DIGITAL EPIDEMIOLOGY

- Ali Ahmadi, Epidemiologist
- Shahrekord University Medical of Sciences (SKUMS)
- aliahmadi2007@gmail.com

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2 PAPER

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Check for updates

Digital technologies in the public-health response to COVID-19

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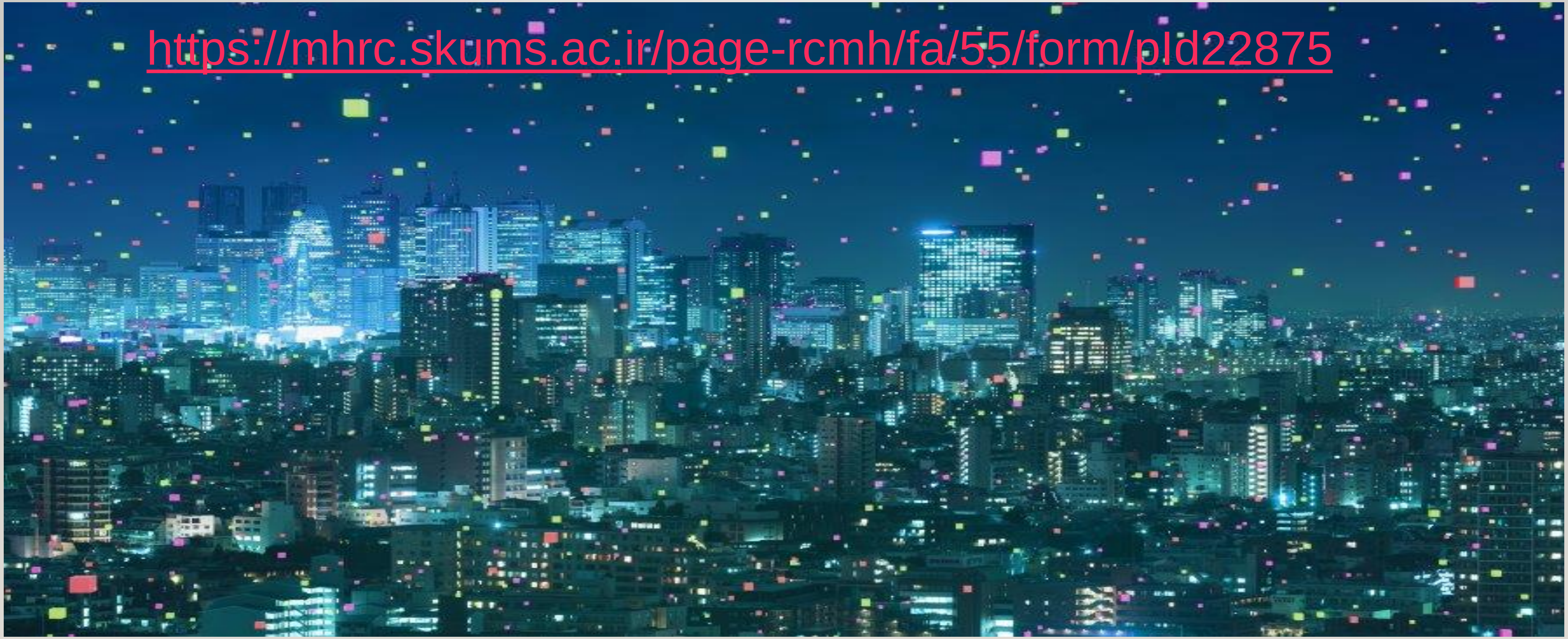
Jobie Budd[1,2], Benjamin S. Miller[1], Erin M. Manning[1], Vasileios Lampos[3], Mengdie Zhuang[4], Michael Edelstein[5], Geraint Rees[6], Vincent C. Emery[7], Molly M. Stevens[8], Neil Keegan[9], Michael J. Short[10], Deenan Pillay[11], Ed Manley[12], Ingemar J. Cox[3,13], David Heymann[14], Anne M. Johnson[15] and Rachel A. McKendry[1,2] ✉

3 DOWNLOAD WEBSITE

You can download the slides, papers, and documents here:

https://mhrc.skums.ac.ir/page-rcmh/fa/55/form/pId22875



OUTLINE

- **Epidemiology, Epidemic, Pandemic**
- **New Methods and Technologies, Digital Revolution,**
- **Digital Epidemiology, E-epidemiology, Computational and** Machine Learning
- **Digital Epidemiological Surveillance**
  - Online data sources for early disease detection
  - Data-visualization tools for decision support
  - Rapid case identification
  - delays between sampling, sending samples to centralized labs, waiting for results and follow-up
  - Interrupting community transmission
  - Digital contact tracing
  - Evaluating interventions through the use of mobility data
  - Public communication: informing populations
  - Implementation
  - Data sharing and data quality
  - Evidence of effectiveness and regulation
  - Legal, ethical and privacy concerns
  - Inequalities and the digital divide
- **Conclusion**

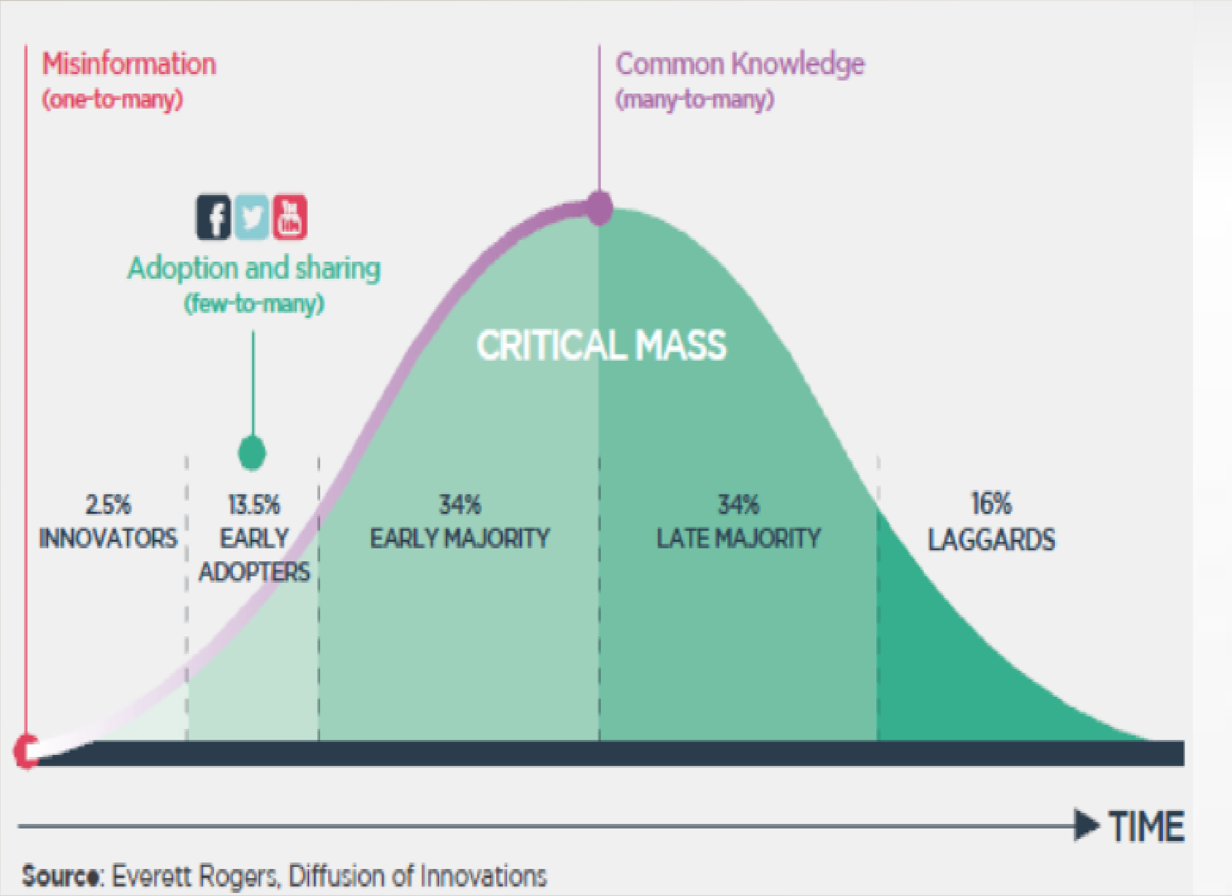
EPIDEMIOLOGY

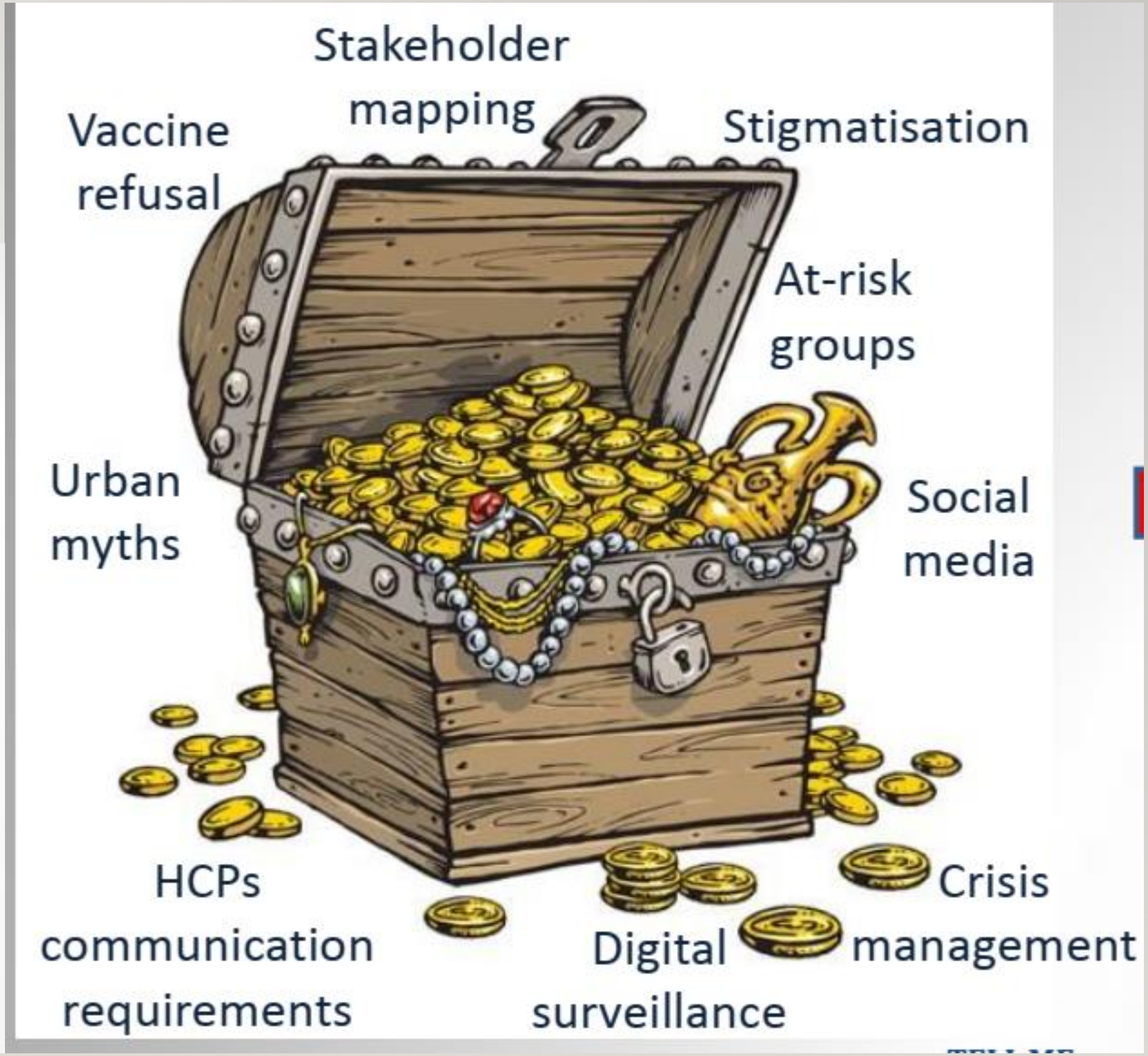
- Epidemiology is the study of the occurrence, distribution, and determinants of health-related states or events in a given population, and the application of this study to the control and management of other health problems (Gordis 2009).

EPIDEMIC, PANDEMIC

- During the plague outbreak that affected 14th-century Europe, isolation of affected communities and restriction of population movement were used to avoid further spread. These public-health measures for outbreak response remain relevant today, including surveillance, rapid case identification, interruption of community transmission and strong public communication. Monitoring how these measures are implemented and their impact on incidence and mortality is essential. All countries are required by the International Health Regulations (2005) to have core capacity to ensure national preparedness for infectious hazards that have the potential to spread internationally.
- COVID-19, a previously unknown respiratory illness caused by the coronavirus SARS-CoV-2 by the World Health Organization (WHO) on 11 March 2020, was declared a pandemic less than 3 months after cases were first detected.

TRANSPARENT COMMUNICATION IN EPIDEMICS:
LEARNING LESSONS FROM EXPERIENCE, DELIVERING EFFECTIVE MESSAGES, PROVIDING EVIDENCE





NEW METHODS AND TECHNOLOGIES

- Online, mobile, global - the ongoing digital revolution affects all aspects of life.
- Massive amounts of data are now shared by billions of people around the globe through mobile phones, social media services, and other outlets, on any issue imaginable, including issues of health.
- These data sources can be mined for epidemiological purposes, giving rise to digital epidemiology.

NEW METHODS AND TECHNOLOGIES

- Research and development of new methods and technologies to strengthen these core capacities often occurs during outbreaks when innovation is an absolute necessity.
- During the outbreak of severe acute respiratory syndrome in 2003, Hong Kong identified clusters of disease through the use of electronic data systems.
- During the Ebola outbreaks in West Africa in 2014–2016, mobile phone data were used to model travel patterns, and hand-held sequencing devices permitted more-effective contact tracing and a better understanding of the dynamics of the outbreaks. Similarly, digital technologies also have been deployed in the COVID-19 pandemic.

DIGITAL REVOLUTION

- The digital revolution has transformed many aspects of life. As of 2019, 67% of the global population had subscribed to mobile devices, of which 65% were smartphones—with the fastest growth in Sub-Saharan Africa.
- In 2019, 204 billion apps were downloaded, and as of January 2020, 3.8 billion people actively used social media.

DIGITAL EPIDEMIOLOGY

- The term digital epidemiology was defined by Marcel Salathé as epidemiology that uses data that was generated outside the public health system, i.e., with data that was not generated with the primary purpose of doing epidemiology (Salathé 2018; Eckmanns et al. 2019).
- Digital epidemiology uses digital methods from data collection to data analysis (Park et al. 2018).
- Digital data include mobile phone network data, data generated by sensors, and data collected at call centers, social media posts (e.g., Twitter and Instagram), search terms and webpage access logs (e.g., Google Google Flu Trends (GFT) Google Trends, Wikipedia views) (Masodi et al. 2019; Park et al. 2018; Salathé 2018; Eckmanns et al. 2019; Lippi et al. 2019; Salathe et al. 2012).

E-EPIDEMIOLOGY

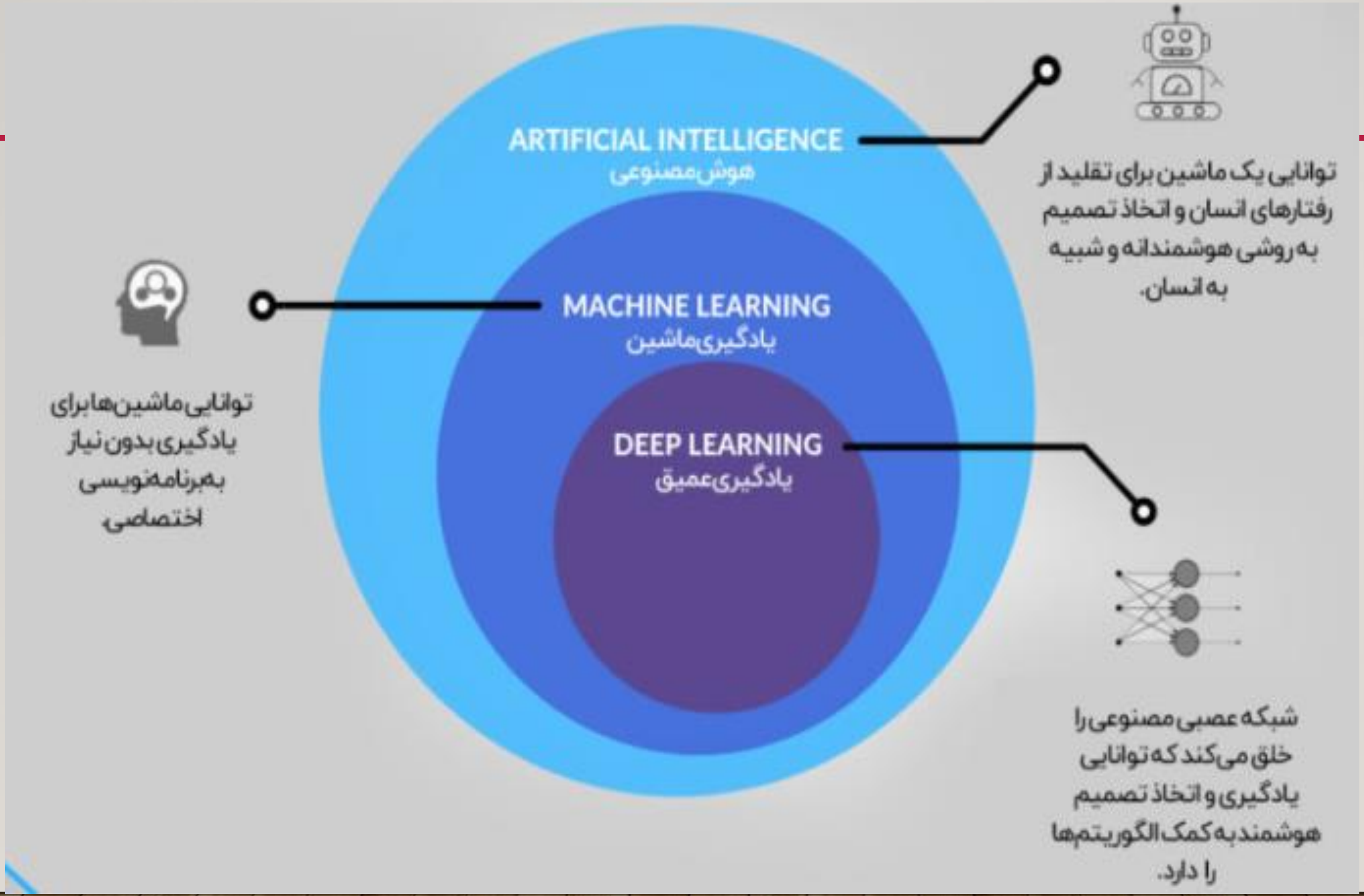
- **E-epidemiology** (also known as Digital Epidemiology) is the science underlying the acquisition, maintenance and application of epidemiological knowledge and information using digital media such as the internet, mobile phones, digital paper, digital TV. E-epidemiology also refers to the large-scale epidemiological studies that are increasingly conducted through distributed global collaborations enabled by the Internet.
- The traditional approach in performing epidemiological trials by using paper questionnaires is both costly and time-consuming. The questionnaires have to be transformed to analyzable data and a large number of personnel are needed throughout the procedure. Modern communication tools, such as the web, cell phones and other current and future communication devices, allow rapidly and cost-efficient assembly of data on determinants for lifestyle and health for broad segments of the population.

DIGITAL EPIDEMIOLOGY

- Researchers have already started to use digital data to support public health surveillance and infectious disease monitoring or to understand public attitudes, perceptions, and behaviors towards health issues (Park et al. 2018). Thus, digital systems for early detection of infectious diseases such as ProMED-Mail, Global Public Health Intelligence Network (GPHIN), HealthMap and Google Flu Trends (GFT) are the key components of the Global Public Health System (Eckmanns et al. 2019). Google Flu Trends (GFT) is an early example of digital epidemiology, using search queries to track influenza-like illnesses (ILIs) (Park et al. 2018, Salathé 2018). In 2009, researchers from Google and the US Centers for Disease Control and Prevention (CDC) published a method to estimate flu activity by region using search queries.

14 DIGITAL EPIDEMIOLOGY

- Increasing numbers of epidemiological studies are using digital data generated for a purpose other than epidemiology. Park et al. 2018 reviewed digital epidemiological studies to characterize them by topic domain, study purpose, data source, and analytic method. There were six main topic domains: infectious diseases (58.7%), non-communicable diseases (29.4%), mental health and substance use (8.3%), general population behavior (4.6%), environmental, dietary, and lifestyle (4.6%), and vital status (0.9%). There were eight categories for the data sources: web search query (52.3%), social media posts (31.2%), web portal posts (11.9%), webpage access logs (7.3%), images (7.3%), mobile phone network data (1.8%), global positioning system data (1.8%), and others (2.8%). Of these, 50.5% used correlation analyses, 41.3% regression analyses, 25.6% **machine learning**, and 19.3% descriptive analyses (Jung et al. 2020).


ARTIFICIAL INTELLIGENCE
هوش مصنوعی
توانایی یک ماشین برای تقلید از رفتارهای انسان و اتخاذ تصمیم به روشی هوشمندانه و شبیه به انسان.
MACHINE LEARNING
یادگیری ماشین
توانایی ماشین‌ها برای یادگیری بدون نیاز به برنامه‌نویسی اختصاصی.
DEEP LEARNING
یادگیری عمیق
شبکه عصبی مصنوعی را خلق می‌کند که توانایی یادگیری و اتخاذ تصمیم هوشمند به کمک الگوریتم‌ها را دارد.

COMPUTATIONAL AND DIGITAL EPIDEMIOLOGY

- The activity of Computational and Digital Epidemiology domain research focuses on the following main areas:
- I. development of the mathematical and computational methods needed to achieve prediction and predictability of disease spreading in complex techno-social systems;
  II. development of large scale, data driven computational models endowed with a high level of realism and aimed at epidemic scenario forecast and policy making;
  III. design and implementation of original data-collection schemes motivated by identified modelling needs, such as the collection of real-time disease incidence, through innovative web and ICT applications;
  IV. set up of a computational platform for epidemic research and data sharing that will generate important synergies between research communities and countries;
  V. evidence-based scenario building in order to enable and to support decision and policy making.
- This research domain proposes a truly interdisciplinary effort combining complex systems science, computational sciences, mathematical epidemiology, and ICT technologies.

DIGITAL EPIDEMIOLOGICAL SURVEILLANCE

- A core public-health function of outbreak management is understanding infection transmission in time, place and person, and identifying risk factors for the disease to guide effective interventions.

DIGITAL EPIDEMIOLOGY

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Table 1 | Digital technologies used in the COVID-19 pandemic

Public-health need	Digital tool or technology	Example of use
Digital epidemiological surveillance	Machine learning	Web-based epidemic intelligence tools and online syndromic surveillance
	Survey apps and websites	Symptom reporting
	Data extraction and visualization	Data dashboard
Rapid case identification	Connected diagnostic device	Point-of-care diagnosis
	Sensors including wearables	Febrile symptoms checking
	Machine learning	Medical image analysis
Interruption of community transmission	Smartphone app, low-power Bluetooth technology	Digital contact tracing
	Mobile-phone-location data	Mobility-pattern analysis
Public communication	Social-media platforms	Targeted communication
	Online search engine	Prioritized information
	Chat-bot	Personalized information
Clinical care	Tele-conferencing	Telemedicine, referral

DIGITAL EPIDEMIOLOGY

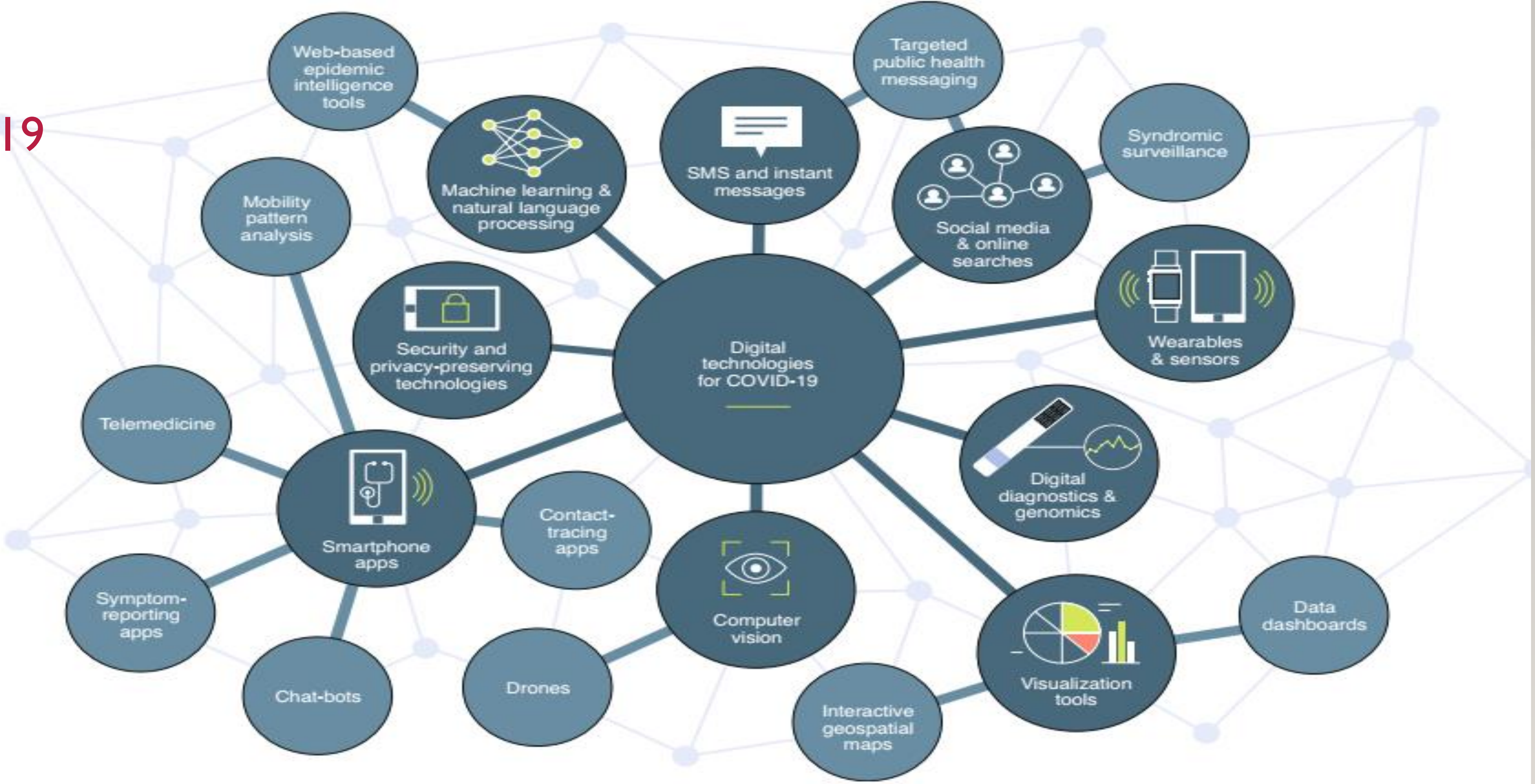


Fig. 1 | The interconnected digital technologies used in the public-health response to COVID-19. Many approaches use a combination of digital technologies and may rely on telecommunications infrastructure and internet availability. Machine learning is shown as a separate branch for clarity, although it also underpins many of the other technologies. Much of the data generated from these technologies feeds into data dashboards. SMS, short message service.

ONLINE DATA SOURCES FOR EARLY DISEASE DETECTION

- Established population-surveillance systems typically rely on health-related data from laboratories, notifications of cases diagnosed by clinicians and syndromic surveillance networks.
- Syndromic surveillance networks are based on reports of clinical symptoms, such as 'influenza-like illness', rather than a laboratory diagnosis, from hospital and selected sentinel primary and secondary healthcare facilities, which agree to provide regular surveillance data of all cases. These sources, however, ultimately miss cases in which healthcare is not sought.
- In the UK, for example, where until recently only hospitalized patients and healthcare workers were routinely tested for COVID-19, confirmed cases represent an estimated 4.7% of symptomatic COVID-19 cases. Identifying undetected cases would help elucidate the magnitude and characteristics of the outbreak and reduce onward transmission.

ONLINE DATA SOURCES FOR EARLY DISEASE DETECTION

- In the past two decades, data from online news sites, news-aggregation services, social networks, web searches and participatory longitudinal community cohorts have aimed to fill this gap.
- Data-aggregation systems, including **ProMED-mail**, **Global Public Health Intelligence Network** (**GPHIN)**, **HealthMap** and **EIOS**, which use natural language processing and machine learning to process and filter online data, have been developed to provide epidemiological insight. These data sources are increasingly being integrated into the formal surveillance landscape and have a role in COVID-19 surveillance.
- The brings together diverse datasets for infectious-disease emergency preparedness and response, including enviroWHO's platform EPI-BRAIN https://www.epi-brain.com/nmental and meteorological data. Several systems have claimed detection of early disease reports for COVID-19, through the use of crowdsourced data and news reports, before the WHO released a statement about the outbreak.
- The UK's automatic syndromic surveillance system scans National Health Service digital records to pick up clusters of a respiratory syndrome that could signal COVID-19. There is also interest in using online data to estimate the true community spread of infectious disease.

ProMED-mail (ProMED) was launched in 1994 as an email service to identify unusual health events related to emerging and re-emerging infectious diseases and toxins affecting humans, animals and plants. It is used daily by public health leaders, government officials at all levels, physicians, veterinarians and other healthcare workers, researchers, private companies, journalists and the general public. Reports are produced and commentary provided by a global team of subject matter experts in a variety of fields including virology, parasitology, epidemiology, entomology, veterinary and plant disease specialists. ProMED operates 24 hours a day, 7 days a week and has over 83 000 subscribers, representing every country in the world.

The Global Public Health Intelligence Network (GPHIN) was set up as a global network of connected professionals working to rapidly detect, identify, assess, prevent and mitigate threats to human health. Formed in the late 1990s by the Government of Canada (Health Canada) in collaboration with the World Health Organization,

HealthMap is a freely accessible, automated electronic information system for monitoring, organizing, and visualizing reports of global disease outbreaks according to geography, time, and infectious disease agent. In operation since September 2006, data from a variety of freely available electronic media sources (e.g. ProMED-mail, Eurosurveillance, Wildlife Disease Information Node) to obtain a comprehensive view of the current global state of infectious diseases.

Epidemic Big Data Resource and Analytics Innovation Network (EPI-BRAIN)

EPI-BRAIN is an innovative global platform that allows experts in data and public health to analyze large datasets for emergency preparedness and response.

DATA-VISUALIZATION TOOLS FOR DECISION SUPPORT

- Data dashboards are being used extensively in the pandemic, collating real-time public-health data, including confirmed cases, deaths and testing figures, to keep the public informed and support policymakers in refining interventions.
- COVID-19 dashboards typically focus on time-series charts and geographic maps, ranging from region-level statistics to case-level coordinate data. Several dashboards show wider responses to the pandemic, such as clinical trials, policy and economic interventions and responses to social-distancing directives. Few dashboards include data on contact tracing or community surveillance from apps or their effectiveness.
- **IHME ,WHO, WORLDMETTER**, …

ترجمان دانش چیست؟

سامانه مصورسازی اطلاعات

با در نظر گرفتن سرعت تولید اطلاعات و تنوع آن در همه حوزه ها، فرایند استخراج دانش از اطلاعات به روش سنتی فرایندی بسیار زمانبر و پرهزینه خواهد بود. علم مصور سازی اطلاعات کمک میکند تا محققان بتوانند تمامی حالات نتایج بدست آمده را در کمترین زمان بررسی کرده و روندها و مفاهیم موجود در اطلاعات را مشاهده نمایند. هدف ما در ویزیت ایجاد دسترسی به اطلاعات موجود و نتایج طرح های انجام شده است، با توجه به نحوه ارائه این اطلاعات که به صورت پویا انجام میشود این دسترسی توام با ایجاد دانشی در کاربران این سیستم خواهد شد. پس از ایجاد این دانش، مدیران میتوانند برنامه عملیاتی خود برای مداخلات را از طریق ابزار "تدوین برنامه عملیاتی" پیاده سازی کنند.

covid19.who.int/region/emro/country/ir

Search by Country, Territory, or Area

Overview Data Table Explore

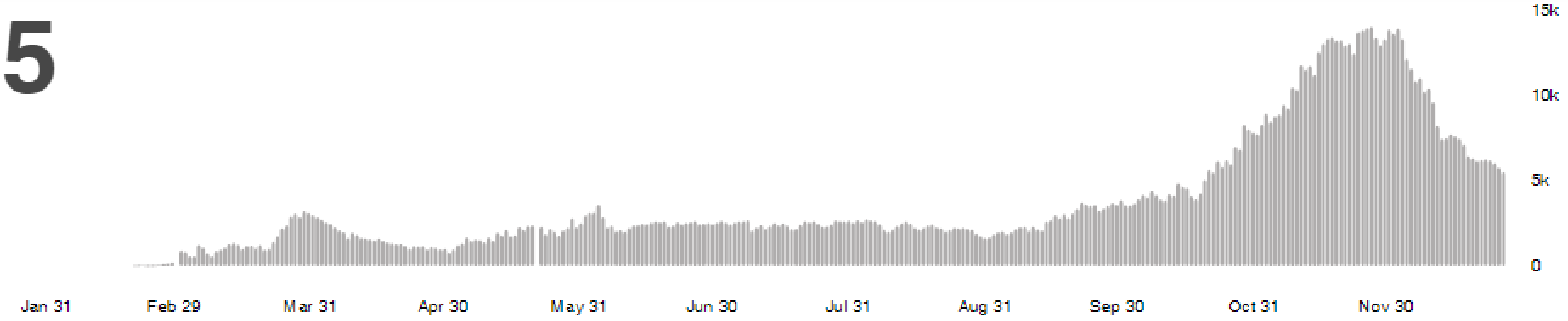
Global > Iran (Islamic Republic of)

Data last updated: 2020/12/28, 9:40am CET

Back to top

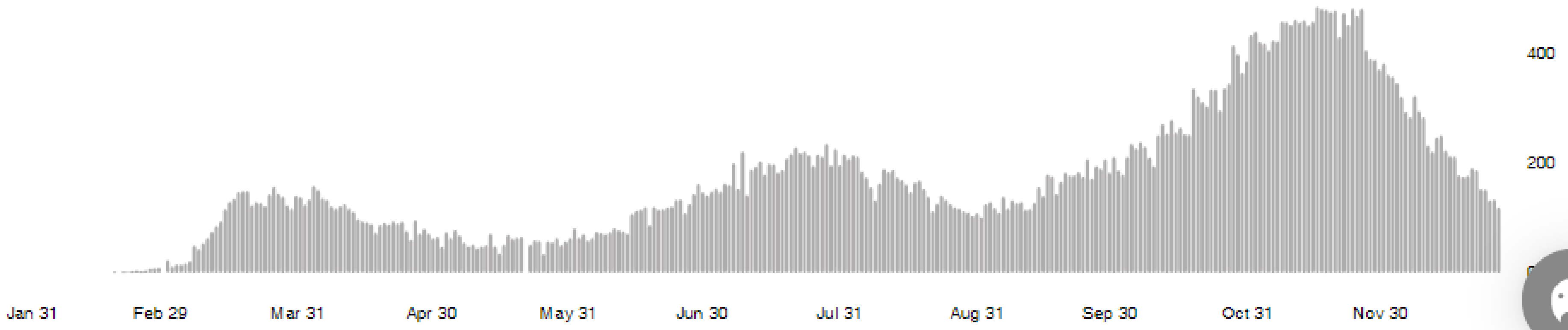
1,200,465

confirmed cases



54,693

deaths



Source: World Health Organization

IHME

COVID-19 Projections

GHDX VIZ HUB

Projection, Masks, Rapid rollout, Rapid rollout to high-risk, and Easing scenarios now include vaccine distribution.

Regions shown are the World Bank regional aggregates.

Last updated December 23, 2020 (Pacific Time)

FAQ | Policy briefings | Publications | Partners

Iran (Islamic Republic of)

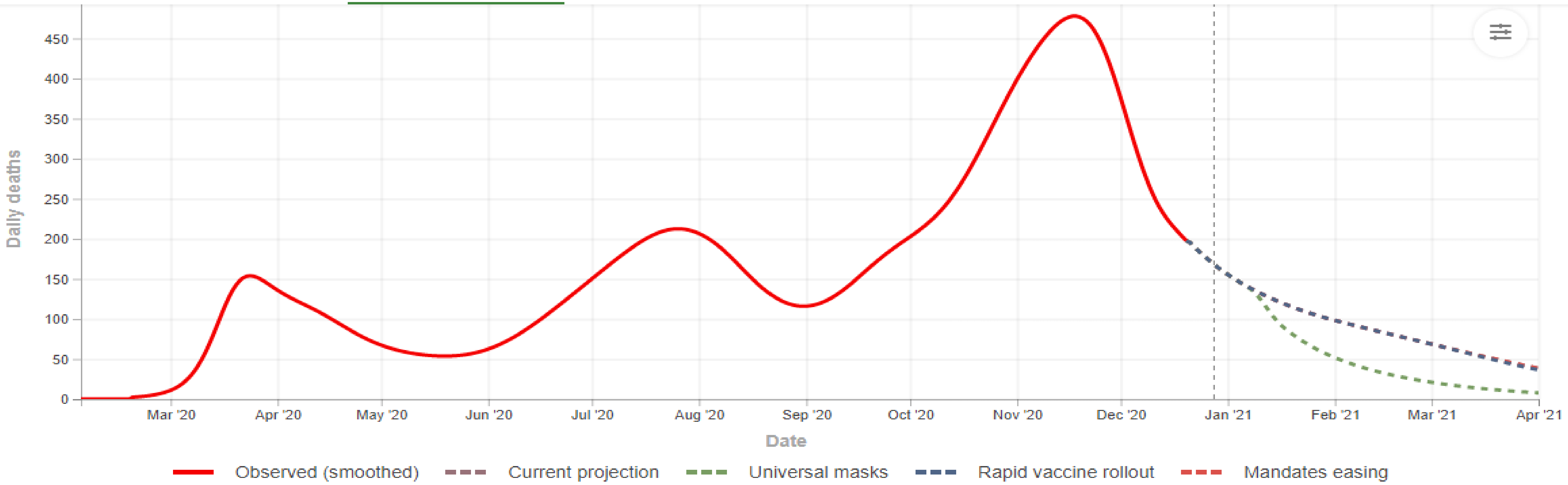
Global
East Asia and Pacific
Australia
> China
Guam

Total deaths | Daily deaths | Mask use | Social distancing

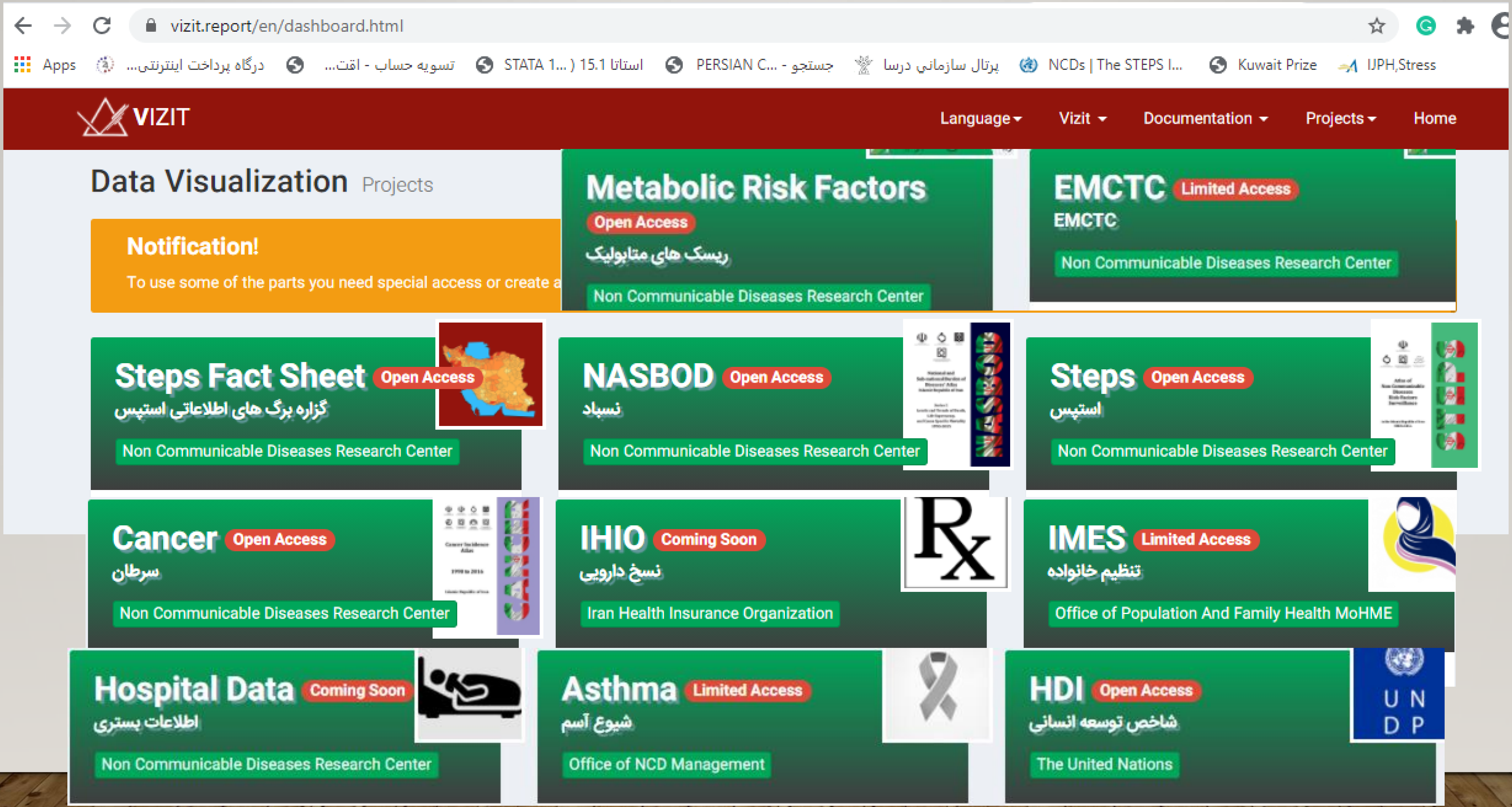
Total deaths

Trend | Compare | Map

Total deaths | Daily deaths | Infections and testing | Hospital resource use | Mask use | Social distancing



All deaths specific to COVID-19 patients.


vizit.report/en/dashboard.html
Apps
درگاه پرداخت اینترنتی...
تسویه حساب - اقت...
STATA 1...) 15.1 استاتا
PERSIAN C... - جستجو
پرتال سازمانی درسا
NCDs | The STEPS I...
Kuwait Prize
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VIZIT
Language
Vizit
Documentation
Projects
Home
Data Visualization
Projects
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Steps Fact Sheet
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NASBOD
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Cancer
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IHIO
Coming Soon
نسخ دارویی
Iran Health Insurance Organization
IMES
Limited Access
تنظیم خانواده
Office of Population And Family Health MoHME
Hospital Data
Coming Soon
اطلاعات بستری
Non Communicable Diseases Research Center
Asthma
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شیوع آسم
Office of NCD Management
HDI
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شاخص توسعه انسانی
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U N
D P

RAPID CASE IDENTIFICATION

- Early and rapid case identification is crucial during a pandemic for the isolation of cases and appropriate contacts in order to reduce onward spread and understand key risks and modes of transmission.
- Digital technologies can supplement clinical and laboratory notification, through the use of symptom-based case identification and widespread access to community testing and self testing, and with automation and acceleration of reporting to public-health databases.
- Case identification by online symptom reporting, as seen in Singapore and the UK, is traditionally used for surveillance, but it now offers advice on isolation and referrals to further healthcare services, such as video assessments and testing. These services can be rapidly implemented but must be linked to ongoing public-health surveillance and to action, such as isolation of cases and quarantining of contacts. Although this approach is suitable for symptomatic people, widespread testing of people and populations, as well as contact tracing, has a crucial role in case identification, as an estimated 80% of COVID-19 cases are mild or asymptomatic.

DELAYS BETWEEN SAMPLING, SENDING SAMPLES TO CENTRALIZED LABS, WAITING FOR RESULTS AND FOLLOW-UP

- Sensors, including thermal imaging cameras and infrared sensors, are being deployed to identify potential cases on the basis of febrile symptoms (for example, at airports). The large numbers of false-positive and false-negative results mean that this is unlikely to have a substantial effect beyond increasing awareness.
- Several point-of-care COVID-19 PCR tests are in development; however, their use is still limited to healthcare settings. Drive-through testing facilities and self-swab kits have widened access to testing. There are inherent delays between sampling, sending samples to centralized labs, waiting for results and follow-up. By contrast, point-of-care rapid diagnostic antibody tests could be implemented in home or community or social-care settings and would give results within minutes. Linking to smartphones with automatic readout through the use of image processing and machine-learning methods could allow mass testing to be linked with geospatial and patient information rapidly reported to both clinical systems and public-health systems and could speed up results. For this to work effectively, standardization of data and integration of data into electronic patient records are required. Machine-learning algorithms are also being developed for case identification by automated differentiation of COVID-19 from community-acquired pneumonia through the use of hospital chest scans by computerized tomography.

INTERRUPTING COMMUNITY TRANSMISSION

- After case identification and isolation, rapid tracing and quarantining of contacts is needed to prevent further transmission.
- In areas of high transmission, the implementation and monitoring of these interventions is needed at a scale that is becoming increasingly unfeasible or at least challenging by traditional means.

DIGITAL CONTACT TRACING

- Digital contact tracing automates tracing on a scale and speed not easily replicable without digital tools. It reduces reliance on human recall, particularly in densely populated areas with mobile populations. In the COVID-19 pandemic, digital contact-tracing apps have been developed for use in several countries; these apps rely on approaches and technologies not previously tried on this scale and are controversial in terms of privacy. Evaluating their accuracy and effectiveness is essential. Early digital tracing initiatives raised concerns about privacy.
  In South Korea, contacts of confirmed cases were traced through the use of linked location, surveillance and transaction data.
- In China, the AliPay HealthCode app automatically detected contacts by concurrent location and automated the enforcement of strict quarantine measures by limiting the transactions permitted for users deemed to be high risk. More-recent voluntary contact-tracing apps have been launched in collaboration with governments; these collect location data by global positioning system (GPS) or cellular networks, proximity data collected by Bluetooth or a combination of those.

DIGITAL CONTACT TRACING

- A key limitation of contact-tracing apps is that they require a large proportion of the population to use the app and comply with advice for them to be effective in interrupting community transmission (effective reproduction number (R<1).
- Placing this in perspective, national uptake of the TraceTogether app in Singapore had reached only 30% as of June 2020. Adoption is also limited by smartphone ownership, user trust, usability and handset compatibility. Key practical issues remain, such as understanding which contacts are deemed to be close enough for transmission and when exposure time is considered long enough to trigger an alert.
  System effectiveness in identifying transmission events is not well described, and it is therefore arguable that human interpretation is still important.

DIGITAL CONTACT TRACING

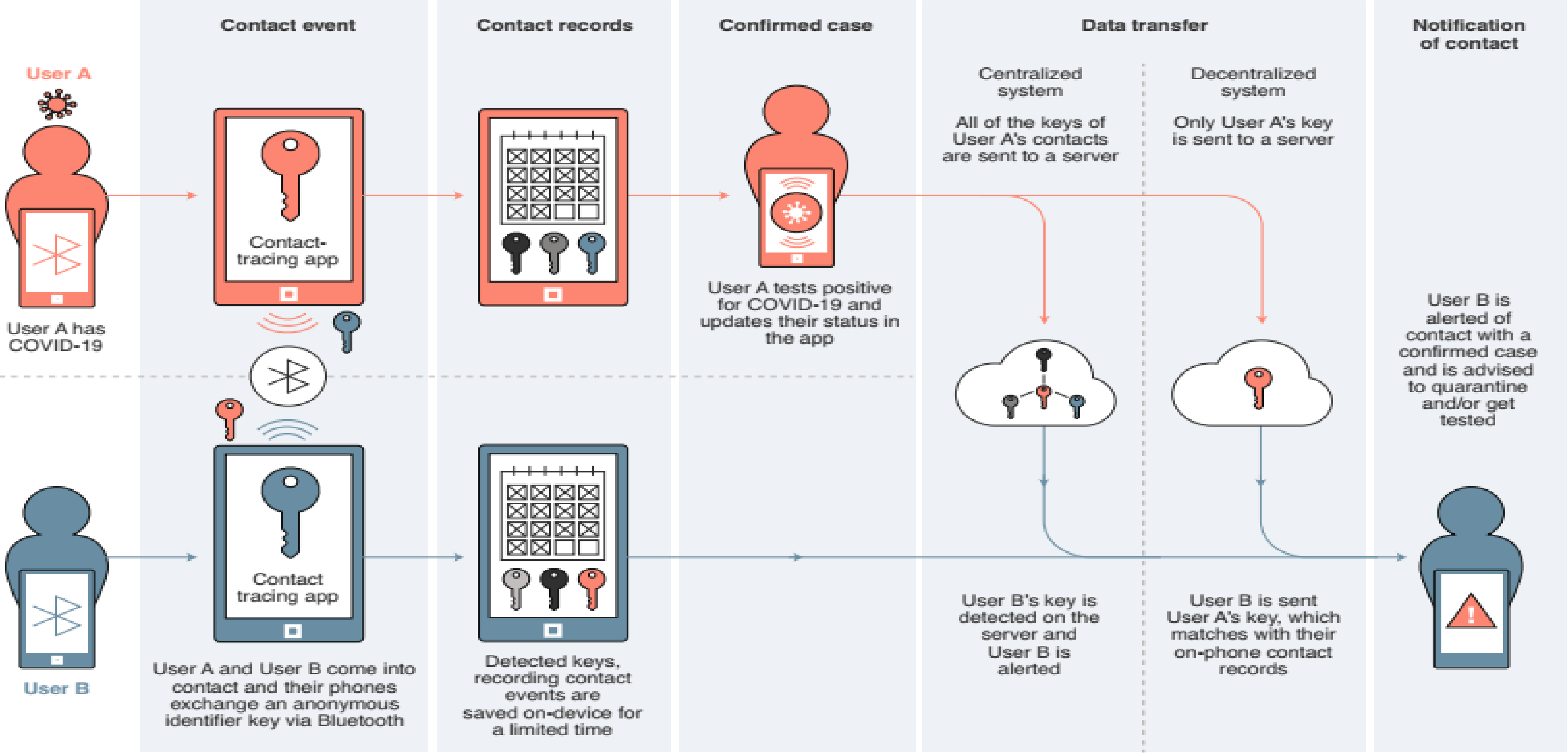

Fig. 2 | Contact tracing for COVID-19 with Bluetooth-enabled smartphone apps. Proximity-detecting contact-tracing apps use Bluetooth signals emitting from nearby devices to record contact events. Centralized apps share information about contacts and contact events with a central server. The centralized TraceTogether app[72] uploads information when a user reports testing positive for COVID-19. Some centralized Bluetooth-enabled contact-tracing apps upload the contact graph for all users[148]. Decentralized apps, such as SwissCovid[149], upload only an anonymous identifier of the user who reports testing positive for COVID-19. This identifier is then broadcast to all users of the app, which compares the identifier with on-phone contact-event records.

EVALUATING INTERVENTIONS THROUGH THE USE OF MOBILITY DATA

- Aggregated location data collected by smartphones via GPS, cellular network and Wi-Fi can monitor real-time population flows, identify potential transmission hotspots and give insight into the effectiveness of public-health interventions such as travel restrictions on actual human behavior. Access to mobility data is a major challenge, and these approaches have raised ethical and privacy concerns.
  Mobility data with privacy-preserving aggregation steps have recently been made available by several technology and telecom companies for the purposes of COVID-19 control; however, the datasets are limited and there is no long-term commitment in place for data sharing.

EVALUATING INTERVENTIONS THROUGH THE USE OF MOBILITY DATA

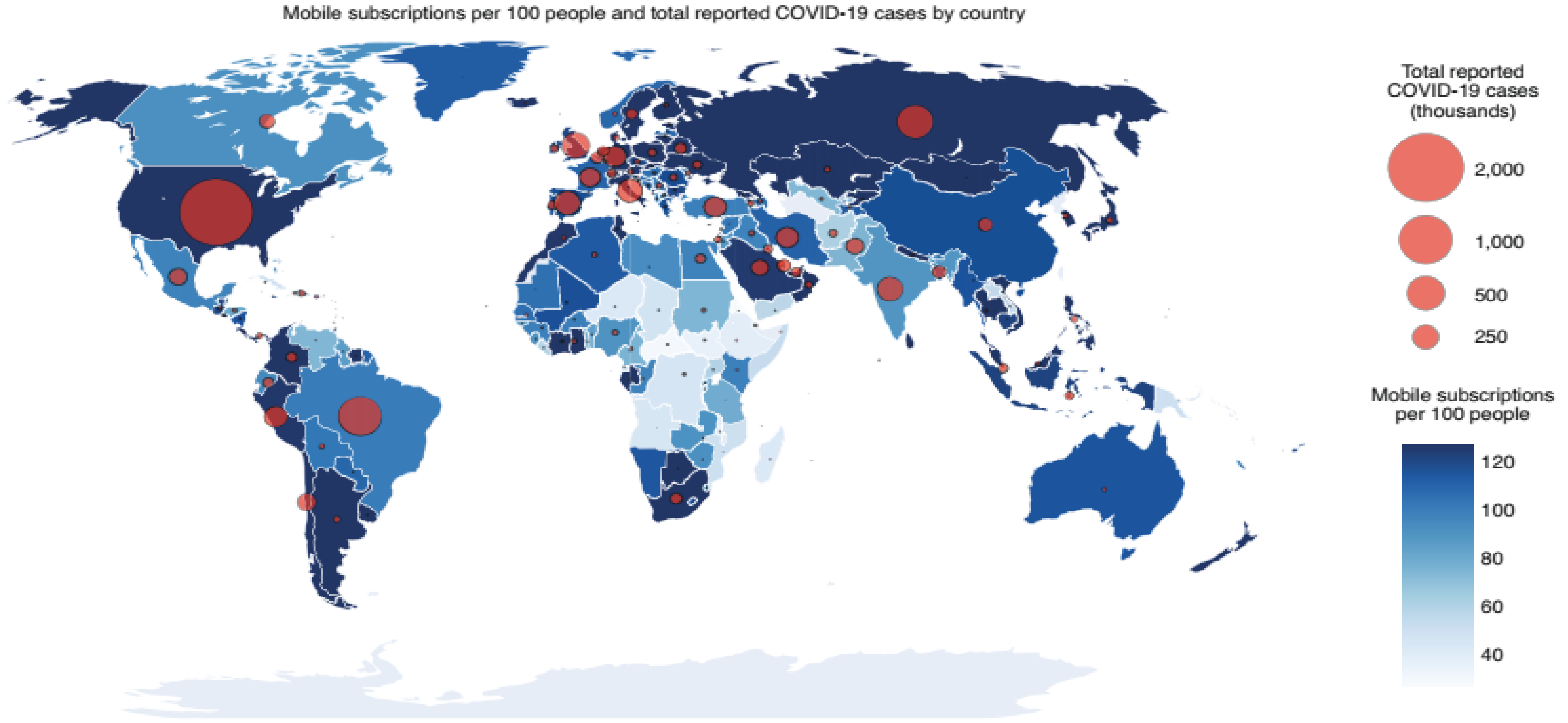

Fig. 3 | The global reach of mobile phones to areas affected by COVID-19. Mobile subscriptions per 100 people (blue; International Telecoms Union[150], 2018) and reported COVID-19 cases by country (red; WHO[151], 8 June 2020). COVID-19 is a global pandemic, yet some countries may be better resourced than others to respond with digital health interventions. There may be intra-country inequalities in mobile subscription rates. Case detection and reporting practices differ among countries, with variable under-reporting of true cumulative case counts.

EVALUATING INTERVENTIONS THROUGH THE USE OF MOBILITY DATA

- Analysis of the location data of Italian smartphone users estimated a reduction of 50% in the total trips between Italian provinces in the week after the announcement of lockdown on 12 March 2020.
- Google has released weekly mobility reports with sub-national granularity, including breakdown by journey type and destination (such as workplaces and parks), and has made their dataset publicly downloadable.
- Apple has similarly released a dataset with daily figures for mobility and assumed method of transport. There is no standardization of these datasets between providers, however, and not all countries or regions are included in these datasets.
  This contextual information can provide insight into the effect of interventions to slow transmission, including the impact of handwashing, social distancing and school closures. The monitoring of social-distancing measures could also be used to forecast health-system demands and will be important in assessing the easing of restrictions when appropriate.

PUBLIC COMMUNICATION: INFORMING POPULATIONS

- Effective implementation of interventions during a pandemic relies on public education and cooperation, supported by an appropriate communications strategy that includes active community participation to ensure public trust.
- With 4.1 billion people accessing the internet and 5.2 billion unique mobile subscribers, targeted communication through digital platforms has the potential to rapidly reach billions and encourage community mobilization.
- Key challenges persist, including the rise of potentially harmful misinformation and digital inequalities.
- Online data and social media have had an ongoing, important role in public communication.
- A United Nations study found that 86% of member states had placed COVID-19 information on national websites by early April 2020, and many are using text messaging to reach populations who do not have access to the internet.
- Chat-bots are also providing information to reduce the burden on non-emergency health-advice call centers, and clinical practice is being transformed by the rapid adoption of remote health-service delivery, including telemedicine, especially in primary care Digital communication platforms are also supporting adherence to social-distancing measures.
- Video conferencing is allowing people to work and attend classes from home, online services are supporting mental health and digital platforms are enabling community-mobilization efforts by providing ways to assist those in need.

IMPLEMENTATION

- Digital technologies cannot operate in isolation and need to be integrated into existing public healthcare systems. For example, South Korea and Singapore successfully introduced contact-tracing apps to support large teams of manual contact tracers as one of many measures, including strict isolation of cases and quarantine. Digital data sources, like any data source, need to be integrated and interoperable, such as with electronic patient records. Analysis and use of these data will depend on the digital infrastructure and readiness of public-health systems, spanning secondary, primary and social-care systems. Looking ahead, there is a need for a systems-level approach for the vision of the ideal fit-for-purpose digital public-health system that links symptom-tracking apps, rapid testing and case isolation, contact tracing and monitoring of aggregated population-mobility levels, access to care and long-term follow-up and monitoring, with public communication (Fig. 4). These types of integrated online care pathways are not new concepts, having been shown to be highly acceptable and feasible for other infectious diseases, such as chlamydia.

IMPLEMENTATION

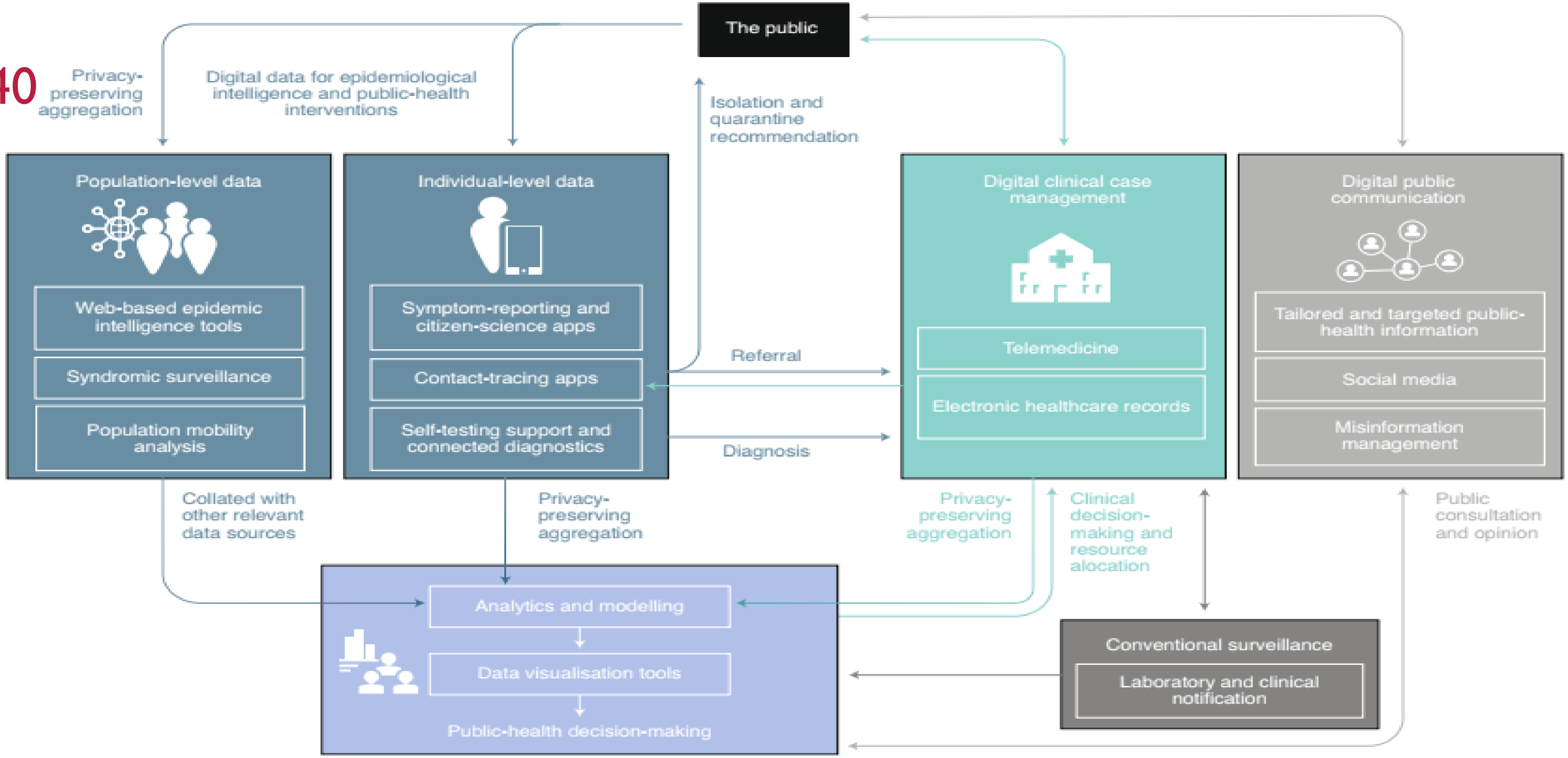

Fig. 4 | The flow of information in a digitally enabled and integrated public-health system during an infectious-disease outbreak. Digital data are created by the public, both at the population level and at the individual level, for epidemiological intelligence and public-health interventions, and for the support of clinical case management. They are also informed by conventional surveillance via laboratory and clinical notification. This feeds into public-health decision-making and communication with the public through digital channels. Other relevant sources of information include population, demographic, economic, social, transport, weather and environmental data.

DATA SHARING AND DATA QUALITY

- Big-data and artificial-intelligence approaches are only as good as the empirical datasets that are put into them, yet detailed public-health and private datasets are often inaccessible, due to privacy and security concerns, and often lack standardized formats or are incomplete. Researchers are calling for technology and telecom companies to share their data in a 'proportionate, ethical and privacy-preserving manner', often citing a moral imperative for these companies to contribute where there is justification for data use. Some companies are making subsets of aggregated data available. These data are not consistent and are not provided within the same timeframe, and there is no standard format or long-term commitment. Researcher-led international collaborations have aimed to aggregate multiple international data sources of voluntarily reported information.

EVIDENCE OF EFFECTIVENESS AND REGULATION

- Evidence of the effectiveness of any new technology is needed for wider adoption, but as the current pandemic is ongoing, many digital technologies have not yet been peer-reviewed, been integrated into public-health systems, undergone rigorous testing or been evaluated by digital health-evidence frameworks, such as the evidence standards framework for digital health technologies of the National Institute for Health and Care Excellence.
- Contact-tracing apps have been launched in at least 40 countries, but there is currently no evidence of the effectiveness of these apps, such as the yield of identified cases and contacts, costs, compliance with advice, empirical estimates of a reduction in the R value or a comparison with traditional methods. Although it is challenging, due to the urgency of the pandemic, evaluation of the effectiveness of interventions is essential. Researchers, companies and governments should publish the effectiveness of their technologies in peer-reviewed journals and through appropriate clinical evaluation.
  There is an urgent need for coordinated international digital public-health strategies, but these have been slow to emerge.
- On 22 March 2020, the WHO release a draft of its global strategy on digital health for 2020–2024.
- On 8 April, the European Union called for a pan-European approach on the use of apps and mobile data for COVID-19

43 LEGAL, ETHICAL AND PRIVACY CONCERNS

- Highly granular or personal data for public-health surveillance raises legal concerns, ethical concerns and security and privacy concerns. Not all digital interventions have allowed consensual adoption or have made the option of consent for specific purposes explicit, and some have been used to enforce measures as well as to monitor them. In many cases, widespread adoption is related to effectiveness, which highlights the need for public trust and engagement. There is concern that emergency measures set precedent and may remain in place beyond the emergency, which will lead to the ongoing collection of information about private citizens with no emergency-related purpose. All systems will need to be 'proofed' against invasions of privacy and will need to comply with appropriate legal, ethical and clinical governance. Data can be shared under a legal contract for a well-defined purpose and time, with requirements for independent audit to ensure data are not used for purposes outside ofthe pandemic. Dynamic consent processes could also allow users to share their data, and privacy-preserving technologies, such as differential privacy and homomorphic encryption, could ensure that access is possible only for specific purposes and is available in a tamper-proof manner to allow auditing.

INEQUALITIES AND THE DIGITAL DIVIDE

- In 2018, the World Health Assembly Resolution on Digital Health recognized the value of digital technologies in advancing universal health coverage and the Sustainable Development Goals. Although trends are narrowing, today there remains a digital divide, and 51% of the world's population does not subscribe to the mobile internet. The lack of access to mobile communications is seen in low- and middle-income countries, although people with lower socio-economic status in high-income countries are also affected. The Pew Research Center reported large disparities between people 18–29 years of age and those over 50 years of age in their mobile-communication access.

  There are also reports of restricted mobile internet access, such as in areas of Myanmar, which have left some populations unware of the pandemic. This outbreak has also disproportionately affected some communities, such as Black and minority ethnic groups, more than others. It is therefore essential to develop tools and messaging that are accessible and can be tailored to specific risks, languages and cultural contexts.

CONCLUSION

- The COVID-19 pandemic is ongoing, and it is too early to fully quantify the added value of digital technologies to the pandemic response. While digital technologies offer tools for supporting a pandemic response, they are not a silver bullet. The emerging consensus is that they have an important role in a comprehensive response to outbreaks and pandemics, complementing conventional public-health measures, and thereby contribute to reducing the human and economic impact of COVID-19. Cost-effectiveness and sustainability will require systems-level approaches to building digital online care pathways that link rapid and widespread testing with digital symptom checkers, contact tracing, epidemiological intelligence and long-term clinical follow up. The COVID-19 pandemic has confirmed not only the need for data sharing but also the need for rigorous evaluation and ethical frameworks with community participation to evolve alongside the emerging field of mobile and digital healthcare. Building public trust through strong communication strategies across all digital channels and demonstrating a commitment to proportionate privacy are imperative.

CONCLUSION

- Digital epidemiology uses "data that was not generated with the primary purpose of doing epidemiology" (Salathé 2018: 2).
- Digital epidemiology
  - is not based on a statistical research design,
  - therefore, the data generating mechanisms are unknown.
  - Population coverage is not complete or unknown,
  - so no valid inferences by design-based approaches are possible.

- Methods of digital epidemiology require access to devices and motivation to participate.
- Availability must be given in all population subgroups, or the relationship between availability and the variable of interest must be known.
- Neither Smartphones nor fitness trackers are uniformly distributed in a population, nor is the functional relationship between their use and health status known.
- Population studies based on this kind of devices will have coverage and nonresponse problems, which in general are studied in Survey Methodology (Biemer/Lyberg 2003).
- We use the bias model of Bethlehem/Biffignandi (2012), initially developed to explain bias in non-probability surveys, as theoretical framework for our argumentation.
- Subgroups owning and using a smartphone or fitness tracker are considered as non-probability samples.

REFERENCES

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Jobie Budd[1,2], Benjamin S. Miller[1], Erin M. Manning[1], Vasileios Lampos[3], Mengdie Zhuang[4], Michael Edelstein[5], Geraint Rees[6], Vincent C. Emery[7], Molly M. Stevens[8], Neil Keegan[9], Michael J. Short[10], Deenan Pillay[11], Ed Manley[12], Ingemar J. Cox[3,13], David Heymann[14], Anne M. Johnson[15] and Rachel A. McKendry[1,2] ✉