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Data Analytics and Artificial Intelligence for Post-Covid Recovery

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Abstract

Aim/Purpose: The aim of this paper is to identify some of the major impacts of Covid -19 through the lens of the Digital Society, which encompasses the domains of health, education, work and the home.

Design/Methodology: The methodology applied is that of observation, collating primary data on observable impacts for each domain which are catalogued and appraised in terms of their overall positive and negative characteristics, extrapolating the lessons to be learned from them. In addition, secondary research is carried out, reporting the findings of an international virtual roundtable on how Artificial Intelligence (AI) is presently being used in helping fight against Covid-19.

Findings: Increasingly likely trends in the post Covid-19 digital society, are identified as those of e-health, e-teaching, e-working and Smart Homes.

Conclusion: The application of data analytics and AI for post-Covid recovery are considered, and whether their leverage can provide a "Big Data Smart Future". Conclusions drawn include suggestions for real world applications, not just for domains observed, but the virus itself.

Limitation: Observations made are limited to those solely from a United Kingdom (UK) perspective, so it may not be possible to generalise the observational findings beyond the UK.

Implication: Unless the Digital Divide and the consequential Digital Exclusion are addressed, the drive towards the e-society could lead to a two-tier society; the digitally included and the digitally excluded.

Originality: The novelty of this research lies in the attempted synthesis of information in a rapidly changing Covid-19 world, from the view of the impacts of the pandemic on the digital society.

Keywords: data analytics, artificial intelligence, Covid-19, digital society.

Introduction

The impact of corona viruses, specifically Covid-19, on the world has been massive; devastating on a very human level with the loss of lives and livelihoods, it has also been monumental for the Digital Society, which encompasses the domains of health, education, work and the home. The aim of this paper is to identify some of the major impacts of Covid-19 through the lens of the digital society. The methodology applied is that of observation, with observations made limited to those solely from a United

Kingdom (UK) perspective. Observable impacts for each domain are catalogued and appraised in terms of their overall positive and negative characteristics, extrapolating the lessons to be learned from them. In addition, the findings of an international virtual roundtable on how Artificial Intelligence (AI) is presently being used in helping fight against Covid-19 are discussed. Finally, conclusions are drawn on the application of data analytics and AI for post-Covid recovery and whether their leverage can provide a "Big Data Smart Future", with suggestions for real world applications, not just for domains observed, but the virus itself.

Literature Review

Big Data, AI, Analytics and the Digital Society

Big Data, Artificial Intelligence (AI) and Analytics are now integral parts of the Digital Society. Big data are commonly described as massive heterogeneous data (unstructured, semi-structured and structured) sets, not solvable (manageable data analysis) using conventional data models, such as relational databases. McKinsey Global Institute (Neaga and Hao, 2013) suggests models for big data characteristics based on the source, with the main key characteristics being those of Volume, Velocity, Variety and Value, plus the characteristic of Veracity. Additional characteristics are those of Variability and Complexity (SAS, 2012).

Big data originates from multiple, often ad hoc sources, and may be a bi-product of other things; data stored in conventional databases, in public and private clouds, gleaned through social media interactions, or sensor data generated as a result of the Internet of Things (IoT). The Internet of Things has been described as "the idea that any item can be embedded with software, sensors and connectivity to exchange data with one another or a central hub" (Palmer, 2015a, p. 14). The IoT has contributed much to the increase of big data, for example, Hive (BritishGas, 2015), a Smart Meter which permits the remote control of heating in the home via the internet. Embedded "things" lead to the generation and usually the recording of significant amounts of data (often from sensors) that are amenable to analytics.

Massive amounts of data require storage. Cloud Computing both adds to, as well as provides a solution for, big data characteristics such as velocity, variety, and (particularly) volume. "The Cloud Computing Model, more commonly referred to simply as Cloud Computing or 'The Cloud', provides access to 'clouds' of shared computing resources, such as storage and applications, over a network, usually the Internet" (Graham, 2013, p. 7). Clouds are commonly classified into Public, Private, Hybrid and Community Clouds (Chang and Wills, 2013, pp. 233-234). Cloud offers a solution for the big data characteristic of volume by providing storage, often in the form of the Hybrid Cloud (a combination of public and private cloud, with the necessary interoperability between the two), allowing organisations and individuals flexibility, with access to variable amounts of data storage, as and when required (for analytics, for example), through distributed computing. The existence of data in the Cloud, further adds to the total volume of data per se, e.g., Microsoft's OneDrive. Analytics can exploit data held in the cloud and cloud storage, adding public cloud data to private cloud data (Gordon, 2013). Many technologies and data sources can be combined to be more pervasive and intrusive, e.g., CCTV (Closed Circuit Television) and GPS (Global Positioning Satellite). It is the transformation of data to information and knowledge through analytics and the fusion of data where issues of ethics become prevalent.

Artificial Intelligence is an umbrella term for a multi-disciplinary approach to making things smarter (intelligent); Interaction Design (formerly known as Human-Computer Interaction (HCI) and originally known as the Man-Machine Interface (MMI)), Natural Language Processing, Knowledge-Based Systems, Robotics, Machine Learning (ML). ML is often used wrongly as a synonym for AI. Arguably, the main problems that AI addresses are viewed to be those of Knowledge Representation

and Search, or Search and more Search. Practical applications of AI include search engines, speech recognition, industrial robots, Computer-Aided Learning (CAL), and interfaces such as Alexa.

The original term CAL, rather than e-Learning is deliberately listed because it is more accurate and it aimed to model human learning. Most e-Learning systems are more web-enabled database than knowledge-based. Graham (2014) depicted the temporal transformations of data to information, and then from information to knowledge, for the purpose of learning (competence achievement). Human learning appears to involve the taking in of raw data with a specific goal, organising the data so that it has meaning, and analysing this information (compare and contrast, applying elements of Bloom's (1956) taxonomy) to a more structured form, namely knowledge. Machine Learning aims to emulate human learning through deep learning, Artificial Neural Networks (ANNs), and the realisation of meta-knowledge. Such knowledge or expertise is the basis of knowledge-based systems and heuristic knowledge models.

Analytics refers to the analysis of data to identify patterns or anomalies, and so to provide descriptions, diagnoses, prescriptions, or to make predictions, using techniques such as machine learning, e.g., ANNs, regression, etc. Analytics can be described by their use; Descriptive, Diagnostic, Prescriptive or Predictive, or categorised by their data format and origin; Text analytics, Speech analytics, Video/image analytics and Combined analytics (Marr, 2015, pp. 105-149). Value is obtained by the application of analytics to big data, effectively reducing the state space, "converting" the data into information (contemporary), or knowledge (future predictive) by making it domain specific. Analytic techniques may lead to the application of established models, such as mathematical (possibly statistical) models or decision trees (which may be part of a knowledge-based model), post processing (filtering, etc.). Analytics are essentially the application of a set of processes (algorithms) and technologies (systems), plus people (skills), to make sense of data (Heger, 2014). For example, ML algorithms are a process of learning a model of the world to predict future outcomes. The type of analytics used is based on the outcome, e.g., classification or clustering (if the outcome is discrete) for a numerical regression problem. Not all big data is stored, as it is not normally possible or desirable.

The data driven approach of big data analytics has led to the epistemology of knowledge itself being challenged, from theory-based hypothesis and experiment driven, to data synthesis and mining with two perspectives on data; data as research objects and data as scientific methodology. Pale et. al. (Cate, 2016) argue that big data is a new approach to scientific inquiry in which data collection and mining alone (without theories) is a legitimate form of scientific enquiry.

Current applications of analytics include medical applications, such as the Human Genome Project, with Genomics becoming increasingly important (Palmer, 2015). One domain source of big data has apparently been utilised successfully for another unrelated domain; the use of an earthquake aftershocks mathematical prediction model applied to crime prediction in Los Angeles (MIT, 2013). This could be the possible identification of a natural generic pattern akin to fractals, for seemingly disparate phenomena, or a unique feature of crime data models, questions requiring further cases and research.

There can be unforeseen consequences of analytics: A scenario (Graham, 2017) was that, in the future, genetic data would be collected at birth and past analytics could enable the determination of all inherited medical conditions, intellect and other attributes, and even compute the date of death of an individual. This future was proven to be not so far-fetched or simple paranoia, after a proposal by the UK Health Minister in 2017 suggesting that all newborns be DNA tested (Smith, 2017); the justification was claimed to be for improved health care (genomics). Such altruism could be viewed with suspicion after the (Google) DeepMind fiasco, where private, confidential patient records were used for the development of commercial software

(Streams). It should be remembered that, rather conveniently, newborns are not capable of giving informed consent and their parents (and society) may not conceive any future data harm. Any database containing the nation's DNA data would be feared to be an infringement of privacy.

The Digital Society describes the digitisation, by the use of technology, of society in all its components; such as in the home, in the workplace, in the community, etc. The digital society is ubiquitous; however, for those people where the necessary technology required to support it is absent, a Digital Divide is created. Probably the greatest manifestation of the digital divide is "being on-line", i.e., having access to the digital resources that exists through the internet. In general, the digital divide tends to be most acute for older age groups and those in relative poverty, without the financial means to afford either the technologies (laptops, smart phones, etc.), or the infrastructure (specifically broadband); this lack of access is known as Digital Exclusion.

Covid-19

Covid-19 is a new corona virus, known to be a zoonotic disease; the deadly microbes of the disease jumped the species barrier from animals into humans, before human-to-human transmission. There is some debate surrounding its origins, whether the virus came from a Wet Market or escaped from a laboratory in Wuhan in China. Covid-19 is highly infectious, with serious or deadly consequences largely for human hosts over eighty years of age. A peculiarity of Covid-19 is that, unlike other corona viruses such as influenza, the very young appear mostly impervious to the virus and are often asymptomatic if infected. The latter attribute is a major problem as it can be spread unknowingly. This factor was a significant enabler in the virus becoming a global pandemic. Political influences may have also played a part, with data and information provided being delayed or incomplete.

Several countries, notably New Zealand and South Korea, responded quickly to the outbreak of Covid-19 by closing their borders, restricting movement and implementing successful test-trace and isolate regimes. This was driven in part by their experience with other previous corona viruses, like Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS).

There have been two significant events since Covid-19 became a global pandemic:

1. The appearance of new variants like those in the UK, Brazil and South Africa.
2. The rapid development and approval of vaccines; six at the time of writing this paper.

Some vaccines were developed using the traditional approach of using an element of the actual virus or antibodies. Vaccines were also developed using the application of genomic sequencing with vaccines mimicking the protein spike of the virus so that the human body can produce an immune response, such as the production of antibodies to this genetic information, delivered using the cold virus ("emptied" of its genetic material) for example.

Methodology

The methodology applied is that of both secondary research (literature, mainly on-line due to the pandemic) and primary research in the form of observation. In Table 1, observable impacts of Covid-19 are provided from a synthesis of multiple sources, too numerous to reference individually.

It is impractical to consider all domains, so discussion will be limited to the impact of Covid-19 on some aspects of the domains of health, education, work and the home. The observations made are confined to the United Kingdom (UK) which is

comprised of the nations of England, Scotland, Wales (Great Britain) and Northern Ireland. Notable geo-political factors specific to the UK:

(i) Great Britain is an island.

(ii) The UK, mainly England and London, is a transport hub (people and goods transit through the UK). Heathrow in London was once the busiest airport in Europe.

(iii) The majority of the UK's population resides in the cities. England is the largest most densely populated nation.

(iv) The UK has a national health service (NHS).

(v) The political decisions and actions by the respective Parliaments revolving around Covid-19 across the UK nations have often been unilateral. Discrimination between scientific and political decisions is seldom clear cut.

(vi) As England has the largest population (and therefore, the available data is more granular), as well as being home to the UK Parliament, observations made are biased towards England.

The observational limitations are in part addressed later by the discussion of findings from an international roundtable.

Observed impacts of Covid-19 on Health

Outside of the hospital environment, which has been predominantly Covid-19 centric often to the detrimental exclusion of other health demands, there has been a minor revolution in primary care (General Practice). Although General Practitioners (GPs) and, in particular, their staff are now involved in the vaccination roll out, major changes have surreptitiously taken place in health care:

GPs have moved to e-health, with most appointments being on-line or by telephone in the first instance at least.

Many GPs are therefore home working to a large extent.

There has been a huge reduction in face-to-face (f2f) consultations.

The reduction in f2f consultations has consequently led to a reduction in the number of (hospital and other) referrals for non-Covid patients.

All communications with GPs begin with the screening out of patients with or without Covid by directing them to web or to telephone services, such as the number 111 telephone service for non-Covid symptoms; the number 119 telephone service now exists for patients exhibiting Covid symptoms or having been in contact with potential Covid sufferers. The few remaining or persistent patients may then proceed to book an e-consultation (on-line or telephone) with a GP.

In emergencies, rather than telephone the emergency number (999) there is now a requirement to dial 111 to be given an Accident and Emergency (A&E) "appointment"!

Observed impacts of Covid-19 on Education

With the exception of children of "key workers" (e.g., nurses, police, refuse workers, etc.) and vulnerable children (a term which more recently includes children without access to technology like laptops), during times of lockdown, children are being taught not f2f at school, but remotely and online at home with the coopting of parents who may additionally be home-working (to be discussed later).

The main impacts of Covid-19 relate to the Digital Divide and the outstanding issues regarding e-learning. The issues surrounding e-learning are well known; however, the sudden reliance on its deployment and therefore the need for internet resources in the home, has highlighted the digital divide and digital exclusion. Many children do not have access to the technologies needed to support any e-learning; laptops, broadband, etc. Further, it has been argued that e-learning does not exist; in reality it is only e-delivery or e-teaching (Graham 2018).

On-line teaching is often of poor quality, more web-enabled database than knowledge based. Computer Mediated Communication (CMC) is impoverished in comparison with f2f interaction.

Schools, teachers and children have been required to make teaching on-line without the necessary history or experience.

Due to the desperate circumstances, the sudden haste may often result in schools just putting their class materials on-line, with no real design involved.

The educational day of children is no longer strictly timetabled or structured.

Parents are having to act as surrogate teachers to their children who may be of different ages or abilities, and may, of course, number more than one.

In addition, parents may be both home-working and home-schooling.

The social implications are enormous. Children obtain far more than academic skills; they learn to make friends, socialise; in short, become valued members of society.

The estimated cost of the disruption to the education of children is believed to run into the millions of pounds.

In 2020, computer algorithms were employed to "calculate" examination results. The algorithms were shown to be biased towards more affluent geographical areas and schools. These grades were later replaced by teacher assessment, but it is highly likely that there was some grade inflation. There was, realistically, no fair way to assess students. With the exception of professional qualification components, examinations for 2021 are now to be abandoned and purely teacher assessment is to be used for the grading of pupils, with moderation measures to try and ameliorate grade inflation.

University students may be nearer the independent learner ideal, but they also have been forced to learn on-line from home, often whilst still paying for unused accommodation and paying full fees. There is little, if any, f2f teaching and no genuine student experience to speak of.

Impacts are both quantitative and qualitative. Quantitative impacts tend to be financial. Qualitative impacts do have real, often hidden financial costs and are perhaps more important; those of a lost generation, their education and well-being, especially their mental health.

In education, the divides in society have been brought to the fore; digital, social and financial. It should be stated that children in many private and independent schools have been largely unaffected by the pandemic by being able to provide all the technologies needed, or they have been able to operate due to having small class sizes or having student boarders.

Observed impacts of Covid-19 on Work

The greatest impact of Covid-19 on the world of work has happened during periods of total lockdown when, with the exception of key workers, customer-facing jobs such as hospitality have been furloughed, and all other work has been moved on-line where possible.

Like education, the move of business to remote and on-line working has been accelerated. Prior to the pandemic, businesses were already being "gigificated" (Braganza and Chen, 2021), adopting the model of the gig economy. In order to merely survive during lockdown, businesses like retail have, in most cases, moved on-line and the hospitality industry, for e.g., restaurants, has become take-away via apps. During the pandemic, hotels have been used for the homeless, and more recently used for the enforced isolation of international travellers. Zoos, gyms and the like, have offered virtual (remote) experiences.

On-line shopping has increased the demand for physical deliveries. Not all retailers have survived, some businesses losing their physical shops with only their on-line brand being sustained, the final nails in the coffin of the traditional (physical)

High Street appear to have been hammered in. In contrast, essential shops, unaffected by lockdown, for instance shops selling goods including (but not necessarily exclusively) food, have profited from both clicks and mortar, in some cases to the further detriment of non-essential, physical shops. Entertainment venues like cinemas and theatres, as well as travel agents, airlines, zoos and gyms, now have a more precarious existence.

Obviously, there are logistical impacts linked directly with more businesses becoming on-line, due to the vast increase in the demand for delivery services. The global pandemic has also led to more local sourcing of goods where possible. Delivery drivers are key workers who are at greater risk of contracting Covid-19 due to the face -to-face nature of their work, and there has been a higher incidence among drivers and transport staff contracting the virus. (On a more tangential note, there has been a greater demand for cardboard, described as beige gold).

In direct contrast with goods, human transport (travel) has reduced at the same time goods transport has surged. Consequently, at the start of the lockdown the lack of traffic due to the absence of schools and business travel has meant less congested roads and a positive environmental impact.

Similar to education, the quantitative impacts are mostly financial and visible. The qualitative impacts of lost work patterns, socialising in the work place and mental health are incalculable. Furthermore, it should be remembered that some parents are having to both home-school and home-work concurrently with limited time and technological resources.

Observed impacts of Covid-19 on the Home

As has been mentioned already, the home has for some become the classroom and the office; during periods of lockdown, it may also have been perceived to be a place of incarceration.

As well as the imposition of the new demands of e-health, e-education and e-work in using technologies for on-line medical consultations, on-line lessons or remote working, there are now additional demands for on-line connectivity in the home, for smart devices for leisure; virtual gyms, streaming of films and television, communication forums and virtual meetings, plus the increasing push for the adoption of smart meters and such like. The pandemic has resulted in an unprecedent expansion of the use of smart technologies, electronic communications and logistics. There have been savings from reduced travel to offices and the use of office buildings, both financial and environmental. Electronic communications have allowed daily activities to continue to some degree, even exercise can be “smart”. The use of cash, partly due to more on-line payments, but also as a direct result of the need to avoid infection spread, has been significantly reduced.

Life in the home lately revolves more around the laptop or Smart TV; watching streamed classes or television, meeting, working, shopping, and having health consultations on-line. Households without facilities are hugely disadvantaged, however, for other households the divisions between the home life and everything else is now completely blurred. As Tree Hll, the CITL CEO states: “We risk creating a society that only connects on-screen" (Computing Daily Update, 2021).

Results

Table 1 summarizes the overall positive and negative impacts of Covid-19 on the Digital Society for health, education, work and the home, and the resulting societal implications. Digital exclusion is applicable to all domain exemplars in the home.

Table 1. Summary of the Positive and Negative Impacts of Covid-19 on the Digital Society for Health, Education, Work and the Home, and the resulting Societal Implications.

Domain Exemplars: Health	**Positive Impacts**	**Negative Impacts**	**Societal Implications**
On-line consultations.	Greater accessibility and convenience for patients with the appropriate technology.	Highlights the Digital Divide. Impoverished CMC in comparison to f2f for diagnoses. Lack of Human-Human Interaction (HHI). Mental health issues due to health service exclusion. Increased big data collection (session capture). Second class service for patients without the technologies required (digital exclusion).	Expansion of e-health.
Analytics: e.g., Google DeepMind. Data Centres, e.g., Care.data.	Often data already exists in the form of legacy systems/ data. The mining of such data applying knowledge-based systems (heuristic) or statistical models for genomics, etc. Storage and analysis of private personal medical records (EPRs – Electronic Patient Records) in Data Centres for the potential improvement of health care. New Covid-19 associated data being used for test and trace, and recognition of variants using genomic sequencing.	Access to, and exploitation of, personal information and medical records without consent by commercial organisations (Burton, 2017). Privacy is a significant issue, as true anonymity cannot be guaranteed. Control and exploitation of private, confidential data in data centres, especially due to the policies of patient opt out, not opt in (Palmer, 2015). Test and trace data invites surveillance. Lack of GDPR enforcement (Computing, 2021c)	Expansion of e-health and Genomics. Continuation of test (track) and trace.
Simulation or Modelling.	Simulation of virus and the epidemiology.	Not negative in itself, but model-based decisions could be.	Expansion of use of simulation and modelling.

Domain Exemplars: Education	**Positive Impacts**	**Negative Impacts**	**Societal Implications**
On-line teaching.	Greater accessibility and convenience for pupils and students with the appropriate technology.	Highlights the Digital Divide. Impoverished CMC in comparison to f2f; screen freezing, loss of immediate whole class feedback, etc. Lack of HHI. Mental health issues due to educational exclusion and loss of routine. Increased big data collection (session capture). Second class service or loss of education for pupils and students without the technologies required (digital exclusion).	Expansion of e-teaching.
Domain Exemplars: Work	**Positive Impacts**	**Negative Impacts**	**Societal Implications**
On-line working.	Greater accessibility and convenience for employers and employees with the appropriate technology and amenable to remote working. Expansion of online presence. Less/no commuting to a place of work. Less transport, so less pollution. Possible housing and transport cost savings. Savings in costs of office space.	Highlights the Digital Divide. Impoverished CMC in comparison to f2f for immediate feedback. Lack of HHI. Mental health issues due to exclusion and loss of routine. Increased big data collection (session capture). Second class service or loss of business for employers and employees without the technologies required, or businesses not compatible with remote working (digital exclusion). Lack of separation between home and work. Loss of support industries; cafes, newsagents, etc.	Expansion of e-working.

Sensors and Drones for Logistics.	Radio Frequency Identification (RFID) for goods and medicines. Remote delivery by drone.	Tracking and tracing of individuals as well as goods. Health and safety issues regarding the use of drones.	Issues of mass surveillance and privacy. Greater use of drones.
Mobile communications and technologies.	Global Positioning Satellite (GPS) can be combined with other technologies, like smart phones, for notifying individuals who have been in close proximity to Covid-19	Real time mass surveillance and privacy issues.	Real time mass surveillance and privacy issues.
Surveillance: Closed Circuit Television (CCTV).	Can be used to monitor the well-being of babies in the home and the elderly in care homes, as well as the health of hospital patients (Computing, 2021).	CCTV when combined with drones can now also be mobile. CCTV can be combined with face recognition software to enable movements of individuals to be monitored (tracked/traced).	Expansion of e-surveillance. Big Brother (Orwell, 1948) in every sense. The location and activities of the population continually observed, recorded and monitored.
Domain Exemplars: Home	**Positive Impacts**	**Negative Impacts**	**Societal Implications**
On-line leisure, e.g., Peloton.	Virtual (exercise) communities. Greater accessibility and convenience with the appropriate technologies.	Highlights the Digital Divide. Impoverished CMC in comparison to f2f. Lack of HHI. Increased big data collection (session capture).	Expansion of e-leisure.
On-line media: e.g., Microsoft's OneDrive, Netflix, Smart Televisions.	External collation and sharing of personal artefacts (photographs, movies, music and data).	Ownership of data may not be clear. Photographs, etc. could be exploited by marketing companies or used by paedophiles. Data can be fused for profiling of individuals by organisations and governments. Data fusion could also be used for identity theft, fraud, and other e-crimes.	Expansion of e-media

Social Media: e.g., Facebook, Twitter, Zoom.	Remote socialising.	Intimate knowledge of individuals by commercial organisations. Additional data accrued through likes and dislikes. Cyber-bullying. Profiling. Control (often by suggestion, e.g., up-selling). Massive security issues if data is lost or hacked.	Expansion of the e-society.
On-line shopping	Convenience. Less/ no travel to shops. Less individual transportation, so less pollution.	Greater demand for (physical) delivery services. Demise of the physical High Street and the shopping experience. Big data generation.	Expansion of e-shopping.
Smart devices for the home. Smart meters, e.g., Hive (BritishGas, 2015).	Can infer health conditions and falls from usage for elderly care home residents (Computing, 2021).	Can identify periods of home occupancy; infer employment from usage hours and health from average temperature. Remote control of devices via the internet. Devices and data could be controlled by parties other than legitimate users, such as hackers or hostile governments.	Move towards Smart Homes.

Current applications of Analytics and AI to Covid-19

At a virtual roundtable organised by the International Telecommunication Union (ITU), the use of AI to help scientists in their mission to beat the Coronavirus pandemic was discussed (Computing, 2021b).

Soo Jun Park, Assistant Vice President, ETRI (Electronics and Telecommunications Research Institute, South Korea), explained how the technology was employed in his country, using the lessons learned during the MERS outbreak of 2015. He described how, at the time, South Korea was the worst-hit region besides the Middle East and that they didn't then know how to cope with infectious diseases. In hindsight, one key problem was "that at that time the government concealed all the information. It didn't release data about patients, hospital capacity, or anything. That exponentially

increased the number of infected patients". The key lesson was about making the data widely available. "We learned that to cope with infectious disease, openness is key, it's not just about gathering the data. You have to let people know what's happening, and let them know the truth about what's going on. We changed laws to accommodate that. Korea had our first confirmed case [of COVID-19] in January 2020, a lady who'd arrived from Wuhan. From that moment the government reacted very quickly, based on our previous experience. We also had the right IT infrastructure in place. We have very sophisticated medical systems, with universal health insurance for everyone. Those things combined helped us handle the pandemic". The infrastructure included a smart quarantine system which gathered information on arrivals from countries where infectious diseases had occurred, tracking and monitoring those diseases during the quarantine period; the data was also shared with medical institutions. South Korea has a self-health check app for new arrivals, contact tracing, and an AI-driven COVID-19 X-RAY and CT image screening.

Moez Draief, a global chief scientist and VP of data science and engineering at Capgemini added that AI is also used in background research. "We're also using AI in the background, where it sifts through thousands of medical papers for relevant information, and helps our understanding of any potential adverse affects of any drugs we're developing". He added that collaboration with regulators is also important, and it is something which the UK could perhaps learn from. "In Europe the regulators are very open to engagement to help innovation progress, there's an understanding that we have to work together. Scientists need to know where the regulator is happy for innovation to happen. And the regulator needs to anticipate where the innovation is likely to happen. We need this to avoid issues occurring down the line where either side is surprised. For instance, contact tracing in France is done hand-in-hand with the regulator to understand how it should be done". He went on to discuss how AI can help with any anti-vaccination sentiment: "We are engaging to understand the arguments and which parts of the population are sceptical about vaccines and why. There's a lot of fake news out there. We have a project where we're looking at communities who have taken cancer drugs, and enabling them to interact, and to have tools to recommend people for them to talk to, to create a dialogue rather than an echo chamber. This is where AI can help, not to solve the problem but at least to facilitate the dialogue".

Another contributor to the forum, Ulla Jasper, Policy Lead from the Botnar Foundation (a philanthropic foundation based in Switzerland), added that more work needs to be done to enable data sharing on a global scale. "There are lots of initiatives and voluntary codes, but too little concerted effort. Not that we need to arrive at a global one-size-fits-all data governance framework, but instead how can we share data across borders? The flow of data during Covid has not been perfect. We're not necessarily looking for one big solution, but we need to find sub-fields where we can see progress more easily. Like data sharing in public health emergencies".

In a similar tone, Fred Werner, head of public engagement at the ITU called for greater data sharing. "There's more data now than ever before. But that doesn't lead to a greater exchange of data and collaboration. I've been in lots of different meetings where data is always the crux of the issue. Someone will ask who has data, and everyone raises their hands. Then someone asks who's willing to share it? And everyone looks at their shoes. So working out how to share it safely and securely is critical. There's not a lack of open source data, but you look at the basics like; is it discoverable, is it labelled correctly, is it freely available or licensed, or peer to peer? These are all bottlenecks".

The roundtable discussion concluded by stating the need to identify and acknowledge the issues raised; having now taken the first step towards solving them, the time to accelerate the next steps is now.

Discussion

Post Covid-19 Digital Society Trends

The following trends are increasingly likely to become reality, through lockdown acceleration:

- Home-based, on-line and remote primary health care, with initial f2f consultations being a rarity. Pre-consultation use of on-line query systems, such as NHS Direct, or the telephone service 111. Many more on-line, remote hospital consultations. Greater use of Genomics and analytics.
- Home-based, on-line and remote learning. Blended learning, already a given for universities, has now become a part of school life due to the pandemic. School and university closures are possible, as well as the expansion of e-Universities.
- Home-based, on-line and remote working to some degree where and when possible, providing time and cost savings for employers (office space costs, meetings, increased productivity, for example), likely to be less beneficial for employees beyond commuting in most cases. Reduced road traffic could mean that motorways are no longer required to be "Smart", with the hard shoulder being reinstated.
- Home-based, on-line and remote shopping and banking. The further demise of physical shops and cash.
- Home-based, on-line and remote leisure; virtual gyms, music and film streaming, social media.

Genomics and new innovations in vaccine research during the pandemic are now being used to produce pill versions of vaccines, and vaccines that, rather than only targeting the spikes on the virus's surface, target the virus's nucleocapsid, the shell that contains the virus's genetic material. Because this shell is much harder for the virus to change, it is harder for the virus to mutate against a vaccine. The hope is that it can lead to a universal vaccine that works against new, more resistant, variants (Nottingham University, 2021). It is possible that the pandemic may have spurred research on the first vaccine for Aids.

It has been reported (Computing, 2021a) that firms as diverse as technology behemoth Google and investment giant Schroders have stated that employees need never return to the office, and that the coronavirus pandemic has left a lasting legacy of permanent change in employee and consumer behaviours. In 2020, Amazon's sales leapt 40%. Similarly, it was reported (BBC, 2021) that for Asda, on-line shopping with them had been accelerated by 10 years, and they would be looking to reduce customer front-facing staff and back-office staff involved in cash transactions, employing more delivery drivers and order pickers.

Back in 2013, Curran (Sumner, 2013, p. 16) argued that "data centres will be the engine rooms driving the 'Fourth Industrial Revolution', which will see the internet of things, and big data transform the way modern businesses operate and societies function"; the pandemic has massively accelerated this transformation.

All of the observed trends are likely to require improved logistics, better communications technologies and generate considerably more big data; their use raises serious ethical issues (Chessell, 2014; CloverETL, 2017; de Lama, 2016, p. 10; Veitch, 2017). As well as the benefits of big data and analytics, there are real concerns about data harm (Cate, 2016, p. 17). During the pandemic, in addition to curtailing freedoms, laws have been changed to permit the unfettered access to some data, raising issues of data harm and whether or not data protection may be fully reinstated (Computing, 2021c).

How Analytics and AI can provide leverage for post-Covid-19 recovery

The roundtable discussion on the use of analytics and AI to combat the pandemic highlighted the need for the early, safe and secure access to data (correctly labelled,

etc.), local and international collaboration, with global data sharing in public health emergencies, the strengths of having a national health service, and good communications with regulators and the scientific community.

AI has already been applied for background research on relevant information on the adverse effects of any developed drugs, by sifting through medical papers as well as AI-driven contact tracing, a self-health check app (for arrivals), Covid-19 X-ray and CT imaging. AI has also been used for identifying anti-vaccination sentiments, understanding the arguments and which parts of the population are sceptical about vaccination and why, with AI facilitating the addressing of fake news by creating dialogues with cancer drugs and other communities.

Conclusions

The domains of Health, Education, Work and the Home are all interconnected in the Digital Society. For some the home has become the classroom, the office, the cinema and the gym, during periods of lockdown, whilst others have been totally excluded. From the trends identified in Table 1, it can be seen that the main effect of Covid-19 on society has been the acceleration of the digitisation of society with the rapid, untested expansion of e-health and Genomics, e-teaching, e-working, e-logistics, e-communications, e-leisure, e-shopping and Smart homes.

The negative impacts of Covid-19 itself on society are not always tangible. There are many more incalculable costs of the virus beyond death and infection statistics, such as the disruption of primary care and education in the widest sense. These intangibles, such as the impacts for mental health, loss of daily routine, lack of human-human interaction (hhi), non-Covid related deaths and diagnoses (harder to quantify), shine a light on the digital divide, educational, work, social and health inequalities. Although the economy may well bounce back in the future, these negative consequences could result in a lost generation, the young paying the costs in terms of their education and mental health, in addition to the long-term national debt.

The pandemic, especially during times of lockdown, has demonstrated the requirements for moving to the digital society, such as providing the necessary infrastructure to support it, and these are the lessons which need to be learned in this new reality, if the whole of society is to be included.

Neither data analytics nor artificial intelligence can directly bring about social change beyond providing data and knowledge to support that change. Post Covid, the demand for greater integration of technology will act as a catalyst for Smart(er) Homes, Smart(er) Working, Smart(er) Schools and Universities, Smart(er) Transport, and so on, to Smart(er) Cities, with the UK heading for a fully Digital, or e-Society. This will be enabled by the further generation and analysis of big data, as the pandemic has massively increased the amount of big data captured, especially medical and logistical data. AI will also be embedded in many more activities in order to deliver the Smart Cities and a Contactless Society using Dynamic Analytics.

AI can, and should be, used to improve e-teaching, making it truly knowledge -based. Analytics and AI are already an intrinsic part of business, logistics and communications.

AI and analytics can be specifically applied to future pandemics. Big data analytics has been employed mostly for the analysis of current infection outbreaks for test and contact trace, often using a form of reverse engineering. Predictive analytics could be further exploited to predict future outbreaks, both when and where, using Covid-19 data as test data. Likewise, AI, namely machine learning, could be used to determine future variants and new viruses by applying genetic algorithms. If successful models can be built applying genetic algorithms, then this self-organising approach could be extended to other diseases and illnesses; there are many possibilities for this application development.

The advent of the Big Data Smart Future through AI, analytics, the IoT and robotics, could lead to challenges to the epistemology of knowledge, the automation of intellect and the loss of human ingenuity, allowing humanity to sleep walk into its own intellectual demise. AI and analytics must be additions to, not a replacement for, methods of scientific inquiry. Society is not threatened by big science or AI, but is threatened by the ill-considered automation and digitisation of every aspect of human life.

The ethical dilemma for big science is balancing the positive possibilities against the potential for data harm. Information is power, as has been demonstrated fully by the pandemic, and the digitisation of society ensures that things are recorded in perpetuity. The pandemic has also meant the realisation of what is important as human beings; humans are basically tactile and social animals, and society is essential to learning, to work, to health and well-being; there is no substitution for physical human contact (there would be no humans in the long run!).

Implications

Acknowledging the research limitations below, society appears to be heading towards becoming a fully digital or e society. However, unless the current digital divide and the resulting digital exclusion is resolved, the unstoppable drive towards the e-society could lead to two parallel societies; one connected and one isolated underclass.

Limitations

As stated, observations were limited to the UK, so there are likely to be potential global differences in the results and conclusions drawn from them.

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