Mobilizing a Revolution

How cellphones

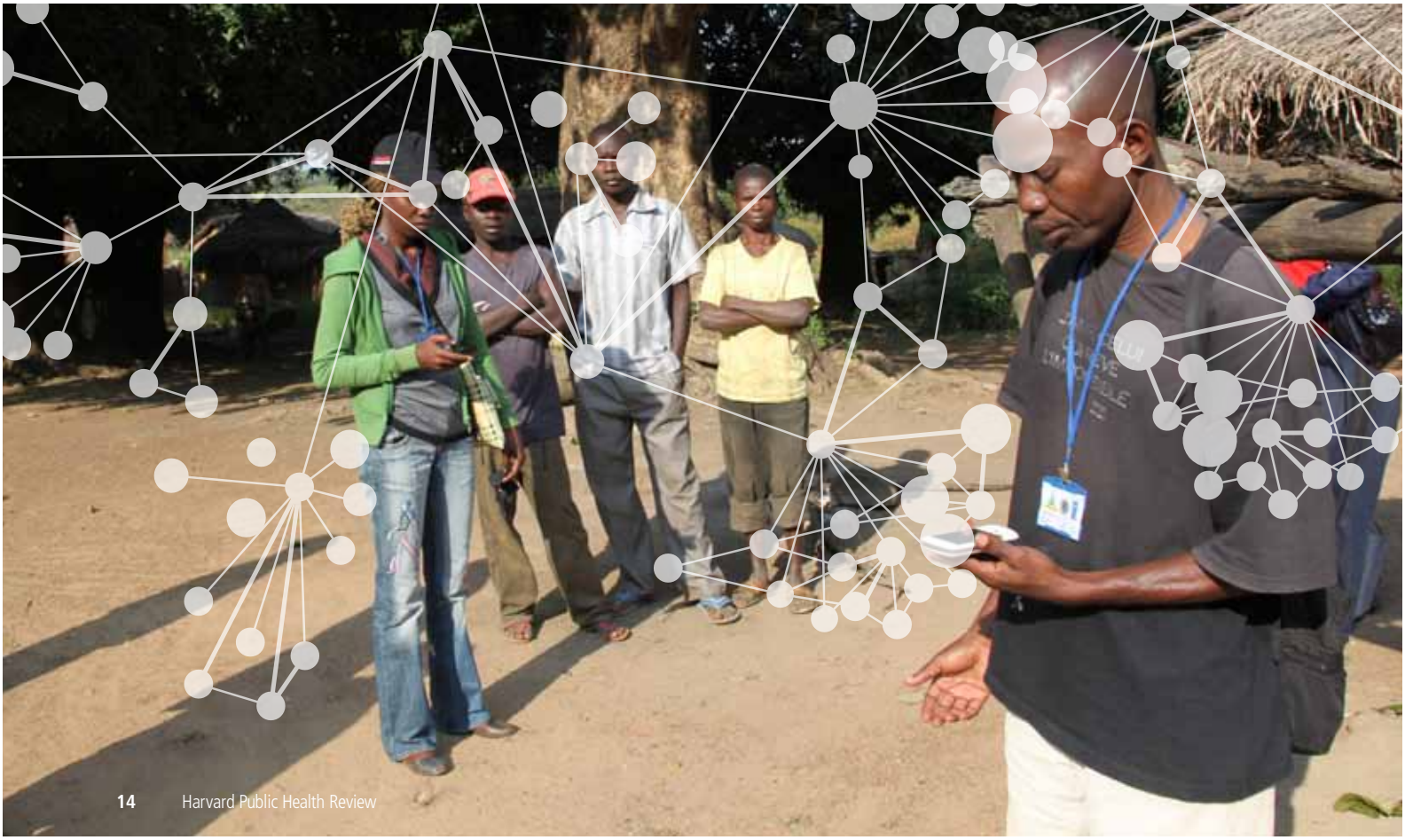
Between 2006 and 2008, outbreaks of cholera—a deadly infection spread by contaminated drinking water—struck hundreds of victims in Rwanda. In response, Nathan Eagle, Harvard School of Public Health adjunct assistant professor of epidemiology and an engineer by training, tapped an unusual source to develop a simple model for predicting cholera outbreaks: cellphone data. His model was predicated on the hypothesis that he might find a telltale sign of an outbreak by tracking people's locations. For instance, if the movements of 100 people within a 10-mile radius suddenly slow, the cause might be illness—and a looming epidemic.

"We could build a surveillance system that alerts local ministries of health if we detect what looks like an outbreak," Eagle says.

Making this prediction model possible are giant data banks run by cellular service providers with records of every phone's history. When a phone receives or sends a message, or moves in or out of a cell tower's range, the network records it. In aggregate, all of the call data records from a given provider can give researchers an invaluable picture of how people behave.

Information that users generate as they move around and use their mobile phones, when combined with other

Field photographs courtesy of Patrick Vinck; portraits, Kent Dayton/HSPH



are transforming public health

data such as public health records, is called "Big Data" because of its volume and variety. But as Eagle discovered, moving from theory to practice in the emerging world of Big Data-driven public health still means working out the kinks.

"What I built turned out to be not a cholera predictor, but a flood detector," he says with a laugh. People moved around less, not because they were sick, but because the roads were washing out. Yet fortuitously, Eagle's prediction model also applied to cholera—because outbreaks generally erupt about two weeks after a flood.

THE NEW FIELD OF "mHEALTH"

Eagle is part of a growing movement at HSPH and within the global health community to leverage the explosion in mobile phone availability—and the data cellphones can share and produce—to change how public health and medical problems are identified, prevented, and treated. This burgeoning field, which has expanded exponentially in the last five years, is called "mHealth."

The variety of mHealth applications under development or available worldwide is staggering and ever evolving. In addition to using Big Data to track people's movements and predict potential public health threats,

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mHealth is putting medical records, appointment reminders, health tips, and detailed standards of care literally in the hands of health workers and patients, whether in Tanzania or Tucson. Today, there are mHealth applications that diagnose medical ailments, manage chronic diseases, and support mental health therapies and addiction control.

Nathan Eagle, HSPH adjunct assistant professor of epidemiology, built a cholera prediction model based on cellphone location data.

mHealth has the potential to help patients, doctors, and researchers make healthier, more informed choices by doing what no other technology can do: deliver valuable, actionable information to the right people at the moment it is needed, no matter where they are. And with projects ranging from outbreak prediction to humanitarian aid, HSPH is among the vanguard institutions defining this new terrain.

There are 6 billion cellphones on the planet—and most subscribers live in the developing world.

"Our faculty have always been leaders in developing interventions to improve health," says Karen Emmons, HSPH associate dean for research. "mHealth provides an important opportunity to explore how to take those interventions to scale, to deliver them in remote places, and to fundamentally change the access of whole populations to evidence-based interventions."

CELLPHONES CURBING DRUG-RESISTANT MALARIA?

Caroline Buckee, HSPH assistant professor of epidemiology, uses call data records from the largest service provider in Kenya to track the movements of 15 million people and correlate those movements with data about malaria. Her work focuses on understanding how human behaviors, such as where people travel and with whom they interact, influence the spread of diseases.

Though using mobility data to make predictive models of the spread of disease is nothing new, the data have generally been either inaccurate or unfeasible to collect

Left, smartphones integrate audio, video, text, data, and geolocation all in one place, making them the ideal tool for mHealth.

Right, using smartphones during research interviews to record information reduces errors and saves time.

"Never before have we been able to look at individual people on this scale, moving in real time. It's a huge deal for infectious disease researchers."

—Caroline Buckee, assistant professor of epidemiology

at large scales. "Never before have we been able to look at individual people on this scale, moving in real time," says Buckee. "It's a huge deal for infectious disease researchers."

In the future, Buckee plans to use these models to intervene at key moments—by sending text messages to travelers heading into malaria-plagued zones, detecting when their phones enter the range of a cell tower in that zone and reminding individuals who have opted to receive notifications to take precautions such as wearing long sleeves and pants and sleeping under a mosquito net.

REACHING THE UNREACHABLE

One of the driving forces behind this new field, in addition to the emergence of the smartphone and other wireless devices, is the rapid spread of mobile phones into remote niches. According to the mHealth Alliance, a research and advocacy organization hosted by the United Nations Foundation, close to 90 percent of the world's population has wireless coverage. There are 6 billion cellphones on the planet—and 7 billion people. Moreover, 65 percent of subscribers reside in the developing world.

While the Internet revolution passed by without appreciably changing the lives of many people in the developing world, mobile technologies offer immediate advantages: they are far cheaper, they don't demand steady supplies of electricity, and they don't require the same extensive infrastructure to reach into people's homes. For all these reasons, mHealth technologies are leap-frogging ahead of the personal computer.

"The use of cellular phones for health care and public health is one of the most promising developments in the quest to achieve universal health coverage worldwide," notes HSPH Dean Julio Frenk, "because mobile phones are rapidly becoming the communication technology of choice—and increasingly so among the poor." ***continued***

TRACKING PANDEMIC FLU

In 2009, HSPH graduate student Martin Lajous, SM '04, SD '11, successfully collaborated with a large cellphone company in Mexico, surveying Mexican residents to characterize outbreaks of H1N1 influenza. Lajous pitched the idea as a test to determine whether cellphone technology could be used for public health response and surveillance. The cellphone company agreed, and the effort showed that cellular surveys may be a practical, inexpensive, and timely complement to traditional surveillance.

"mHealth is going to happen no matter what. I believe it can happen in one of two ways. In one, it benefits people equitably. In the other, it goes to the highest bidder."

—Marc Mitchell, HSPH lecturer on global health

IMPROVING MATERNAL AND CHILD HEALTH

Marc Mitchell, a pediatrician, management specialist, and lecturer on global health at HSPH, says 70 percent of the population in Tanzania has access to a mobile phone. He is among those leading the way in evaluating potential mHealth interventions in the developing world, having spent 20 years designing, validating, and delivering clinical protocols to guide health workers through examinations, diagnoses, and treatments.

Mitchell is a firm believer in mHealth as an effective and inexpensive means of getting such step-by-step protocols into the hands of health care practitioners when and where they're needed. mHealth extends the reach of these protocols to remote places and makes them easier to apply. Mobile technologies automatically keep protocols current with the latest medical advances and supplement them with other valuable features such as digital appointment management tools and electronic patient records, two systems that many clinics in the developing world lack. In some clinics, the only records of patient visits are logbooks that patients sign on arrival, and the only records of diagnoses and treatment plans are on index cards that patients themselves carry.

Mitchell has launched several pilot projects in Tanzania using mobile phones to improve maternal health, child health, and malnutrition using time-tested protocols. Through his not-for-profit organization D-Tree (which stands for "decision tree," a type of flowchart that is part of many clinical protocols), Mitchell runs a maternal health program in Zanzibar funded by the Bill

Left, a village leader in Ombella, Central African Republic, draws a map of the village. Interviewers use the map to plot a geographic sampling of households and individuals.

Right, a solar charger (background) provides energy to operate smartphones without access to electricity.

& Melinda Gates Foundation. Also in Zanzibar, in a project funded by UNICEF, a mobile app that assists health workers as they screen children for malnutrition has helped reduce errors in health care delivery. If pilot projects such as this prove effective, says Mitchell, the next step will be scale-up.

INTERNATIONAL IMPACT

Just a few years ago, according to Erica Kochi, co-lead of the Tech Innovations Team at UNICEF, people weren't interested in using mobile technologies in health care in the developing world. "They laughed when we brought it up," she says. After all, just five years ago, only the urban rich owned mobile phones in the developing world. Today, there are mobile phone owners in even the most remote villages. "Now, everyone is including mobile technology in their plans."

mHealth applications enable aid workers to map where a crisis is unfolding in real time, giving researchers and aid workers a better shot at swiftly responding to threats of violence, disease, or malnutrition. Applications also provide patient monitoring, send text messages reminding patients to take needed medications, or offer suggestions for maintaining health while pregnant, even in war-ravaged places.

For organizations like the U.S. Centers for Disease Control and Prevention and the World Health Organization, with missions to avert dangerous epidemics, "this technology is a potential powerhouse," adds Phuong Pham, a research scientist at HSPH and director of evaluation and implementation science at the Harvard Humanitarian Initiative, a University-wide program dedicated to developing ways to improve the delivery of health services in areas facing war, conflict, or natural disasters. "In epidemiology, determining person, place, and time are crucial. If you can look at those three components in real time, you can immediately make informed decisions and take action."

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mHEALTH AND WOMEN'S HEALTH

"Mothers wanted us to leverage the one piece of technology they have access to: the mobile phone," says Priya Agrawal, a visiting scientist and obstetrician and gynecologist working with the Women *and* Health Initiative at HSPH. The resulting tool, the Mother/Baby 7-day mCheck, was designed by mothers, for mothers. The checklist-based intervention cues mothers to examine their infants for common danger signs during the first week after birth.

Of mothers and babies who die during childbirth, two-thirds die in these critical first seven days. Mobile phones not only remind mothers to do the checks, but also help them connect to medical aid and transport, when needed.

CELLPHONES AND INCENTIVES FOR BETTER HEALTH

In addition to his role at HSPH, Nathan Eagle is CEO of Jana (formerly txteagle), a technology company that has built a platform capable of awarding billions of people with free mobile airtime in exchange for completing surveys or purchasing products.

This arrangement sprang from one of Eagle's first mHealth projects, helping a hospital in rural Kenya prevent frequent blood supply shortages. He developed a text message application enabling nurses to alert the main blood bank about shortages before they became emergencies. But the project fell flat; the cost of sending daily text messages is a big chunk of a rural nurse's income.

Eagle responded with airtime compensation, a system that automatically gives users free service in exchange for data transmission charges for each message sent. The scheme worked, and the nurses started texting again.

LONG-TERM RESEARCH STUDIES USING mHEALTH

Mobile technologies are also energizing the workhorse of public health research—longitudinal studies, which collect behavioral and health data over time to reveal factors that may threaten or improve health.

For example, HSPH is developing a program to monitor the day-to-day behaviors of half a million people in sub-Saharan Africa over several decades, gathering information on what they eat and drink, where they live, and whether they smoke or exercise. The first study of its kind in this region, it will use an mHealth survey platform developed by Eagle that enables researchers to survey people in places too remote to reach with paper or personal interviews.

"Longitudinal data may be the most promising area in mHealth," Eagle says. "It could change how we think about preventative health."

RISKS AND OBSTACLES

Scientific evidence that mHealth interventions actually work is beginning to emerge. Recent studies, for instance, have shown that mobile phones have assisted in relief effort coordination in Haiti and that text message reminders about proper malaria treatment have improved the care of sick children in Kenya.

But will mHealth deliver on its early promise? The answer depends largely on who invests in mHealth and how. If the biggest investments are made by those who stand to profit, then, according to Mitchell, "mHealth would not reach those who most need it," particularly those who cannot afford mobile phones without assistance, such as under-resourced clinics, women, and the poorest of the poor. Mobile health care could become boutique health care.

Privacy is another issue. Even though Buckee and Eagle depersonalize the data they use, there are no international standards that define what needs to be done to call data before it is handed off to researchers.

Equity is also a key issue. In Africa, for example, mobile phone owners still tend to be male and relatively affluent. "We need to be cognizant of the bias," says Eagle. "It's easy to slip into the idea that we've discovered a universal law of human behavior, when really we've identified a pattern in a subset of behavioral data from a subset of mobile phone subscribers in one country."

A major concern is that academia and technology don't typically operate on the same time frames. In the years it takes an investigator to write a proposal, submit it, and get it reviewed and funded, what had been cutting-edge mobile technology may become obsolete. And if mHealth applications race ahead of scientific and regulatory safeguards, the trend could backfire and do more harm than good.

Left, smartphones are plugged in and synchronized locally, allowing researchers to analyze data on the ground.

Right, solar batteries charge smartphones at night.

mHEALTH AND HUMAN RIGHTS

In a decade-long mission asking survivors of war and mass conflict how they were faring and what they and their societies needed to heal, Patrick Vinck and his wife Phuong Pham often felt hampered by standard paper-and-pencil surveys. Both work at the Harvard Humanitarian Initiative (HHI)—Vinck as director of the Program on Vulnerable Populations, and Pham as the director of Evaluation and Implementation Science. Today, with open-source software that they themselves developed, called KoBo, the researchers are able to document both the complexities of postwar suffering and the most pressing public health needs in ravaged populations.

"mHealth technology represents the second wave of humanitarian assistance," says Vinck. "When you ask victims how to redress war suffering, they will often say, 'Help me get prosthetics for my injuries. Build a hospital for my children. Improve the health care system.' In the past, we've seen billions of dollars poured into proceedings meant to help the victims—but nobody was asking the victims exactly what they wanted and needed. With digital technologies, we can do just that."

"mHealth technology represents the second wave of humanitarian assistance."

—Patrick Vinck, director of the Program on Vulnerable Populations, Harvard Humanitarian Initiative

Adds Pham, "We wanted smartphones that integrated audio, video, text, data, and geolocation all in one place, and we wanted it to be freely available." Compared with conventional data-gathering tools, their mobile digital technology is more secure, more cost-effective, easier for trained health workers to use, and its results can be swiftly translated into case management and timely evidence-based policy recommendations. Ultimately, the phones could help health care workers diagnose disease, document human rights violations, photograph (through an attachment to a light microscope) a smear of blood potentially laced with malaria parasites, and even gauge through surveys how post-traumatic stress disorder colors postwar attitudes toward transitional justice and reconciliation.

Despite these questions, there is a gathering momentum and sense of inevitability about the nascent technology. "I'm doing this because mHealth is going to happen no matter what," Mitchell says. "I believe it can happen in one of two ways. In one, it benefits people equitably. In the other, it goes to the highest bidder."

—Elizabeth Dougherty is a freelance science journalist and novelist living in central Massachusetts.