Open

Original Article

The impact of digital technology on health of populations affected by humanitarian crises: Recent innovations and current gaps

Sandra Mesmar[a], Reem Talhouk[b], Chaza Akik[a], Patrick Olivier[b], Imad H. Elhajj[c], Shady Elbassuoni[d], Sarah Armoush[e], Joumana Kalot[e], Madeline Balaam[b], Aline Germani[e], and Hala Ghattas[a,*]

[a]Center for Research on Population and Health, Faculty of Health Sciences, American University of Beirut, P.O.Box 11-0236/EPHD, Riad El Solh, Beirut 1107 2020, Lebanon

[b]Open Lab, Newcastle University, Newcastle upon Tyne, UK

[c]Department of Computer and Communications Engineering, Faculty of Engineering and Architecture, American University of Beirut, Beirut, Lebanon

[d]Department of Computer Science, Faculty of Arts and Sciences, American University of Beirut, Beirut, Lebanon

[e]Center for Public Health Practice, Faculty of Health Sciences, American University of Beirut, Beirut, Lebanon

*Corresponding author. E-mail: hg15@aub.edu.lb

Abstract Digital technology is increasingly used in humanitarian action and promises to improve the health and social well-being of populations affected by both acute and protracted crises. We set out to (1) review the current landscape of digital technologies used by humanitarian actors and affected populations, (2) examine their impact on health and well-being of affected populations, and (3) consider the opportunities for and challenges faced by users of these technologies. Through a systematic search of academic databases and reports, we identified 50 digital technologies used by humanitarian actors, and/or populations affected by crises. We organized them according to the stage of the humanitarian cycle that they were used in, and the health outcomes or determinants of health they affected. Digital technologies were found to facilitate communication, coordination, and collection and analysis of data, enabling timely responses in humanitarian contexts. A lack of evaluation of these technologies, a paternalistic approach to their development, and issues of privacy and equity constituted major challenges. We highlight the need to create a space for dialogue between technology designers and populations affected by humanitarian crises.
Journal of Public Health Policy (2016) 37, S167–S200.
doi:10.1057/s41271-016-0040-1

Keywords: digital; humanitarian; refugee; health

The online version of this article is available Open Access

Introduction

In 2016, 37 countries are facing humanitarian crises. The UN Office for the Coordination of Humanitarian Affairs (UNOCHA) estimates that 88 million people are in need of humanitarian assistance globally.[1] The recent influx of refugees into Europe highlights the political, social, and economic complexities that result in displacement both within and across borders. Traditional and social media coverage of these events has increased awareness of the plight of refugees, and highlighted how digital technologies have become essential tools for humanitarian workers and affected populations alike.[2]

Digital technology allows for storage and analysis of large amounts of data using electronic devices.[3] Since the response to the Haiti earthquake in 2010, in which social media, text messages, and satellite imagery played an important role,[4] the use of digital technology in humanitarian action is now viewed as both "essential and inescapable."[5] Such technologies underpin the functions of many humanitarian actors, including data collection, data analysis, information dissemination, coordination, advocacy, and fundraising. Networks of technicians have also been established to provide data analysis and geospatial technical assistance to humanitarian organizations.[6]

The potential of digital technologies to support the health and social well-being of populations affected by humanitarian crises lies in their use to better understand complex situations and the needs of the affected communities, facilitating humanitarian response efforts, and engaging the affected populations in the response.[5] Our objectives were to (1) review the current landscape of digital technologies used by humanitarian actors and affected populations, (2) examine their impact on the health and well-being of affected populations, and (3) consider the opportunities for and the challenges faced by users of these technologies.

Methods

We conducted a systematic literature search to identify reports of the use of digital technologies to improve health assistance, health, or its determinants in populations affected by humanitarian crises. These

populations were defined as people exposed to natural disasters, war, armed conflicts, or rescue missions, including displaced populations, refugees, forced migrants, or evacuated populations. Digital technologies refer to both hardware and software applications such as (but not limited to) mobile and desktop computers, telemedicine, telehealth, eHealth, and mHealth. We included studies or reports dating from 2005 to 2015 that aimed to improve the health of displaced populations or to facilitate the health work of humanitarian organizations. We excluded news articles, blogs, media reports, theoretical models of technology, and disaster planning documents, monthly and weekly updates from humanitarian agencies, and opinion pieces as well as reports about economic migrants. We also excluded initiatives that focused on shelter, water, sanitation and hygiene improvements, as they generally focused on the engineering of infrastructure, and were more than one degree removed from health.

We searched Medline (our strategy is included in Supplementary Material), Embase, Global Health, PyschInfo, Popline, and the Association for Computing Machinery (ACM) Library for published literature, and used Google to locate reports of projects for displaced populations, digital technology, disaster context, and health. We included peer-reviewed articles, books, book chapters, periodic reports, one-time reports, and websites published between 2005 and 2015. No language restrictions were placed on the search. We imported the articles and reports retrieved into Endnote X7 and removed duplicates. Two researchers conducted title-abstract and full-text screening independently according to the inclusion criteria outlined. Figure 1 presents the resulting review flow chart.

Results

The findings of this landscape review are structured according to an organizational framework illustrated in Figure 2. They are divided into technologies used by humanitarian actors and those used by populations affected by crises. Digital technologies are used in humanitarian programming to facilitate various functions of the preparedness for, response to, and recovery from emergencies, supporting health assistance and health and its determinants.[7] We identified a set of digital technology initiatives used largely by those affected by humanitarian crises and that

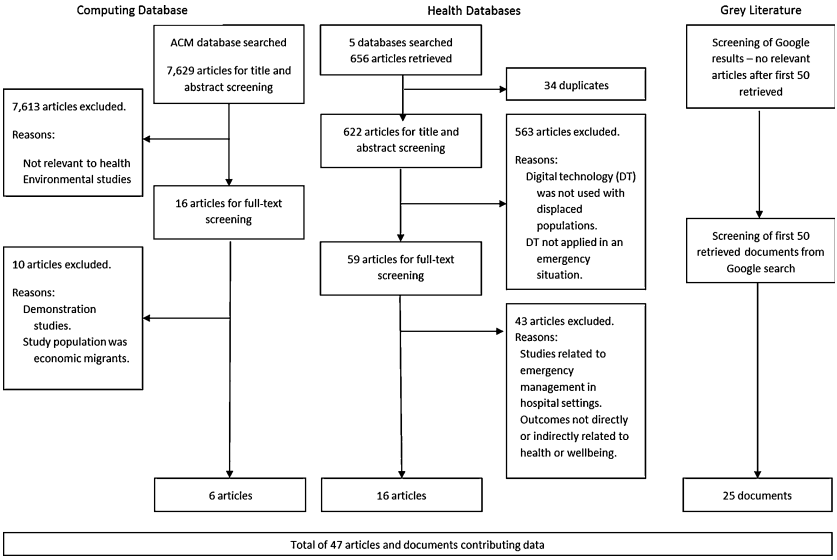

Figure 1: Flow chart for the review of the literature on digital technologies to improve health in humanitarian crises

can impact the various determinants of health including income, education, social support, access to healthcare services and others.[8]

Table 1 summarizes the number of articles or reports we found through the systematic search for different types of digital technologies, defines these technologies, and categorizes them by user (humanitarian versus affected population).

Technology Used by Humanitarian Actors

Table 2 summarizes the technologies used by humanitarian actors and aid workers, the context in which they have been deployed, their purpose, impact, and at what point in the humanitarian program cycle they have been used (preparedness, response, or recovery).

Humanitarian crisis preparedness

Five initiatives were found that use technologies in preparedness, of which geographical information systems (GIS) has been a major game changer. GIS now underpins risk assessments, vulnerability models, and spatial decision support systems (SDSS) that predict outbreak and

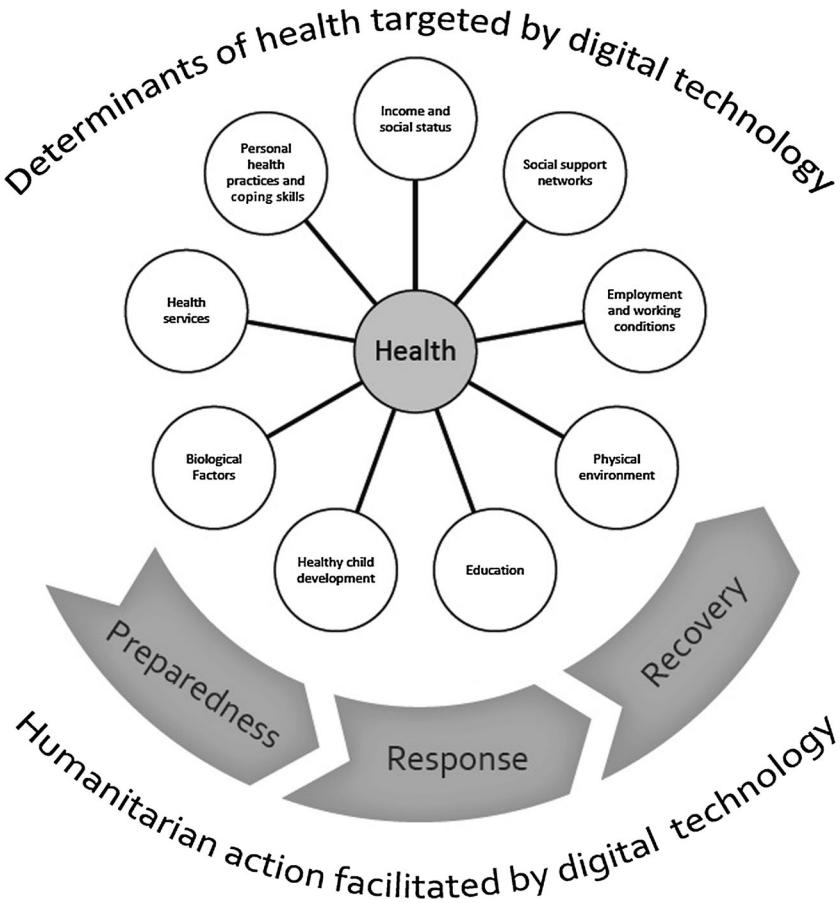

Figure 2: Digital technology can play a role in facilitating humanitarian action and improving the determinants of health. Adapted from Inter-agency Standing Committee's Humanitarian Program Cycle and Determinants of Health from Health Canada[7,8]

spread of diseases.[9,10,63,64] Examples include disease surveillance systems that assess disease risk during natural disasters, and emergency preparedness of households with specific health needs.[63,64] These systems have been found to enable continuity of care throughout a disaster.[63,64]

Another important element of preparedness is training. Game-based simulation exercises have been used to improve humanitarian responses and reduce evacuation time [See Table 2; mixed reality triage and evacuation (MiRTE)].[11]

Table 1: Types of technologies retrieved, their definitions, and articles/documents that refer to these by user of technology

Type of technology		*Number of articles/documents retrieved by user of technology*	
Technology	*Definition*	*Humanitarian organization*	*Displaced population*
Digital classrooms/instant classrooms Digital story telling	A tool kit with built-in 3G network, loaded with e-books, HD hand-held cameras, graphic design and video software, documentaries, movies, arts and crafts materials, projector, Games, and one built-in stage for musical and theatrical representations		2[42,51]
Digital communication	Communication between agencies and decision making	2[29,66]	
Electronic health records	An electronic version of a patient's medical history and records, maintained by the health care provider over time, and may include administrative and clinical data relevant to the persons' care	4[5,37–39]	
Electronic voucher (e-voucher) cash cards	Mobile network operators work with humanitarian organizations to provide financial mobile money services where vouchers are given and can be topped up at recharge machines using landline connection		3[18,43,50]
Gaming	The use of digital games that take place in both reality and virtual reality	1[11]	
GIS	A system that allows for the portrayal of multiple layers of data on interactive maps	12[5,9,10,18,22,24–26,32,48,59]	1[60]
Hand-held electronic data entry	Input biographical data to identify those in need	5[18,20,21,49,64]	
Low-cost computers	Credit card sized computer that can be inserted in monitors or small motherboards preloaded with educational material and act as information portals to access education in areas with intermittent internet access		1[18]
Portable medical equipment	Medical devices that have been redesigned to be compact and portable	1[33]	

Robotics	The use of programmable machines	2[30,31]	
Social media	Websites and applications that allow content sharing to create a network of shared users	4[12,13,27,28]	1[46]
SMS (and radio talk, radio and television talk shows)	Text messaging service information is given on early warning alerts and local assistance numbers	1[34]	1[5]
Spatial decision support system (SDSS)	Interactive system that assists decision making while taking into account spatial dimensions	2[61,67]	
Spoken Language Translation in the medical domain	Translates spoken language to healthcare providers	1[41]	
Surveillance Systems	The collection, analysis and interpretation of health data to guide interventions in real time	8[13,15–17,35,36,63,65]	
Website	A group of webpages that are connected to each other and can be accessed through the internet	2[5,40]	
3D Printing	Low-cost digitally fabricated prosthetics and fabrication laboratories equipped with laser cutters, vinyl cutters, milling machines, 3D printers, and scanners	1[47]	1[47]
Total		47	

Table 2: Digital technology used by humanitarian actors, aid workers, and healthcare providers, its purpose, and impact

Type of technology	*Name of technology*	*Organization/Country and context technology deployed*	*Purpose of technology*	*HPC stage*[a]	*Impact of technology*
Digital communication and coordination technologies	Syria Regional Refugee Response[29]	*Governmental Agencies, Academics NGOs, UN agencies*/MENA countries hosting Syrian refugees	Portal where multiple stakeholders can view resources to be able to communicate and share information to improve decision making	Response	Not reported
	Google Hangout[66]	*N/A*/Japan 2011 earthquake		Response	Not reported
Electronic health records	N/A[38]	*UNRWA*/Palestinian refugees in Jordan	Evaluation of chronic disease control interventions by primary healthcare centers	Preparedness Response Recovery	Not reported
	Refugee Assistance Information system[37]	*UNHCR and partnering humanitarian agencies*/Iraqi refugees in Jordan	Monitoring and evaluating the health status of Iraqi refugees registered with UNHCR	Preparedness Response Recovery	Not reported
	Japan's Health Management System[5]	*Japan's National Institute of Public Health*/Japan's post 2011 earthquake	Maintenance of electronic health records in cases of disasters on a cloud-based system	Preparedness and Response	Not reported
Geographical information system	Activity Info[18]	*WASH Mercy Corps UNICEF*/ Displaced populations in Mali Somalia and DRC	Multiple stakeholders can view resources to be able to communicate and share information to improve decision making	Response	Not reported
	Strategic Needs Analysis Project (SNAP)[22]	*Assessment Capacities Project* provides this service to be accessed by NGOs and governmental agencies/Portrays areas of conflict in Syria	Documenting intensity of conflict and number of people in need of aid in Syria and surrounding countries	Response	Not reported

Ushahidi[60]	*Victims of violence and Ushahidi*/Natural disasters such as those in Haiti, Chile, and Pakistan	SMS, Twitter, Facebook, and Flicker were used to provide OCHA a live crisis map showing the movement of people, health	Response	Not reported
Libya Crisis Map[5]	*OCHA*/Crisis in Libya	logistics, and security allowing for communication between agencies. This allowed general population to input data, enabling two-way communication	Response	Rich data was integrated into the United Nations' (UN) official Who-is-doing-What-Where (3W) aiding coordination. Led to the launch of the Digital Humanitarians Network
N/A[48]	*Humanitarian agencies*/Haiti Earthquake		Response	Not reported
N/A[59]	*Governmental agencies and NGOs*/Haiti cholera outbreak	The use of mobile SIM card reports was used for risk assessment of cholera outbreak (by tracking population movements) and notification of those in high-risk zones for disease containment and risk aversion	Response	Estimates of population movements during disasters and outbreaks can be delivered rapidly to organizations and with potentially high validity in areas with high mobile phone use
Humanitarian OpenStreetMap Team (HOT)[25]	*NGOs*/Ebola outbreak in West Africa	Assessment of the risk of Ebola outbreak and notification of those in high-risk zones through portrayal of resources and sharing information between stakeholders	Response	Not reported

Table 2: *continued*

Type of technology	*Name of technology*	*Organization/Country and context technology deployed*	*Purpose of technology*	*HPC stage*[a]	*Impact of technology*
	N/A[26]	*UNHCR*/N/A	Tracking the distribution of aid and incidence of communicable diseases	Response	Not reported
	N/A[24]	*NGOs*/Japan 2011 earthquake	Directed supplies according to the demands of communities affected by the 2011 earthquake. Supplies were matched with needs via website	Response	Not reported
	HumanNav[5]	*World Food Program and International Federation of Red Cross (IFRC) UNHCR*/N/A	Evaluation of security and road safety of delivery routes and the effectiveness of vehicles	Response	Not reported
	N/A[9]	*Academics*/2004 Tsunami in Aceh	Conducting vulnerability models and spatial decision support systems to create models that help predict the outbreak and spread of diseases	Preparedness and Response	Tsunami mortality rate in Aceh estimated by demographic models was similar to official figures (131,066 and 128063, respectively)
	N/A[10]	*N/A*/Dadaab refugee camps in Kenya	Risk assessment of cholera outbreaks in order to notify and create models that help predict the outbreak and spread of diseases	Preparedness and Response	Not reported
GIS and type of spatial decision support system (SDSS)	N/A[67]	*Academics*/N/A	Decision-making and problem-solving tool to help inform and coordinate where to evacuate crisis victims from the scene of the incident	Preparedness	Not reported

Hand-held devices and data entry	Support to Life[18]	*Support to Life*/displaced and refugee populations in Turkey, Pakistan, and Georgia	Social workers identify and input data of individuals displaced due to disasters to generate a photo identification card with a barcode to assess and monitor food security and mortality rates	Response	Not reported
	Last Mile Mobile Solutions[49]	*UNICEF*/Displaced populations in Iraq		Response	IOM's Displacement Tracking and Monitoring (DTM) unit conducted registrations covering 3,587 households representing 14,448 individuals in UN House and 4,314 households representing 14,520 individuals in Tomping, South Sudan
	Biometric Technology[20]	*International Organization for Migration*/Displaced populations following disaster South Sudan		Response	The aggregation of data from SMART surveys allowed for the evaluation of mortality and nutrition indicators from conflict affected lands
	Digital surveying using Computer Assisted Personal Interview (CAPI)[21]	*Oxfam*/Post Typhoon in Philippines and in Thailand	Responses can be recorded during interviews on hand-held devices with the aim to achieve food security and sustainable income	Response	Timely and accurate data entry, which allowed for efficient data monitoring as well as tracing accountability while maintaining data security. Potential for coding errors, heightened security risks for data collectors, weather challenges, and inequalities in technological literacy

Table 2: *continued*

Type of technology	*Name of technology*	*Organization/Country and context technology deployed*	*Purpose of technology*	*HPC stage*[a]	*Impact of technology*
	N/A: Survey on handheld devices[64]	*Academics*/Tsunami in southern Thailand	Risk assessment to compare the preparedness behaviors of households with and without special-needs members	Preparedness	Loss of livelihood was significantly associated with 3 mental health outcomes: post-traumatic stress disorder, anxiety, and depression. After the 9-month follow-up survey, prevalence rates of symptoms of post-traumatic stress disorder, anxiety, and depression among displaced persons decreased. Timely and accurate data entry, efficient data monitoring, traced accountability, maintained data security
Healthcare provider communication technologies	Website: Ethnomed[40]	*Healthcare providers*/Seattle, USA	Familiarizing healthcare providers with the cultural beliefs and health issues of refugee communities to improve quality of care given to refugee populations	Preparedness Response Recovery	Not reported
	Medical spoken Language Translation[41]	*British primary healthcare providers*/Somalia	Improving communication between healthcare providers and Somalian refugees to improve the quality of care they receive from healthcare providers	Preparedness Response Recovery	Not reported

Humanitarian Aid Education technologies:	Youtube[5]	*Healthcare providers in Boston*/Syria crisis	Educating doctors in Syria on how to preform lifesaving surgeries	Response	Not reported
	SMS, Social Media: MAMA[34]	*Women's Refugee Commission* *Social Media and Development Company*/ India	Providing humanitarian workers with SMS's and Facebook posts that aim to train healthcare providers and public health practitioners on care provision during crisis	Response	Not reported
	IFRC Website[5]	*IFRC*/N/A	Training volunteers on basic courses through the website	Preparedness Response Recovery	Not reported
	Gaming: MiRTE[11]	N/A (simulation)	Mixed reality triage and evacuation game developed to train users on how to respond to crises and improve decision making by healthcare providers and humanitarian workers during times of mass evacuation	Preparedness	Evacuation time and redundant visits decreased. However, this was a scenario-based evaluation
Humanitarian aid supporting services	Portable Medical Equipment[31]	*Not mentioned*/healthcare providers conduct field work during crises for refugee populations in remote areas	Making health services more accessible during emergencies	Response	Not reported
	Cellophone[33]	*Medecins Sans Frontières*/N/A	Phone application that runs optical tests to test for tuberculosis by analyzing bodily fluids and to measure blood parameters relevant to HIV patients	Response	Not reported

Table 2: *continued*

Type of technology	*Name of technology*	*Organization/Country and context technology deployed*	*Purpose of technology*	*HPC stage*[a]	*Impact of technology*
	3D printing[47]	*Refugee Open Ware*/Zaatari Camp, Jordan	Making health services more accessible during emergencies by 3D printing umbilical cord clippers	Response	Not reported
Robotics	UN/Aid Necessities Transporters[31]	N/A	Improving the delivery of humanitarian aid in hard to access areas	Response	Not reported
	Unmanned aerial vehicles[30]	*UNOCHA*/Haiti & Philippines after Typhoon Yolanda	Demonstrating the scale of the damage and recovery status; rescue and relief through scanning buildings for survivors and mapping those that could not be located due to rubble with infrared cameras	Response	Not reported
Social Media and Geolocation	N/A[14]	*Philippines Government*/ Typhoon in Philippines	Compiling and analyzing data regarding the effects of crisis, creating evacuation and emergency response models that help predict the outbreak and spread of diseases	Preparedness	Not reported
	N/A: social media and geolocation[12]	*Academics*/New York Hurricane Sandy		Preparedness and Response	Not reported
	Cholera Surveillance system[13]	*Academics*/Refugee camps in Kenya	Risk assessment of cholera outbreak to create models that help predict outbreak and spread of disease. The system understands temporal developments and carries out correlations between outbreaks mentioned in Twitter and official sources	Preparedness and Response	Not reported

	Artificial Intelligence for Disaster Response (AIDR)[28]	*Academics*/2013 Pakistan Earthquake	Aggregating tweets, filtering them, and presenting them in an easy-to-use manner to improve communication and decision-making between agencies	Response	In the 2013 Pakistan earthquake, AIDR was able to differentiate between informative and noninformative tweets to improve response
	CrisisLex[27]	*Academics*/Chilean earthquake of 2010 Hurricane Sandy as climate change related events	Aggregating and filtering tweets in order to present them in an easy-to-use manner. Providing a list of terms that can be used when broadcasting during crisis communication between agencies	Response	Not reported
Surveillance systems	Type of Real time Surveillance system[65]	*Houston Department of Health and Human Services*/Hurricane Katrina	Collecting information through web-based forms from evacuees seeking health services inside shelters: demographic information, vital signs, chief complaints, disabilities, chronic conditions, past medical and surgical histories, medication history, exposure to substances or toxic materials, clinical laboratory results, follow-ups recorded, discharge notes, and diagnoses, dialysis requirements, and free text entries for any other information	Preparedness Response Recovery	The surveillance system was able to detect a number of communicable diseases such as (1) respiratory infections, (2) bloody diarrhea, (3) chicken pox and (4) watery diarrhea. The system also allowed for the monitoring of referrals to healthcare providers

Table 2: *continued*

Type of technology	*Name of technology*	*Organization/Country and context technology deployed*	*Purpose of technology*	*HPC stage*[a]	*Impact of technology*
	Type of Real time Surveillance system[17]	*Mississippi Department of Health (MDH) and the American Red Cross (ARC)*/Mississippi Post Hurricane Katrina	A symptom-based, case reporting method was developed and distributed to shelter staff, which was linked with health professionals by a toll-free telephone service. Hotline staff investigated potential infectious disease outbreaks, provided assistance to shelter staff regarding optimal patient care, and helped facilitate the evaluation of ill evacuees by local medical personnel	Preparedness Response Recovery	The system was able to record 8,800 patient encounters. Additionally, outbreaks of psychological and gastrointestinal diseases were detected
	N/A[15]	*Center for disease control*/ Haiti Earthquake	NGO camp clinics voluntarily submitted reports of observed conditions on a daily basis. Improved communication between agencies and decision making	Response	Infrequent and inconsistent reporting between NGOs. This limited the system as it made it difficult to create meaningful geographic disease trend maps

Internet-based forms[16]	*Academics*/Hurricane Katrina, Georgia	Internet-based surveillance forms for evacuation shelters and an internet-based death registry. District epidemiologists, hospital-based physicians, and medical examiners/coroners electronically completed the forms to improve communication between agencies and decision making	Response	As a result of multiple users and multiple clinics submitting forms through the system, both noncommunicable and communicable diseases were detected, and data on mortality were provided
N/A[35]	*Academics*/Hurricane Ike, Galveston, and Chambers counties	Health outcome evaluation focusing on mental health by structured telephone interviews assessing immediate effects of Hurricane Ike (damage, loss, displacement).	Response	The data collected enabled the assessment of mental health morbidity after the crisis. Diseases detected included posttraumatic stress disorder, depressive episodes, and generalized anxiety disorder. Furthermore, it allowed the identification of underlying factors such as lack of clean clothing, money, transportation, water, food, and electricity

Table 2: *continued*

Type of technology	*Name of technology*	*Organization/Country and context technology deployed*	*Purpose of technology*	*HPC stage*[a]	*Impact of technology*
	Phone calls[63]	*Academics*/southeastern/ Southern Pennsylvania evacuation emergency preparedness for special needs.	Risk Assessment to compare the preparedness behaviors of households with and without special-needs members	Preparedness	Not reported
	Fax, e-mail, or telephone[36]	*The Louisiana Department of Health and Hospitals, Office of Public Health (LAOPH)*/Louisiana	Monitoring of chronic and nonchronic diseases for risk assessment	Response	Forms submitted were further reviewed, and patients that warranted further investigation were contacted by telephone. 74 % of the patients contacted were then referred for further follow-up by the office of public health

[a]Humanitarian program cycle.

Humanitarian crisis preparedness and response

Five technologies linked preparedness to response and were used mostly in the context of natural disasters and conflicts. Social media and geolocation technologies inform decision-making and are used by humanitarian personnel to compile and analyze location data to create evacuation and emergency response models.[12–14]

Surveillance systems based on social media were used to assess emerging disease risk, such as cholera-related tweets (Twitter) as an indicator of cholera outbreak in refugee camps in Kenya.[13] This innovative data compilation method allows a temporal analysis of such data and, when combined with GIS and SDSS, can enable the prediction of disease outbreaks and their mortality quite accurately.[9,13] Surveillance of web-based fora allows clinics run by NGOs in camps to submit reports of numbers of cases of disease observed, among vulnerable populations.[15] This aids risk assessment that can improve communication between agencies and support decision-making.[16,17] Finally, use of cloud-based electronic health records can successfully recover health records in case of disasters and damage to physically held records and local databases (See Table 2; Japan's Health Management System).[5]

Humanitarian crisis response

We identified thirty technological initiatives that primarily serve humanitarian responses. Data entry with mobile devices is now widely used to facilitate the registration of displaced individuals, to conduct surveys, identify those in need of assistance, and to capture data on issues such as food security, vaccination rates, and mortality. (See Table 2; Last Mobile Solutions).[18–20] Accurate and timely data entry supported efficient data monitoring and provenance while maintaining data security. Practical challenges, however, include potential for coding errors, heightened security risks for data collection teams, weather challenges, and inequalities in technological literacy.[21]

Geographic information systems (GIS) are used to portray areas of conflict through the creation of live crisis maps that document the intensity of conflict and identify the number of people in need of assistance. They are used for demand-based responsive supply for displaced populations and to create warnings (See Table 2; Ushahidi).[5,22–24] GIS can also be used to track population movements, to

identify those in high-risk zones in cases of disease outbreaks, and to send text messages containing health information that can be sent to those proximal to an outbreak area.[10,25] Technologies that combine GIS and social media have made it possible for humanitarian organizations to aggregate posts and broadcast information to public officials or to rescue and relief organizations (See Table 2; Artificial Intelligence for Disaster Response Crisis Lex).[18,26–29]

When humanitarian response is initiated, GIS can evaluate the security, road safety, and effectiveness of vehicles, to inform logistics, coordination, and evacuation. In addition, unmanned aerial vehicles have been used to deliver humanitarian aid in hard to access areas and to map survivors (See Table 2; UN Aid necessities transporter).[30,31]

Digital technologies such as the internet, SMS, and social media are also used to deliver training for healthcare providers during crises.[32–34] Portable medical devices enable physicians to run tests[32,33] (See Table 2; Cellophone) including eye examinations, tests for tuberculosis, and the identification of biomarkers for HIV positive patients.

Preparedness, response, and recovery

Surveillance systems enable information gathering about displaced populations or evacuees.[65] Data aggregation and analysis are used to detect communicable diseases, and to support follow-up on damage, loss, mental health diagnoses, and chronic conditions.[15–17,35,36]

In addition to the resilience provided by cloud-based electronic health records, they aid the monitoring and evaluation of health status of registered refugees over the longer term, potentially improving continuity of care, especially in protracted crises (See Table 2; Refugee Assistance Information System).[37–39]

Technologies intended to overcome language and cultural barriers include websites and spoken language translators to increase communication and familiarize healthcare providers with cultural beliefs of refugee populations (See Table 2; Ethnomed).[40,41]

Affordable training and education applications can cover all stages of humanitarian programming. The International Federation of the Red Cross, for example, trains its volunteers via an online platform that provides modules and a space for online dialogue and peer review.[5]

Technology Used by Populations Affected by Humanitarian Crises

Although technological initiatives used by displaced populations do not have direct health objectives, they can have indirect effects on health and its physical, social, and economic determinants (See Figure 2). Table 3 summarizes these technologies, the context in which they have been used, their purpose, impact, and the determinants of health that they address.

Education, social support networks, and healthy child development

Low-cost computers and digital classrooms have increased access to education (including health education) for affected populations in low resource settings. Information portals with preloaded content enhance access to information that addresses human rights, protection from violence and abuse, and computing skills (See Table 3; ideas box).[18] By learning collectively through creative media expression and by supporting those who are illiterate, technologies such as digital storytelling provide children with a sense of social inclusion and community interaction to promote mental health, well-being, and healthy child development (See Table 3; Voices Beyond Walls).[42] Feedback from users of such programs suggests the use of simpler activities prior to complex forms of expression. This might mean role-play, dance/movement, and story boarding around topics not tied to struggles of displacement.[42]

Use of SMS during natural disasters can facilitate social support networks. To save lives and property, one initiative received inquiries through SMS and created interactive live radio and television programs for risk coordination and communication (See Table 3; TERA).[5]

Improving income, social status, access to health services, and the physical environment

In emergencies, electronic voucher programs have played a pivotal role and gained recognition as a dignified form of humanitarian assistance that gives affected populations the liberty to use cash for what they deem important (i.e. food, shelter, health, pharmaceuticals, water, sanitation), thereby improving income, social status, and access to health services (See Table 3; WFP's e-voucher program).[43,44,50]

Table 3: Digital technology used by displaced populations, its purpose, and impact

Type of Technology	*Name of Technology*	*Organization/Country and Context Technology Deployed*	*Purpose*	*Determinant of Health*	*Impact of Technology*
Digital classrooms and digital story telling	Voices beyond walls-digital storytelling[42]	*Voices beyond Walls*/Palestinian refugee camps in the West Bank, East Jerusalem, and Jordan	Support for post-traumatic stress disorder Strengthening peace and reducing community tensions	Education Social support networks	Not reported
	Ideas Box[51]	*UNHCR and Vodaphone Foundation*/Displaced children in Syria, Jordan, Lebanon, Iraq, Turkey, Central African Republic, Sudan, Kenya, and Democratic Republic of Congo	Improving sense of security, inclusion for those who are illiterate. Improved information security and risk prevention from rumors and misinformation	Healthy child development	15 % increase in attendance rates in Kenyan schools
Electronic voucher (e-voucher) program	WFP E-voucher program[43–45,50]	*World Food Programme*/ Displaced populations in Kenya, Philippines, and Lebanon	Refugees have the liberty of utilizing cash resources for needs such as shelter, food, health (access to antenatal care), pharmaceuticals, water, sanitation, hygiene products, and cash transfers	Income and social status Health services	Improved financial literacy of refugees. Improved food security. A significant difference in food consumption was observed where recipients had 78 % increase in food consumption scores versus 49 % in non-recipients. Created 1300 jobs and led to 3$ million dollars investments in capital expenditure and increased benefit to Lebanese economy and food products sector. Creates dependence on vouchers, with potential for exacerbations in the status of beneficiaries in case of disruption of transfers

	Support to Life[18]	*Support to Life staff*/Displaced population Turkey	Improving living conditions as well as promoting environmental health	Physical environmental	Not reported
Low cost computers	Raspberry Pi[18]	*UNICEF*/Syrian Refugees in Lebanon	Computer is preloaded with health content and libraries of health videos to improve health literacy. Provides refugees with solutions for provision of healthcare, protection from violence and abuse, and education on human rights. Aims to teach basic computing skills	Education Social support networks Health child development	Not reported
SMS	Trilogy emergency relief application and community outreach program (TERA)[5]	*IFRC*/The 2010 Haiti earthquake and the 2004 Indian Ocean tsunami	Inquiries received are forwarded and shared with community members and used to create interactive live radio and television programs with the aim of improving coordination and risk communication during natural disasters to save lives and property	Physical environment Social support network	Not reported
Social media	Facebook/Twitter[46]	*UNHCR*/Syrian Zaatari camp in Jordan	The accounts are information hubs for camp residents such as schedules for distribution of aid, available job opportunities, and access to services, weather forecast warnings and preparedness, with the aim of improving communication, advocacy, and health promotion	Employment Access to health services	Not reported

Table 3: *continued*

Type of Technology	*Name of Technology*	*Organization/Country and Context Technology Deployed*	*Purpose*	*Determinant of Health*	*Impact of Technology*
3D printing	Refugee open warefare[47]	*Refugee Open Ware*/Residents of Zaatari camp in Jordan	Refugees who have suffered injuries in wars are trained to use 3D printing labs to learn how to print prosthetic body parts. Empowers refugees to be involved in the process of creating solutions to the problems they deem to be important	Health services Personal health practices and coping skills Biology and genetic endowment	Not reported

E-voucher programs have also been used to remunerate those who have helped clear municipal waste from public areas after natural disasters, thus improving living conditions as well as promoting environmental health.[43,45]

Social media platforms such as Facebook and Twitter pages for refugee camps allow information sharing among camp residents (See Table 3; Zaatari camp Facebook page).[46] These platforms have been used for information dissemination about services provided in camps (including health), scheduling of aid distribution, advertising available job opportunities, and for weather forecast warnings.[46]

Personal health practices and coping skills

Thus far, the technologies mentioned have been integrated in marginalized populations with outcomes indirectly impacting health. Whereas personal fabrication technologies have the potential to empower those who have been injured in conflicts, perhaps to 3D print their own prosthetic body parts (See Table 3; Refugee Open Ware).[47]

Discussion

Although many digital technologies do not have direct health objectives, they may have indirect effects on health and its physical, social, and economic determinants. For technologies used by humanitarian actors, our framework categorizes initiatives by the stage in the humanitarian program cycle. We recognize that this limited view of humanitarian action may not apply in protracted emergencies where the lines between preparedness, response, and recovery are blurred. Phases overlap, sometimes for decades, such as is the situation in many long-term crises.

Our results highlight the fact that digital technologies facilitate communication, coordination, and the collection and analysis of large amounts of data, enabling timely responses in humanitarian contexts, particularly sudden-onset disasters. The impacts of these technologies most often include their ability to: assess risk and identify the number and location of people with specific health needs, including health services and assistance; to maintain health records; and to enable follow-up, continuity, and improve quality of care. They have also

provided a platform for the remote training of healthcare professionals and humanitarians, particularly in hard to reach locations, plus facilitated the coordination and logistics of humanitarian assistance with implications for the determinants of health.

The rise of internet activism around issues of social justice, human rights, education, health equity, and sustainable environments are likely to continue to raise awareness, and pave the way for social change and for health promotion for affected populations.

Our attempt to examine the impact of these technologies on the health and well-being of crisis-affected populations has, however, been hampered by the lack of impact assessment in the design and use of these technologies. Here we identify several gaps and concerns with current digital humanitarian practices:

Lack of evaluation

While surveillance systems have been routinely evaluated, including their impact on health outcomes, very few evaluations exist of other uses of digital technologies in humanitarian contexts. Although many technologies promise social change, evaluation models have not been integrated in humanitarian intervention technologies and remain underdeveloped.[46] Most other technologies discuss purpose and lessons learned with no other evaluative framework.[48] Specified criteria for assessment were often described, but for many technologies, we found neither methodologies nor evaluation reports.[18,49–51,63] Where methods were described, deficiencies included shortcomings in the reporting of denominators and response rates.[15,63] The elusive nature of displaced populations as well as uncertainty and unpredictability of events may be underlying reasons discouraging investments in evaluation.[5,43,46] Rigorous monitoring and evaluation should, however, be conducted to inform funding priorities, and enhance learning for the design of future digital initiatives, as well as to provide an understanding of pathways by which these initiatives can improve health. Process, impact, and outcome indicators would need to be integrated at all levels of design.

Our review of web-based technologies for health promotion suggests that given the complex settings in which health technologies are deployed and disseminated, evaluations of health outcomes and impacts may be very difficult.[52] Humanitarian health innovations, however, might adopt action-oriented research frameworks that

integrate evaluation of the design, development, and deployment processes. Health promotion research models such as the Spiral Technology Action Research and the e-Technology Participatory Action Research, emphasize the importance of engaging and working with user communities to identify and clarify the goals of the technology and of reporting back to inform its design iteratively.[53,54]

A paternalistic approach

Most technologies cited in this review are tailored to meet the needs and functions of humanitarian organizations; to be top-down paternalistic innovations. Within this approach, there is an inherent assumption that humanitarian actors collect data to understand populations' needs, without explicit involvement of the target population.[55,56] Big datasets, however, do not necessarily lead to improved response, particularly if data management and analysis capacities are insufficient.[56]

Even when technologies are intended to be used by affected populations (See Table 3), involvement is often superficial. It usually takes place in the data collection phase, not in data analysis and interpretation. We only found one initiative[47] that included the affected population in the design process. Data were rarely made available as a resource for the affected communities themselves. Even with more inclusive design processes, a balance must be struck between designers creating products in a paternalistic manner and the use of potentially invasive participatory design methods which may overburden communities in the process.[57] Technology designers need to gain a deeper understanding of the population's context, health beliefs, and use of technology. Over-reliance on technology raises resilience challenges. Will health be detrimentally affected instead of improved?[55] Despite pressure to introduce and experiment with new technologies, these should be balanced with alternatives for action.

Issues of privacy and equity

As technology continues to facilitate the work of organizations that respond to humanitarian crises, issues of privacy and equity need attention. People caught in humanitarian crises fear having their personal information leaked or their location identified. They raise questions about privacy and fears of being tracked.[43] Data security and

privacy should engender trust of the affected communities, to protect the vulnerable and ensure their rights to assistance.[56]

The political blockade of information, such as internet censorship and surveillance, as well as intermittent or nonexistent access to internet and mobile data connections can hinder technologies and information dissemination.[46] Unequal access to technology therefore remains a key challenge. Socioeconomic, age, and gender gaps in technology use and access are well known.[5] They further magnify disparities in access to information relevant to health.[5]

Similarly, inequities at national levels, where local organizations and governments in low-income countries face challenges in accessing financial, human, and technological resources, reinforce unequal power relations.[5] Crowdsourcing might redress this imbalance, by diffusing knowledge ownership beyond humanitarian actors. Where government disaster responses have led to the rise of new decentralized crisis mapping platforms, this may be the foundation for greater community participation in humanitarian action.[56,58]

Recommendations and conclusions

Rigorous evaluation of digital technologies in humanitarian crises must be integrated into design and deployment, to strengthen the evidence base for decision-making, including their impacts on health. Increased awareness of the criticisms and potential risks of digital technology use in humanitarian contexts is needed to ensure that technology is used responsibly.

Future work must strive to create a space for dialogue between technology designers and the populations affected by humanitarian crises to achieve increasing relevance and sustainability of innovations.[62] Care should be taken to ensure that participation is not just a token. Indeed, the culture of technology use by affected populations is on the rise. In many cases, the affected populations are the innovators. They should be supported as they adapt and appropriate digital technologies to their own needs.

About the Authors

Sandra Mesmar is a graduate in Public Health. She is a researcher, and consultant at the Center for Research on Population and Health at the American University of Beirut.

Reem Talhouk is a Doctoral Trainee in Digital Civics at Open Lab, Newcastle University and a founding member of the Arab Digital Public Health Initiative.

Chaza Akik holds a doctorate in Public Health and is a post-doctoral research fellow with a specialization in public health nutrition policy at the Centre for Research on Population and Health at the American University of Beirut.

Patrick Olivier is a Professor of Human-Computer Interaction at Newcastle University. He is also Director of the Open Lab, Principal Investigator of the EPSRC Centre for Doctoral Training in Digital Civics, and Director of the EPSRC Digital Economy Research Centre.

Imad H. Elhajj is an Associate Professor at the Department of Electrical and Computer Engineering at the American University of Beirut.

Shady Elbassuoni is an Assistant Professor at the Computer Science Department of the American University of Beirut.

Sarah Armoush is a Licensed Dietitian & Nutritionist and Coordinator at the Center for Public Health Practice at the Faculty of Health Sciences at the American University of Beirut.

Joumana Kalot is an Instructor of Public Health Practice at the Center for Public Health Practice (CPHP), and in the Department of Health Promotion and Community Health at the Faculty of Health Sciences at the American University of Beirut.

Madeline Balaam is a Lecturer in Interaction Design at Newcastle University. She co-leads the Digital Public Health strand of the Digital Economy Research Centre (DERC) launched at Open Lab.

Aline Germani is an Instructor at the Department of Health Management and Policy, and is the Director of the Center for Public Health Practice at the Faculty of Health Sciences, American University of Beirut as well as a founding member of the Arab Digital Public Health Initiative.

Hala Ghattas is an Assistant Research Professor and Associate Director of the Center for Research on Population and Health at the American University of Beirut, and is a founding member of the Arab Digital Public Health Initiative.

All authors are members of the Arab Digital Public Health Initiative (ArabsDigPH), founded in 2014 by a multidisciplinary group of researchers and practitioners at the American University of Beirut and Newcastle University to explore the use of digital solutions for public health research and practice in the Arab region.

References

1. OCHA. (2016) Global Humanitarian Overview. OCHA.
2. Brunwasser, M. (2015) A 21st-Century Migrant's Essentials: Food, Shelter, Smartphone: New York Times, http://www.nytimes.com/2015/08/26/world/europe/a-21st-century-migrants-checklist-water-shelter-smartphone.html?_r=1, accessed 25 October 2015.
3. Mansell, R. (2002) *Inside the Communication Revolution: Evolving Patterns of Social and Technical Interaction*. Oxford, New York: Oxford University Press.
4. Meier, P. (2015) *Digital Humanitarians: How Big Data is Changing the Face of Humanitarian Response*. Boca Raton: CRC Press.
5. Brophy-Williams, S., *et al* (2013) *World Disasters Report*. Geneva: IFRC.
6. Meier, P. (2015) *Digital humanitarian network-digital networks for humanitarian response*. Boca Raton: CRC Press.
7. ISAC. (2015) Reference module for the implementation of the humanitarian program cycle.
8. Health Canada. (2016) Determinants of health — Hub-and-spoke diagram: Health Canada Website, http://www.conceptdraw.com/examples/determinants-of-health, accessed 15 April 2016.
9. Doocy, S., Gorokhovich, Y., Burnham, G., *et al* (2007) Tsunami mortality estimates and vulnerability mapping in Aceh Indonesia. *American Journal of Public Health*, *97*(Suppl 1), S146–S151.
10. Crooks, A. *et al* (2013) Disease modeling within refugee camps: A multi-agent systems approach. *Proceedings of the Winter Simulation Conference*; 8 December; Washington, D.C.: IEEE Press, pp. 1697–706.
11. Yu, X. *et al* (2011) MiRTE: Mixed Reality Triage and Evacuation game for Mass Casualty information systems design, testing and training. *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine & Biology Society*. Boston, MA: IEEE Press, pp. 8199–202.

12. Wang, Q. and Taylor, J. E. (2014) Quantifying human mobility perturbation and resilience in hurricane sandy. *PLoS One,* 9(11), e112608.
13. Nattiya Kanhabua, A.S. *et al* (2012) Supporting Temporal Analytics for Health-Related Events in Microblogs *Proceedings of the 21st ACM international conference on Information and knowledge management*; 29 October- 02 November; Maui, Hawaii: ACM, pp. 2686–2688.
14. OCHA. (2014) World Humanitarian Data and Trends. OCHA.
15. CDC. (2010) Rapid establishment of an internally displaced persons disease surveillance system after an earthquake in Haiti: CDC, https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5930a2.htm, accessed 1 November 2015.
16. Cookson, S. T., Soetebier, K., Murray, E. L., *et al* (2008) Internet-based morbidity and mortality surveillance among Hurricane Katrina evacuees in Georgia. *Preventing Chronic Disease,* 5(4), A133.
17. Cavey, A. M., Spector, J. M., Ehrhardt, D., *et al* (2009) Mississippi's infectious disease hotline: a surveillance and education model for future disasters. *Prehospital & Disaster Medicine,* 24(1), 11–17.
18. Gilmore, L. 10 ways technology is giving hope for humanity, http://thenextweb.com/insider/2015/09/10/10-ways-tech-is-delivering-hope-for-humanity/, accessed 30 September 2015.
19. Laguardia, C. (2015) Use of mobile technology reduces the time to register displaced people in Iraq, http://www.wvi.org/syria-crisis/article/use-mobile-technology-reduces-time-register-displaced-people-iraq, accessed 10 October 2015.
20. Murthi, H. (2014) IOM Pilots Biometric Registration for Displaced People in South Sudan: IOM, https://www.iom.int/news/iom-pilots-biometric-registration-displaced-people-south-sudan, accessed 30 September 2015.
21. Tomkys, E., *et al* (2015) *Going Digital-Using Digital Technology to Conduct Oxfam's Effectiveness Reviews*. Oxford: Oxfam.
22. ACAPS. (2015) Strategic Needs Analysis Project, http://www.acaps.org/en/pages/syria-snap-project, accessed 30 September 2015.
23. Using Ushahidi and Women Web Portal for Gender Based Violence Reporting: The Open Institute, http://open.org.kh/en/using-ushahidi-and-women-web-portal-gender-based-violence-reporting#.Vk2znHYrLcs, accessed 2 November 2015.
24. Utani, A. *et al* (2011) How geeks responded to a catastrophic disaster of a high-tech country. *Proceedings of the Special Workshop on Internet and Disasters*; 6-9 December, Toyko, Japan: ACM, pp. 1–8.
25. Digital Humanitarians supporting the West Africa Ebola Response: Digital Humanitarian Network, http://digitalhumanitarians.com/DHNEbolaStoryboard/, accessed 22 September 2015.
26. Malik, S. (2011) Out of Isolation: How technology is supporting refugees: Microsoft, http://blogs.microsoft.com/firehose/2011/06/20/out-of-isolation-how-technology-is-supporting-refugees/, accessed September 30, 2015.
27. Olteanu, A. *et al* (2014) CrisisLex: A Lexicon for Collecting and Filtering Microblogged Communications in Crises. *AAAI Conference on Weblogs and Social Media*; Oxford, UK: ICWSM.
28. AIDR. (2015) AIDR Overview: GitHub, https://github.com/qcri-social/AIDR/wiki/AIDR-Overview, accessed 5 November 2015.
29. UNHCR. (2015) Syrian Regional Refugee Response: UNHCR portal, http://data.unhcr.org/syrianrefugees/regional.php, accessed 22 September 2015.
30. Gilman, D. (2014) *Unmanned Aerial Vehicles in Humanitarian Response*. New York: OCHA.
31. Barcock, A. (2015) Solutions That Are Saving Lives in Humanitarian Response. Aid & International Development Forum, http://www.aidforum.org/disaster-relief/top-solutions-that-are-saving-lives-in-humanitarian-response, accessed 9 October 2015.
32. Ahorlu, C., *et al* (2014) *World Disasters Report-Focus on Culture and Risk*. Geneva: IFRC.

33. Turner, C. (2010) The Potential of Mobile Health Technology to Fundamentaly change the way groups such as UNHCR and MSF to conduct health care for refugees: TechChange, https://www.techchange.org/2010/11/01/refugee-health-the-potential-of-mobile-health-technology/, accessed 11 October 2015.
34. M4ID. (2011) Mama: Together for Safe Births in Crises: Women's Refugee Comission, http://www.care2.com/causes/mama-together-for-safe-births-in-crises-saving-womens-lives-through-social-media.html, accessed 29 September 2015.
35. Ruggiero, K. J., Gros, K., Mccauley, J. L., *et al* (2012) Mental health outcomes among adults in Galveston and Chambers counties after Hurricane Ike. *Disaster Medicine and Public Health Preparedness, 6*(1), 26–32.
36. CDC. (2006) Surveillance in hurricane evacuation centers Louisiana. CDC, https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5502a3.htm, accessed 30 September 2015.
37. Mateen, F. J., Carone, M., Nyce, S., *et al* (2012) Neurological disorders in Iraqi refugees in Jordan: data from the United Nations Refugee Assistance Information System. *Journal of Neurology, 259*(4), 694–701.
38. Khader, A., Farajallah, L., Shahin, Y., *et al* (2014) Hypertension and treatment outcomes in Palestine refugees in United Nations Relief and Works Agency primary health care clinics in Jordan. *Tropical Medicine & International Health, 19*(10), 1276–1283.
39. Alexander, R., Pablo, P., Karl, B., *et al* (2015) The effectiveness of interventions for non-communicable diseases in humanitarian crises: a systematic review. *pLOS One, 10*(9), e0138303.
40. Howard, E. *et al* (2002) Using the internet to communicate with immigrant/refugee communities about health. *Proceedings of the ACM International Conference on Digital Libraries*; 14 July; Portland, OR: ACM.
41. Somers, H. (2006) Language engineering and the pathway to healthcare: a user-oriented view. *Proceedings of the Workshop on Medical Speech Translation*; 9 June; Stroudsburg, PA: Association for Computational Linguistics, pp. 28–35.
42. Sawhney, N. (2009) Voices Beyond Walls: The Role of Digital Storytelling for Empowering Marginalized Youth in Refugee Camps. *Interactive Design Conference*.
43. Groupe Speciale Mobile Association. (2014) Disaster Reponse: Mobile Money for the Displaced. Groupe Speciale Mobile Association.
44. El-Huni, E.M. (2015) WFP e-voucher programme in Lebanon: Field Exchange, http://www.ennonline.net/fex/48/wfpevoucher, accessed 21 September 2015.
45. WFP. (2015) Cash and vouchers stories: World food programme, accessed 22 September 2015.
46. Betts, A., Bloom, L. and Weaver, N. (2015) Refugee Innovation Humanitarian innovation that starts with communities.
47. Daniel, A. (2015) The remarkable way 3D printers are saving lives in refugee camp. Upworthy, http://www.upworthy.com/the-remarkable-way-3d-printers-are-saving-lives-in-refugee-camps, accessed 9 September 2015.
48. Crowley, J., *et al* (2014) Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies. Harvard Humanitarian Initiative.
49. SMART Methodology. (2015) Smart Timeline: SMART, http://smartmethodology.org/about-smart/development/, accessed 22 September 2015.
50. WFP. (2013) World Food Progam's Electronic Vouchers: An innovative transfer modality for social safety net progammes in Lebanon.
51. Collins, K. (2015) Vodafone 'Instant Classroom' is digital school in a box for refugees: Wired.CO.UK, http://www.wired.co.uk/news/archive/2015-03/01/vodafone-instant-classroom, accessed 29 September 2015.
52. Chou, Y. S., Prestin, A. and Wen, Y. (2013) Web 2.0 for Health Promotion: Reviewing the Current Evidence. *American Journal of Public Health, 1*(103), e9–e18.

53. Flicker, S., Ridgley, A. and Biscope, S. *et al* (2008) Using technology and participatory action research to engage youth in health promotion. *SAGE Journals*.
54. Skinner, H. A., Maley, O. and Cameron, D. N. (2006) Developing internet-based ehealth promotion programs: The spiral technology action research (STAR) model. *Health Promotion Practice, 7*(4), 406–417.
55. Sandvik, K. B., Jumbert, M. G. and Karlsrud, J., *et al* (2014) Humanitarian technology: a critical research agenda. *International Review of the Red Cross, 96*(893), 219–242.
56. Reada, R., Taithea, B. and Gintya, R. M. (2013) Data hubris? Humanitarian information systems and the mirage of technology. *Third World Quarterly, 37*(8), 1314–1331.
57. Loy, J., Tatham, P., Healey, R. *et al* (2016) *3D Printing Meets Humanitarian Design Research: Creative Technologies in Remote Regions. Creative Technologies for Multidisciplinary Applications*: Creative Technologies for Multidisciplinary Applications.
58. Meier, P. (2011) New information technologies and their impact on the humanitarian sector. *International Review of the Red Cross, 93*(884), 1239–1263.
59. Bengtsson, L., Thorson, A. and Garfield, R., *et al* (2011) Improved response to disasters and outbreaks by tracking population movements with mobile phone network data: A post-earthquake geospatial study in haiti. *PLos Medicine, 8*(8), e1001083.
60. Roberts, S. (2015) Supporting Online Volunteer Response to the Nepal Earthquake: Ushahidi, https://www.ushahidi.com/2015/04/25/supporting-online-volunteer-response-to-the-nepal-earthquake/, accessed 30 September 2015.
61. Amram, O., Schuurman, N. and Hedley, N., *et al* (2012) A web-based model to support patient-to-hospital allocation in mass casualty incidents. *The Journal of Trauma and Acute Care Surgery, 72*(5), 1323–1328.
62. Talhouk, R. *et al* (2016) Syrian refugees and digital health in Lebanon: Opportunities for improving antenatal health. *Proceedings of the CHI Conference in Computing System;* Santa Clara, CA: ACM, pp. 331–342.
63. Uscher-Pines, L., Hausman, A. J., Powell, S., DeMara, P., Heake, G. and Hagen, M. G. (2009) Disaster preparedness of households with special needs in southeastern Pennsylvania. *American Journal of Preventive Medicine, 37*(3), 227–230.
64. van Griensven, F. (2006) Mental health problems among adults in tsunami-affected areas in southern Thailand. *JAMA, 296*(5), 537
65. Mirhaji, P., Casscells, S.W., Srinivasan, A. et al (2006) Services oriented architectures and rapid deployment of ad-hoc health surveillance systems: lessons from Katrina relief efforts. *Annual Symposium Proceedings*; Chicago, IL, pp. 569–573.
66. Yamazaki, F. (2014) Using technology to help displaced residents in Namie, Japan: Code for America, https://www.codeforamerica.org/2014/08/07/using-technology-to-help-displaced-residents-in-namie-japan/, accessed 20 September 2015.
67. Amram, O., Schuurman, N. and Hameed, S. M. (2011) Mass casualty modelling: a spatial tool to support triage decision making. *International Journal of Health Geographics, 10*, 40.

Electronic supplementary material The online version of this article (doi:10.1057/s41271-016-0040-1) contains supplementary material, which is available to authorized users.