment, especially as AI-generated media becomes more sophisticated and it becomes challenging to distinguish between 'real' and 'fake'. At the same time, the data infrastructures that underpin the web are becoming more centralised, and further technology development is necessary to create system architectures that decentralise data access and use in ways that can empower a wider range of groups and individuals.

The impact of digital technologies on work and the economy, meanwhile, is influenced by trends that pre-date the digital revolution: the relationship between capital and labour, the unequal distribution of financial wealth, and the disruptive potential of technology have long influenced patterns of economic growth and wellbeing. For more than a decade, economic and technology developments have contributed to the spread of internet-enabled devices, globalisation of supply chains, and the growth of online platforms, with labour patterns changing as a result. It is clear that digital technologies will influence work, but the nature of these changes is less clear.

There are many plausible paths along which digital technologies could progress, and researchers, policymakers, and publics all play a role in shaping how they affect human lives and experiences. Dialogues between these communities will be important in shaping the values embedded in technology development, and the extent to which all in society are able to benefit from advances in digital technologies.

The nature of digital transformation

While it seems clear that digital technologies will transform human lives and experiences across many spheres of life, the full implications of these transformations are not yet well-understood. Do digital tools provide a temporary enhancement to human abilities? Or are there longer-term changes to human capabilities that have not yet been uncovered?

The ability to offload cognitive tasks to technological tools – extending the capacity of the mind – is a hallmark of human intelligence. As individuals and technologies change, new capabilities emerge, and some capabilities might be lost. Experience of previous waves of emerging technologies seems to show that it is not the nature of the tools themselves that change human capabilities, but the ways in which these tools are put to use.

The potential for digital technology to foster new forms of over-dependence or over-reliance is an important emerging ethical concern, with implications for both individuals and communities. Part of the challenge today lies in identifying ways in which technology could empower their users and support their autonomy, creating compelling and imaginative visions for the future in which digital technologies could be deployed in the service of society. There is an opportunity to redefine how individuals and digital technology interact, optimising these systems to empower their users and support beneficial social outcomes. To create this future, technologies need to be designed for desirable outcomes, with these outcomes defined through dialogue with diverse stakeholders and developed through collaborations across research disciplines and with publics.

Insights from computer science, economics, sociology, behavioural sciences, human-computer interactions, and more, can help better understand the types of disruption that can arise as digital technologies are deployed in different areas of life. These can help address questions such as:

- What factors are most important in making technology accessible to a wide range of users?
- What spaces can support collaborative technology development?
- How does technology affect human cognition, and how can technologies support users to strengthen their metacognition and empower their users?
- What architectures, infrastructures, or supporting technologies are needed to avoid further concentration of the web?
- What forms of information provenance or management are necessary to help users distinguish between authentic and synthetic information sources? For example, how can viewers more easily identify fake video, images, or audio?
- What influence do filter bubbles have on individuals and communities? What are the wider implications for society?
- What are the environmental impacts of digital technologies, and how can research address this?

The relationship between individuals and technology

Perceptions about the role of technology in society – and in day-to-day life – and the risks and benefits it brings shape how people relate to it. As digital technologies become more pervasive, these conceptualisations are evolving, raising questions such as:

- Should digital technologies be a form of civic architecture? To what extent are data and the tools to use it part of public infrastructure? What does this require in terms of technological capabilities, the values embedded in technology design, and access to technology?
- What are the boundaries of augmentation, and at what point does technology become an extension of an individual, rather than an outside augmenting force?
- Are the natures of the potential benefits and harms different to what technologies have brought in the past?

As digital technologies advance and their role in daily life evolves, new understandings of their harms and benefits will be needed, and further dialogues about the nature of the transformations to human lives, capabilities, and experiences that they may bring.

Digital technologies and human transformations

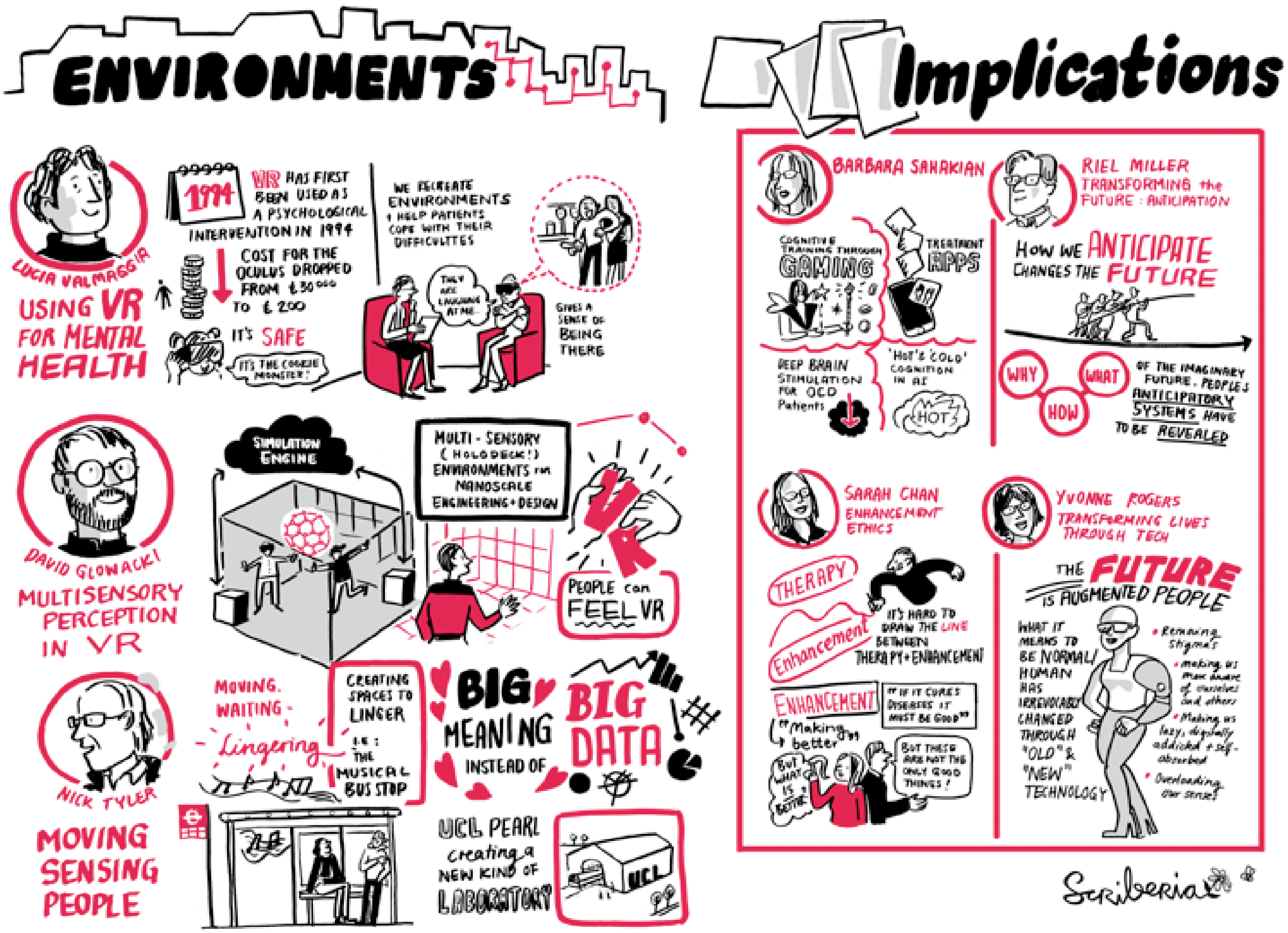
Data and digital technologies are already transforming the way individuals live, work and learn. As research advances and new applications emerge, further transformations will follow.

These technologies and applications can make a great contribution to human flourishing. Ensuring the best possible environment for the safe and rapid deployment of these technologies will be essential for enhancing the UK's economic growth, wellbeing, and security.

They also, however, present significant choices and dilemmas: as technologies advance, researchers, policymakers, and publics will need to consider how to balance the distribution of benefits and risks for individuals, communities, and society. Careful stewardship will be necessary to help ensure that the benefits of digital technologies are shared across society.

Graphic representations of ‘Digital Technologies and Human Transformation’ workshops

MOVING AND SENSING

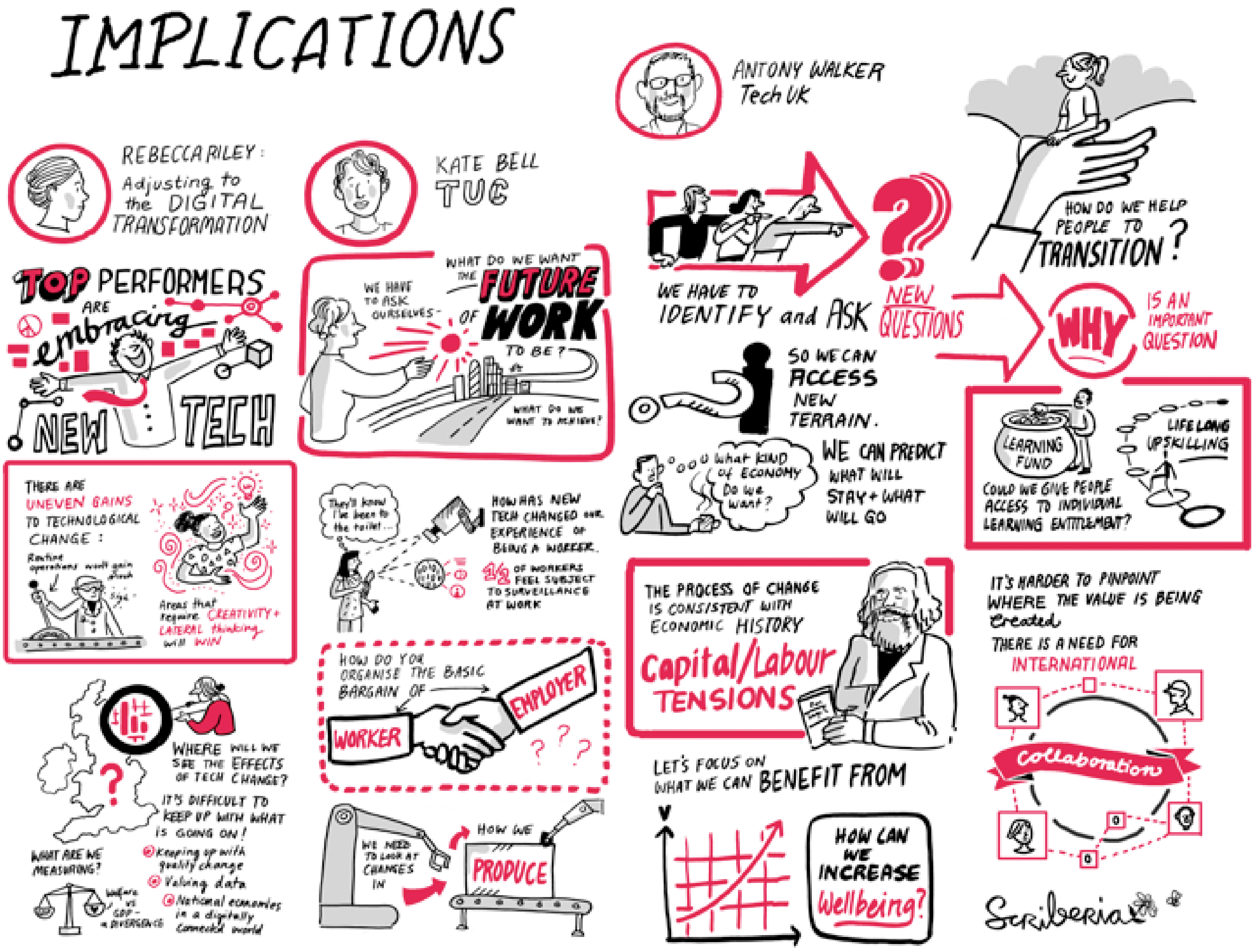


ENVIRONMENTS
Implications
LUCIA VALMAGGIA
USING VR FOR MENTAL HEALTH
1994
VR HAS FIRST BEEN USED AS A PSYCHOLOGICAL INTERVENTION IN 1994
COST FOR THE OCULUS DROPPED FROM £30 000 TO £200
IT'S SAFE
WE RECREATE ENVIRONMENTS + HELP PATIENTS COPE WITH THEIR DIFFICULTIES
GIVES A SENSE OF BEING THERE
DAVID GLOWACKI
MULTISENSORY PERCEPTION IN VR
SIMULATION ENGINE
MULTI-SENSORY (HOLODECK!) ENVIRONMENTS FOR NANOSCALE ENGINEERING + DESIGN
PEOPLE CAN FEEL VR
NICK TYLER
MOVING SENSING PEOPLE
MOVING, WAITING - Lingering
CREATING SPACES TO LINGER
I.E.: THE MUSICAL BUS STOP
BIG MEANING INSTEAD OF BIG DATA
UCL PEARL creating a NEW KIND OF LABORATORY
UCL
BARBARA SAHAKIAN
COGNITIVE TRAINING THROUGH GAMING
TREATMENT APPS
DEEP BRAIN STIMULATION FOR OCD Patients
'HOT' & 'COLD' COGNITION IN AI
HOT
RIEL MILLER
TRANSFORMING the FUTURE : ANTICIPATION
HOW WE ANTICIPATE CHANGES THE FUTURE
WHY
WHAT
HOW
OF THE IMAGINARY FUTURE, PEOPLE'S ANTICIPATORY SYSTEMS HAVE TO BE REVEALED
SARAH CHAN
ENHANCEMENT ETHICS
THERAPY
Enhancement
IT'S HARD TO DRAW THE LINE BETWEEN THERAPY + ENHANCEMENT
ENHANCEMENT
"Making better"
"IF IT CURES DISEASES IT MUST BE GOOD"
BUT WHAT IS BETTER?
BUT THESE ARE NOT THE ONLY GOOD THINGS!
YVONNE ROGERS
TRANSFORMING LIVES THROUGH TECH
THE FUTURE IS AUGMENTED PEOPLE
WHAT IT MEANS TO BE NORMAL/HUMAN HAS IRREVOCABLY CHANGED THROUGH "OLD" & "NEW" TECHNOLOGY
Remaining stigmas
making us more aware of ourselves and others
Making us lazy, digitally addicted + self-absorbed
Overloading our senses
Scriberia


HUMAN TRANSFORMATION
REMEMBERING
& LEARNING
PHILIP BOND
Learning IS CRITICAL TO OUR FUTURE SUCCESS
17% OF UK ADULTS ARE FUNCTIONALLY ILLITERATE
24% ARE FUNCTIONALLY INNUMERATE
ABIGAIL SELLEN
A.I. & MACHINE LEARNING
will have an impact on work as a whole...
THE ROYAL SOCIETY AIMS TO PROMOTE SCIENCE & TECHNOLOGY THAT WILL BENEFIT MANKIND
REMEMBERING
HUGO SPIERS
WHAT'S THE EFFECT OF TECHNOLOGY ON HUMAN MEMORY?
WE NEED TO EMPOWER OUR NATURAL MINDS
TECHNOLOGY SHOULD BE MADE TO BE MORE HUMAN
NIR GROSSMAN
TEMPORAL INTEFERENCE
CAN STIMULATE ACTIVITY IN DEEP-BRAIN STRUCTURES –
NON-INVASIVE BRAIN STIMULATION
CAN HELP PROCESS OF LEARNING & REMEMBERING
SHAPING MEMORY THROUGH DIGITAL TECHNOLOGY
MICHAEL ANDERSON
KARINA VOLD
TECHNOLOGY IS CHANGING THE NATURE OF COGNITION
THE INTERNET AND SOCIAL MEDIA ARE AMPLIFIERS OF ADAPTIVE FORGETTING
NOT THE INFORMATION ITSELF...
OUR TOOLS ARE JUST AS ESSENTIAL TO OUR COGNITION AS SYNAPSES IN OUR BRAINS
MEMORIES
EXTRACT WHAT WE WANT
SUPPRESS WHAT WE DON'T
Scriberia

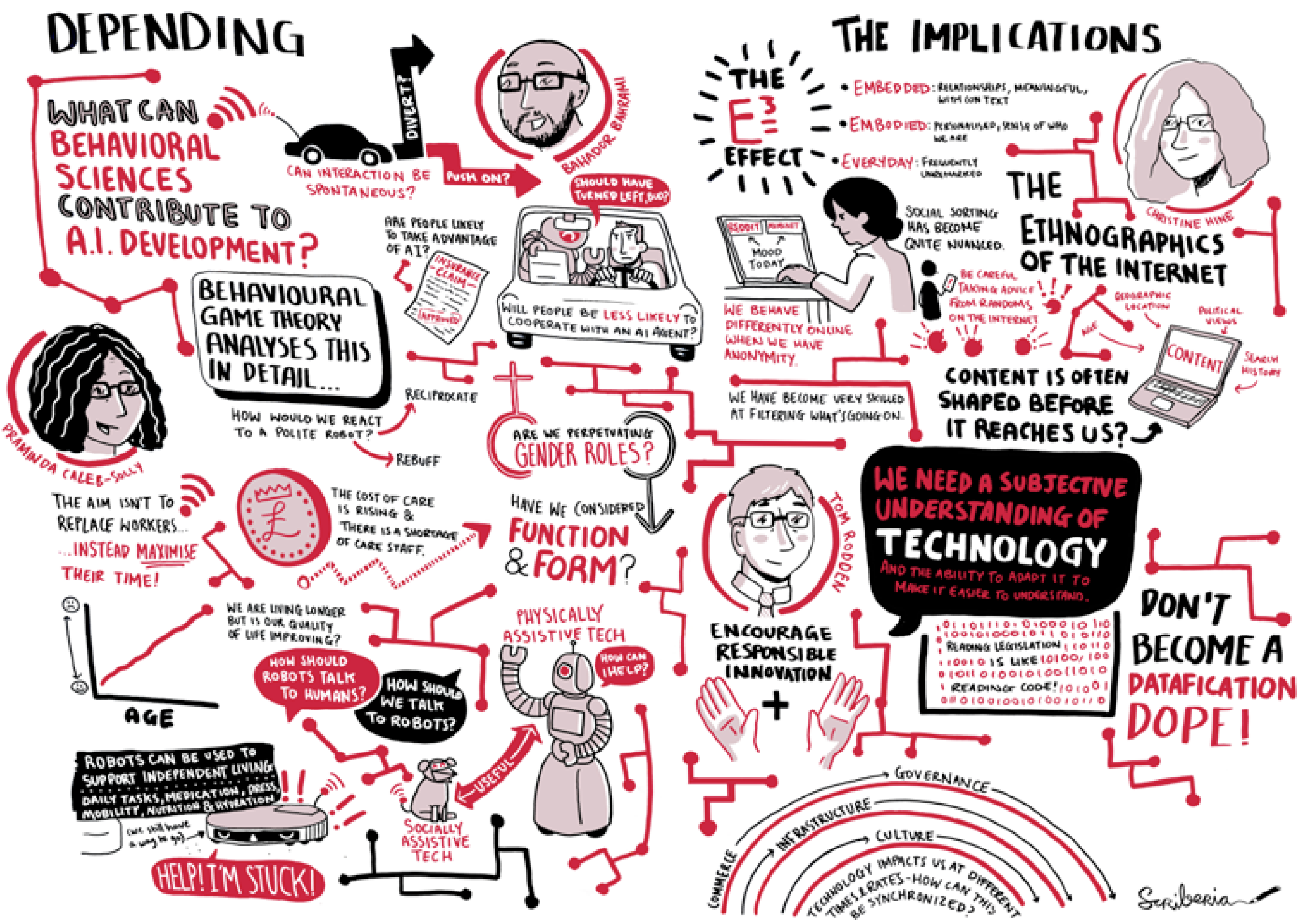
LEARNING
DIANA LAURILLARD
FEEDBACK
VIRTUAL LEARNING ENVIRONMENTS
SHARING
ENABLE SHARING AND PEER REVIEW...
PLAYER #1
PLAYER #2
IS OUR TECHNOLOGY EMPOWERING US, OR IS IT DISEMPOWERING?
HOW DO WE DEFINE WHAT EMPOWERMENT ACTUALLY IS?
WHAT ARE THE INCENTIVES
WHAT MOTIVATES PEOPLE TO ENGAGE
SYSTEMS ARE NOT TRAINING US TO NOT NEED THEM
A.I. CAN OFFER FEEDBACK FROM LEARNER TO TEACHER
PROMOTE A MORE SCIENTIFIC UNDERSTANDING OF LEARNING AMONGST EDUCATORS...
TECH CAN ENCOURAGE LEARNING THROUGH GAMES AND GIVING IMMEDIATE FEEDBACK
PROF. HOWARD JONES
VALUES
ETHICS
FEEDBACK
IS ONE OF THE MOST IMPORTANT WAYS YOU CAN IMPROVE LEARNING
EDUCATION IS THE ONLY THING THAT WILL ALLOW US TO TACKLE THE FUTURE!!!
WE NEED TO IDENTIFY DIFFERENT SEGMENTS OF SOCIETY AND HOW TECH CAN HELP THEM
AGE
STATUS
FOCUS ON THE TEACHERS
NOT THE MACHINES
MAREN DEEPWELL
INCREASE IN HIGHER EDUCATION
ADAPTION OF TECH TOOLS TO EVALUATE LEARNING
WE NEED TO LOOK THROUGH A HUMAN PERSPECTIVE
WE NEED MORE INFORMATION ABOUT TECHNOLOGY RATHER THAN BLINDLY CONSUMING
PEOPLE ARE NOT BEING CHALLENGED WITH CRITICAL THINKING
TECHNOLOGY SHOULD EMPOWER EDUCATORS, NOT OPPRESS THEM
WE CAN UTILISE TOOLS LIKE MASSIVE OPEN ONLINE COLLABORATIONS FOR LEARNING &DEVELOPMENT
Scriberia

HUMAN TRANSFORMATION: WORKING + EARNING
IS THIS EMERGING DISRUPTION DIFFERENT FROM WHAT HAS COME BEFORE?
YES IT IS FASTER + DEEPER
A FLUX OF DATA
BROUGHT A.I TO THEIR OWN
AI IDENTIFIES PATTERNS AND CONNECTIONS
WORK, WORKING LIFE and the ECONOMY
IFOW
ANNA THOMAS
- INSTITUTE FOR THE FUTURE OF WORK
WHAT WE SHOULD FOCUS ON?
JOB CREATION
NEW JOBS
AUGMENTATION
DISTRIBUTION
TRANSITION
OLD TO NEW WORK
BUMPY ROAD
URSULA HUWS
PROFESSOR OF LABOUR AND GLOBALISATION
PLATFORMISATION: A CONVERGENCE OF TRENDS
INFORMAL ECONOMY
THE MODERN WORKER PATCHES TOGETHER INCOME FROM DIFFERENT SOURCES
THE FRACTURING OF THE OCCUPATIONAL IDENTITY
DIPPING IN & OUT OF IDENTITIES
WORK FOUND VIA ONLINE PLATFORMS IS OFTEN OCCASIONAL AND SUPPLEMENTS OTHER FORMS OF WORK
THE GROOMING OF LOGGED LABOUR
ECONOMIC GROWTH IS NOT EVENLY DISTRIBUTED
ARE DEVELOPMENTS DRIVEN BY POLICY OR BY CHANCE?
BUT IT ENABLES MICRO BUSINESSES TO HAVE A GO!
WORKERS ARE DRIVEN/CONTROLLED BY CUSTOMER RATINGS



IMPLICATIONS
REBECCA RILEY: Adjusting to the DIGITAL TRANSFORMATION
TOP PERFORMERS ARE embracing NEW TECH
THERE ARE UNEVEN GAINS TO TECHNOLOGICAL CHANGE:
Routine operations won't gain much
Areas that require CREATIVITY + LATERAL thinking will WIN
WHERE WILL WE SEE THE EFFECTS OF TECH CHANGE?
IT'S DIFFICULT TO KEEP UP WITH WHAT IS GOING ON!
WHAT ARE WE MEASURING?
Keeping up with quality change
Valuing data
National economies in a digitally connected world
Welfare vs GDP - a DIVERGENCE
KATE BELL TUC
WE HAVE TO ASK OURSELVES -
WHAT DO WE WANT THE FUTURE OF WORK TO BE?
WHAT DO WE WANT TO ACHIEVE?
They'll know I've been to the toilet...
HOW HAS NEW TECH CHANGED OUR EXPERIENCE OF BEING A WORKER.
1/2 OF WORKERS FEEL SUBJECT TO SURVEILLANCE AT WORK
HOW DO YOU ORGANISE THE BASIC BARGAIN OF
WORKER
EMPLOYER
WE NEED TO LOOK AT CHANGES IN
HOW WE PRODUCE
ANTONY WALKER Tech UK
WE HAVE TO IDENTIFY and ASK NEW QUESTIONS
WHY IS AN IMPORTANT QUESTION
SO WE CAN ACCESS NEW TERRAIN.
What kind of ECONOMY Do we want?
WE CAN PREDICT WHAT WILL STAY + WHAT WILL GO
HOW DO WE HELP PEOPLE TO TRANSITION?
LEARNING FUND
LIFE LONG UPSKILLING
COULD WE GIVE PEOPLE ACCESS TO INDIVIDUAL LEARNING ENTITLEMENT?
THE PROCESS OF CHANGE IS CONSISTENT WITH ECONOMIC HISTORY
Capital/Labour TENSIONS
LET'S FOCUS ON WHAT WE CAN BENEFIT FROM
HOW CAN WE INCREASE Wellbeing?
IT'S HARDER TO PINPOINT WHERE THE VALUE IS BEING Created
THERE IS A NEED FOR INTERNATIONAL
Collaboration
Scriberia


HUMAN TRANSFORMATION
CONNECTING
& DEPENDING
ARE WE ON THE VERGE OF A NEW AGE OF ENLIGHTENMENT?
RACHEL COLDICUTT
HAVE WE LOST POTENTIAL FOR THE FUTURE?
10 YEARS OF ENTHUSIASM & NAIVETY SURROUNDING TECHNOLOGY
IT ISN'T THE LAST MILE, IT'S THE FINAL 10CM
SEEK WAYS TO STRENGTHEN SOCIETY
AND IT'S UNDERLYING INFRASTRUCTURE
HANNAH KNOX
THE CONNECTION EVER CHANGES
THE DESTINATION
LIKE ELECTRICITY DATA CAN BE CREATED IN ONE PLACE & INSTANTLY USED IN ANOTHER!
IT CREATES... INFINATE POSSIBILITIES
WE CAN USE GAMES TO TEST LEVELS OF COMMITMENT.
"HOW MIGHT DATA & DIGITAL TECH SHAPE HUMAN LIVES & EXPERIENCES?"
PROF. NIGEL SHADBOLT
WE MUST MOVE BEYOND THE NETWORK
HOW DO WE CONNECT AS FIGURES IN PROCESS SOCIOLOGY?
ANDREAS HEPP
JOHN MICHAEL
HOW DO PEOPLE WITH BPD ENGAGE WITH SOCIAL MEDIA?
HIGHER LEVELS
USAGE
BLOCK|UNFRIEND
REGRET POSTS
GOODS
FOOD
SEARCH
MAPS
BANKING
A.I. TERM WAS COINED IN 1956
SOCIAL MEDIA: ARE INDIVIDUALS BEING CONSISTENTLY PRESENTED WITH A NARROW VERSION OF THE WORLD, CONSISTENT WITH THEIR CURRENT PERSPECTIVE?
FRAMES OF RELEVANCE CHANGE
& BECOME ENTANGLED WITH MEDIA
GOOD
BAD
CREATE APPS ...TO HELP THERAPISTS ANALYSE & MONITER SOCIAL MEDIA USAGE


DEPENDING
WHAT CAN BEHAVIORAL SCIENCES CONTRIBUTE TO A.I. DEVELOPMENT?
CAN INTERACTION BE SPONTANEOUS?
DIVERT?
PUSH ON?
BAHADOR BAHRAMI
SHOULD HAVE TURNED LEFT, DUD?
ARE PEOPLE LIKELY TO TAKE ADVANTAGE OF AI?
INSURANCE CLAIM
APPROVED
WILL PEOPLE BE LESS LIKELY TO COOPERATE WITH AN AI AGENT?
BEHAVIOURAL GAME THEORY ANALYSES THIS IN DETAIL...
HOW WOULD WE REACT TO A POLITE ROBOT?
RECIPROCATE
REBUFF
PRAMINDA CALEB-SOLLY
ARE WE PERPETUATING GENDER ROLES?
THE AIM ISN'T TO REPLACE WORKERS...
...INSTEAD MAXIMISE THEIR TIME!
THE COST OF CARE IS RISING & THERE IS A SHORTAGE OF CARE STAFF.
HAVE WE CONSIDERED FUNCTION & FORM?
WE ARE LIVING LONGER BUT IS OUR QUALITY OF LIFE IMPROVING?
AGE
HOW SHOULD ROBOTS TALK TO HUMANS?
HOW SHOULD WE TALK TO ROBOTS?
PHYSICALLY ASSISTIVE TECH
HOW CAN I HELP?
USEFUL
SOCIALLY ASSISTIVE TECH
ROBOTS CAN BE USED TO SUPPORT INDEPENDENT LIVING DAILY TASKS, MEDICATION, DRESS, MOBILITY, NUTRITION & HYDRATION
HELP! I'M STUCK!
THE IMPLICATIONS
THE E3 EFFECT
• EMBEDDED: RELATIONSHIPS, MEANINGFUL, WITH CONTEXT
• EMBODIED: PERSONALISED, SENSE OF WHO WE ARE
• EVERYDAY: FREQUENTLY UNREMARKED
REDDIT
MUMSNET
MOOD TODAY
SOCIAL SORTING HAS BECOME QUITE NUANCED.
BE CAREFUL TAKING ADVICE FROM RANDOMS ON THE INTERNET
WE BEHAVE DIFFERENTLY ONLINE WHEN WE HAVE ANONYMITY.
WE HAVE BECOME VERY SKILLED AT FILTERING WHAT'S GOING ON.
THE ETHNOGRAPHICS OF THE INTERNET
CHRISTINE HINE
GEOGRAPHIC LOCATION
POLITICAL VIEWS
AGE
CONTENT
SEARCH HISTORY
CONTENT IS OFTEN SHAPED BEFORE IT REACHES US?
TOM RODDEN
WE NEED A SUBJECTIVE UNDERSTANDING OF TECHNOLOGY
AND THE ABILITY TO ADAPT IT TO MAKE IT EASIER TO UNDERSTAND.
READING LEGISLATION IS LIKE READING CODE!
ENCOURAGE RESPONSIBLE INNOVATION
DON'T BECOME A DATAFICATION DOPE!
GOVERNANCE
INFRASTRUCTURE
CULTURE
COMMERCE
TECHNOLOGY IMPACTS US AT DIFFERENT TIMES & RATES - HOW CAN THIS BE SYNCHRONIZED?
Scriberia

Annex 1: Polling results reported in this report

The statistics quoted in this summary are drawn from polling carried out by YouGov on behalf of the Royal Society. Total sample size was 2034 adults. Fieldwork was undertaken between 29 March – 1 April. The survey was carried out online. The figures have been weighted and are representative of all GB adults (aged 18+). The questions asked in this polling were:

QUESTION 1

Before taking this survey, how much, if anything, did you feel you knew about each of the following technologies? (Please select the option that best applies on each row)

Virtual reality (VR) (i.e. a computer-generated simulation of an environment, story or experience that can be interacted in a seemingly real way, by a person wearing special goggles or headset)

- ☐ I had heard of it, and have a good understanding of it
- ☐ I had heard of it, and understand it a little
- ☐ I had heard of it, but only by name
- ☐ I had not heard of it

Augmented reality (AR) (i.e. a technology that layers a computer-generated image on a user's view of the real world, e.g. on their phone or tablet)

- ☐ I had heard of it, and have a good understanding of it
- ☐ I had heard of it, and understand it a little
- ☐ I had heard of it, but only by name
- ☐ I had not heard of it

Artificial intelligence (AI) (i.e. intelligence demonstrated by machines, or the ability for computer systems to carry out tasks that would require some level or type of intelligence in humans

- ☐ I had heard of it, and have a good understanding of it
- ☐ I had heard of it, and understand it a little
- ☐ I had heard of it, but only by name
- ☐ I had not heard of it

Blockchain (i.e. a digital ledger in which transactions made in bitcoin or another cryptocurrency are recorded chronologically and publicly)

- ☐ I had heard of it, and have a good understanding of it
- ☐ I had heard of it, and understand it a little
- ☐ I had heard of it, but only by name
- ☐ I had not heard of it

Cloud computing (i.e. a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer)

- ☐ I had heard of it, and have a good understanding of it
- ☐ I had heard of it, and understand it a little
- ☐ I had heard of it, but only by name
- ☐ I had not heard of it

Neural interfaces/ brain-computer interfaces (i.e. technology which allows the brain to control real-world applications directly)

- ☐ I had heard of it, and have a good understanding of it
- ☐ I had heard of it, and understand it a little
- ☐ I had heard of it, but only by name
- ☐ I had not heard of it

Co-bots (i.e. collaborative robot, a robot that is capable of learning multiple tasks so it can assist human beings)

- ☐ I had heard of it, and have a good understanding of it
- ☐ I had heard of it, and understand it a little
- ☐ I had heard of it, but only by name
- ☐ I had not heard of it

Social media platforms (e.g. Twitter, Facebook, Instagram, Snapchat etc.)

- ☐ I had heard of it, and have a good understanding of it
- ☐ I had heard of it, and understand it a little
- ☐ I had heard of it, but only by name
- ☐ I had not heard of it

Internet of things (IoT) (i.e. devices that are connected over the internet so they can 'talk' to us, applications, and each other. For example, a smart fridge that could tell you it was out of milk by texting you if its internal cameras saw there was none left)

- ☐ I had heard of it, and have a good understanding of it
- ☐ I had heard of it, and understand it a little
- ☐ I had heard of it, but only by name
- ☐ I had not heard of it

QUESTION 2

For the following question, by 'digital technologies', we mean any digital or computer device which have practical uses in everyday life.

Overall, how useful, if at all, do you think digital technologies could be in each of the following industries over the next 10 years (i.e. between now 2029)? (Please select the option that best applies on each row)

Healthcare

- ☐ Very useful
- ☐ Fairly useful
- ☐ Not very useful
- ☐ Not at all useful
- ☐ Don't know

Education

- ☐ Very useful
- ☐ Fairly useful
- ☐ Not very useful
- ☐ Not at all useful
- ☐ Don't know

Transport

- ☐ Very useful
- ☐ Fairly useful
- ☐ Not very useful
- ☐ Not at all useful
- ☐ Don't know

QUESTION 3

Please read the text below carefully before answering the question that follows.

With digital technology being used or proposed in more areas of everyday life, there are discussions about the risks and benefits of its use.

Some benefits often discussed are that processes are becoming quicker and more efficient, as well as there being new and innovative ways of approaching things and in some instances proving to be more effective.

The risks often discussed are processes being distanced from humans, with computers taking a greater role in traditional human roles or tasks. Privacy might also be an issue, with people having to give out personal information or data to be able to use some technology.

The following question will present 6 ways in which digital technology is being used in everyday life. For each one, please consider the risks and benefits you think might be associated before answering the question.

Which ONE of the following comes closest to your views regarding the benefits and risks for each of the following uses of digital technology? (Please select the option that best applies on each row)

Digital games for school education

- ☐ The benefits outweigh the risks
- ☐ The benefits and risks are equal
- ☐ The risks outweigh the benefits
- ☐ Don't know

Prosthetics that give people the sense of touch (i.e. prosthetic hands)

- ☐ The benefits outweigh the risks
- ☐ The benefits and risks are equal
- ☐ The risks outweigh the benefits
- ☐ Don't know

New ways to access to transport services (e.g. through Uber, CityMapper etc.)

- ☐ The benefits outweigh the risks
- ☐ The benefits and risks are equal
- ☐ The risks outweigh the benefits
- ☐ Don't know

Social media as a source of news (e.g. through posts from people you follow, posts from news organisations etc.)

- ☐ The benefits outweigh the risks
- ☐ The benefits and risks are equal
- ☐ The risks outweigh the benefits
- ☐ Don't know

Technology that helps people with dementia and memory loss (e.g. communication aids, home care robots, reminder messages etc.)

- ☐ The benefits outweigh the risks
- ☐ The benefits and risks are equal
- ☐ The risks outweigh the benefits
- ☐ Don't know

Digital tools for people management and work allocation (e.g. apps which delegate jobs within teams or ways of finding work, for example TaskRabbit.)

- ☐ The benefits outweigh the risks
- ☐ The benefits and risks are equal
- ☐ The risks outweigh the benefits
- ☐ Don't know

Annex 2: Royal Society Steering Group

Steering group

The members of the Steering Group involved in this report are listed below. Members acted in an individual and not a representative capacity. Members contributed to the project on the basis of their own expertise and good judgement.

Steering group
Professor Geoffrey Boulton OBE FRS FRSE, Regius Professor of Geology Emeritus, University of Edinburgh
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Professor Uta Frith DBE FRS FBA FMedSci, Emeritus Professor of Cognitive Development, University College London
Professor Abigail Sellen FREng, Deputy Director, Microsoft Research Cambridge
Professor Sir Nigel Shadbolt FRS FREng, Principal, Jesus College, and Professorial Research Fellow in the Department of Computer Science, University of Oxford

Royal Society staff

Royal Society staff
Dr Natasha McCarthy, Head of Policy, Data
Jessica Montgomery, Senior Policy Adviser
Connie Burdge, Policy Adviser

Workshop participants

The Digital Technologies and Human Transformation workshop series ran in February and March 2019, and was conducted under the Chatham House rule. The Society would like to express its thanks to all those who presented and participated at these workshops.

The Royal Society is a self-governing Fellowship of many of the world's most distinguished scientists drawn from all areas of science, engineering, and medicine. The Society's fundamental purpose, as it has been since its foundation in 1660, is to recognise, promote, and support excellence in science and to encourage the development and use of science for the benefit of humanity.

The Society's strategic priorities emphasise its commitment to the highest quality science, to curiosity-driven research, and to the development and use of science for the benefit of society. These priorities are:

- Promoting excellence in science
- Supporting international collaboration
- Demonstrating the importance of science to everyone

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