

HOW MHEALTH, 3-D PRINTING & ROBOTS WILL CHANGE THE WORLD FOR PEOPLE WITH SPECIAL NEEDS

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THE INCREDIBLE POWER OF SMARTPHONES, PLUS ADVANCES IN 3-D PRINTING AND ROBOTICS, WILL PROVIDE THOSE WITH SPECIAL NEEDS AND THEIR CAREGIVERS WITH NEW WAYS TO TRACK HEALTH INFORMATION, PRINT PROSTHETICS, GAIN ASSISTANCE FROM ROBOTS, AND HAVE ACCESS TO NEW AND WIDE RANGING ENABLING TECHNOLOGIES.

In 1976, Seymour Cray, the father of super-computing, introduced the most powerful computer in the world, the Cray-1. It was super in many respects. It cost \$5-\$10 million, weighed more than 5 tons, and used as much electricity as ten homes.¹ Super as it was, the Cray-1 had no app store, could not play a song, or even make a phone call. However, scientists and researchers embraced the Cray-1 because it enabled them to perform scientific simulations and explore data at a speed not previously possible.

Fast-forward four decades from the introduction of the Cray-1 to Apple and Android smartphones. We call them phones, but they are really computers; supercomputers 100+ times more powerful than the Cray-1. Hundreds of millions of people around the world carry them in their pocket or purse. The incredible power of the smartphones, plus advances in 3-D printing and robotics, will provide those with special needs and their caregivers with new ways to track health information, print prosthetics, gain assistance from robots, and have access to new and wide-ranging enabling technologies.

MHEALTH

Consumers and caregivers are taking a more active role in healthcare and taking advantage of new mobile health (mHealth) apps and devices. By measuring and tracking their health, consumers will have more data than ever before. Although some providers are not comfortable with consumer technology for self-diagnosis, the new technologies will lead to a new model of collaboration between patient and physician. Parents and caregivers will extend the use of mHealth to those with special needs.

People are finding tracking one's health is a good tool for improving one's health. More than half of Americans track weight, diet, or exercise.² Innovators are developing new mHealth apps and devices at a frenetic pace, and consumers have a healthy attitude about adopting them. According to industry estimates cited by the FDA, more than a billion smartphone users worldwide will be using a mobile healthcare application by 2018, including healthcare professionals, consumers, and patients.³ An explosion of development resulted in 325,000 mobile health apps available in 2017. Many of these are fitness related, but as consumers adopt mHealth devices, they will be using apps to perform tests at a much lower cost than traditional laboratories and in a convenient way, enabling them to send data to their doctor.

The term "regulation" is unfavorable to many technology innovators who fear government bureaucrats will inhibit getting new ideas to market. When it comes to healthcare, however, regulation is a different story. The FDA sees the widespread adoption and use of mobile technologies as creating new ways to improve health and the delivery of healthcare services. It's hard to come up with an exact number the FDA has approved but, according to Jonah Comstock, Editor in Chief, at MobiHealthNews, "What is clear is that there are a lot of FDA-cleared apps, easily hundreds, and that the number of apps going through the FDA goes up every year." The explosion of healthcare related apps and devices connected to smartphones is enabling a consumer-led revolution in healthcare.⁴

In the past, consumers had to make an appointment and drive to a doctor's office to get "checked". Now, consumers can check an increasing number of health indicators for themselves or for a person with special needs. Being able to monitor critical measurements on a regular basis can make all the difference in people's lives. The Internet has empowered consumers for more than 20 years. mHealth has provided even more empowerment to consumers in a short time through smartphones. The pace of mHealth adoption will accelerate; self-monitoring and self-diagnosis are here to stay. A new model of collaboration between patient and provider is emerging.

3-D PRINTING

The U.S. Centers for Disease Control and Prevention reported four in 10,000 children are born with some congenital hand loss. There is a need for 1,500 child hand prosthetics each year. A prosthetic can cost up to \$40,000, and insurance has usually not covered them. As children grow, they can have trouble adapting to a prosthetic. The need for pediatric prosthetics spawned a network of volunteer medical workers, engineers, designers, parents, and 3-D printing enthusiasts who have been designing, printing, and outfitting children with prosthetics.

Meredith Cohn at *The Baltimore Sun* wrote about how Albert Chi, a trauma surgeon at Johns Hopkins, was able to print a hand for a two-year-old.⁵ Chi said, "We thought the child was too young, but we weren't even able to finish strapping it on, and the kid was picking an object up." A network of thousands of volunteers and non-profit e-NABLE are using 3-D printing

technology to create free printed hands and arms for those in need. With free designs available online and the advent of sub-\$1,000 printers, families may be printing hands at home with free designs from e-NABLE's website. With prosthetics below \$20, it is practical to print new ones every few months as children grow. They can also pick their favorite color. Clinical trials are underway led by non-profit Limbitless Solutions to create 3-D printed arms. The organization is devoted to building a generation of innovators who use their skills and passion to improve the world around them, including creating arms for those in need.

Another powerful use of the technology is for printing models to aid in surgery. A case at Morgan Stanley Children's Hospital in New York represents a touching story which demonstrated the potential. A two-week-old baby suffering from a congenital heart defect was in urgent need of surgery. The baby's heart was riddled with holes and presented a highly complex surgical

challenge. Rather than stop the heart and examine its interior to determine a surgical strategy, as would have been the only option in the past, 3-D printing was used to create a model of the baby's heart using data from an MRI.⁷ The model served as a guide both for planning and during the surgery. Thanks to 3-D printing and the skill of a Columbia Presbyterian Hospital surgeon, the baby should lead a normal life. Thirty-five thousand babies are born each year with congenital heart defects. 3-D printing has the potential to improve the outcomes for those needing surgery.

3-D printing has already expanded to printing tissues of organs and bones. The promise of healthcare innovation using 3-D printing technology is extraordinary. A 60-year-old British man suffered from chondrosarcoma of the pelvis, a rare form of untreatable cancer. The only option was to replace the diseased half of his pelvis. Such surgery would have been unheard of in the recent past, but with the advent of 3-D scanners and printers, there was a

RECENT DEVELOPMENTS IN mHEALTH TECHNOLOGY

▷ **ALIVECOR HAS A HEART MONITOR** sensing device, called a Kardia, which attaches to the back of a smartphone or can be placed next to a smartphone. You put two fingers from each hand on the device sensors and the iPhone creates a 30-second EKG. You can save it, email it to your doctor, or click to have an AliveCor vetted cardiologist or technician provide an analysis for a small fee. The company also has a version of the Kardia with the sensing technology built into an Apple Watch band. In December 2018, Apple introduced an Apple Watch app which produces an EKG when the watch wearer holds his or her index finger against the watch crown for 30 seconds. Apple also received FDA clearance for an algorithm able to detect atrial fibrillation, an irregular and often rapid heart rate that can increase risk of stroke, heart failure and other heart-related complications. Alongside the EKG, the algorithm allows the Watch to screen users' heart rhythm in the background and send notification if it detects an irregular rhythm that appears to be atrial fibrillation.

▷ **HEALTHCARE PROVIDERS ARE BEGINNING TO** take advantage of the availability of consumer health data from mHealth devices and apps. Cedars-Sinai has integrated consumer data with the hospital's electronic health record (EHR) system for thousands of patients. Cardiac data will flow from

the Apple Watch or a Kardia sensor to the iPhone Apple Health database on an iPhone to the EHR database. Cardiologists will have access to vastly more data about a patient's heart than previously.

▷ **THE CELLSCOPE OTO TURNS A** smartphone into an ear-inspecting otoscope. A small attachment to a smartphone can capture a video of the eardrum. A companion app called Seymour analyzes the video and detects ear infections. A family member can email data from the Seymour app to a doctor to confirm diagnosis. Contrast this with making an appointment, driving across down, and sitting in the waiting room.



▷ **mHEALTH WILL PROVIDE GREAT HEALTHCARE** convenience for consumers. The convenience will eventually extend to blood tests. A team of engineers at Cornell University has developed The Smartphone Cholesterol Application for Rapid Diagnostics, or "smartCARD". The smartCARD accessory optically detects biomarkers in a drop of blood, sweat, or saliva. A consumer can extract a single drop of blood onto a strip. The smartphone camera attachment takes a photo of the strip and a smartphone app performs a colorimetric analysis displaying cholesterol level. The test takes about a minute.

chance of success. A United Kingdom implant maker used a 3-D scan and then printed a custom model of the half pelvis. The 3-D printing process used a laser to fuse multiple layers of titanium powder to create the new pelvis part. The part was then coated with a mineral receptive to the growth of new bone. The surgical team used a surgical robot to assist in the 12-hour procedure. The final step was to perform a hip replacement to fit into a socket of the new pelvis part.

British newspapers reported three years after the complex procedure, the man was able to walk with the help of a cane.⁸ A few years from now, the complex set of steps for 3-D printing of a pelvis or other human parts may seem primitive. More fully automated processes leading from diagnosis to treatment will seem commonplace.

A final example demonstrates the potential for young people. Peking University doctors implanted a 3-D printed vertebra successfully in a 12-year-old boy who had a malignant spinal cord tumor.⁹ A digital model was created from which the vertebra was printed.



Most 3-D printing uses polymers or metals but, in this case, the University used titanium powder, which is typically used for orthopedic implants. What was atypical was the implant did not require cement or screws because the implant was made to fit precisely. Normally, implants come in pre-determined sizes and may not fit exactly, hence requiring cement or screws. The 3-D printed implant included holes which allowed bone tissue to grow into the implant and hold it in place.

ROBOTS

Robots will play an increasingly important role in all aspects of healthcare in the years ahead. Westminster Technologies, Inc. in Cleveland, Ohio has developed a small child-like robot. The target market for the robots is K-12 schools. Some STEM programs (science technology engineering mathematics) have funding for the technology. Kids can learn how they work and develop programs the robot can execute. A simple example would be a program which

▷ **A SAN DIEGO STARTUP NAMED CUE** has developed a compact, consumer-oriented device which can detect five biological conditions at a molecular level including inflammation, vitamin D, fertility, influenza, and testosterone. The company is seeking FDA approval.

▷ **GLOOKO, A DIGITAL DIABETES CARE** company, has received FDA clearance for its Mobile Insulin Dosing System (MIDS). The app-driven tool recommends insulin dose adjustments using data collected directly from a patient's blood glucose meter. The MIDS module allows clinicians to create a customized treatment plan and send it to Type 2 diabetes patients directly through the company's unified mobile diabetes management app. Instead of relying on patients to input their own fasting blood glucose, however, the system pulls readings from the patient's blood glucose meter.

▷ **CAMBRIDGE, MA-BASED EMPATICA HAS DEVELOPED** a device that is worn on the wrist, called Embrace, which can continuously record physiological signals from multiple sensors and detect epileptic seizures. Embrace transmits data to a paired smartphone via a Bluetooth® connection, and from the smartphone to Empatica's secure servers which notifies caregivers. Although the FDA has approved the device, users will



have to secure a prescription from their neurologist to use the device's seizure-detecting features.



▷ **KINSA HAS A SMART STICK** Thermometer which is FDA-cleared for accuracy. The lightweight device requires no batteries and connects directly to your smartphone for an easy temperature read in less than ten seconds. The thin and flexible device plugs into the audio jack of an iPhone or Android smartphone.

Children can be intimidated by the temperature measurement process, but with the Kinsa thermometer, the process is more like a game. The smartphone retains a record of the temperature for one or more family members and can be annotated with other symptoms such as shivers or headache. A log over multiple days can be emailed to the doctor.

▷ **THE ENVIRONMENT OF A HOSPITAL** or doctor's office can also be intimidating to children. Pedia Pals has developed clinical furniture, such as a Dinosaur Exam Table to bridge the gap between children and medical professionals. Although not apps or devices, the company says their products "provide an entertaining and calming focus for children while improving diagnosis and treatment for these often frightened patients."

reads a text file. This may have applicability in home healthcare. A robot could remind a chronically ill patient when it is time to take a medication. For mentally ill patients or anyone with chronic illness, robots can become a trusted and helpful companion.

In theory, robots could take on a much greater role in home healthcare. They could help people recovering from a stroke to re-learn how to perform basic functions. Therapists and aides can perform the task, but such therapy can be expensive and not pleasant to administer. Robots, on the other hand, can work around the clock, and they never get bored with repetitive tasks. The question about robots is whether people will accept them and not be intimidated by them. A reason to be hopeful is that while the technology is gaining more and more capabilities, it is also becoming more human-like. Health attitudes will adapt, and robots will become allies in our healthcare.

Researchers at the Personal Robots Group at MIT's Media Lab have developed a robot with a baby face with a round head, small chin, and wide eyes that appears more capable of feeling than robots of other designs.¹⁰ The MIT Group found people prefer baby-faced robots for medical advice and for tasks that depend on emotion such as from a therapist. The research also showed child-faced robots are less likely to threaten the autonomy of elderly individuals. The Robot Group at MIT has built a robot named Nexi that exhibits many of the characteristics which may be critical to the long-term future of robots in healthcare. The MIT Media Lab's goal is to build socially engaging robots and interactive technologies to help people live healthier lives.¹¹

Dr. Adam Waytz, Assistant Professor at Northwestern University's Kellogg School of Management, and Dr. Michael Norton, Professor at Harvard Business School have developed a

list of five human-like characteristics they believe will be most important in the acceptance of robots. Faces and voices may be the most obvious. The ability to express empathy is a close third. More surprising but important characteristics Waytz and Norton believe will be important are the ability to provide mimicry and unpredictability.¹² The latter two characteristics pique the interest of humans and result in more acceptance and trust. The reason is these two characteristics are more like humans.

HEALTHCARE TECHNOLOGY IS EVOLVING VERY RAPIDLY. THE PROGRESS WE WILL SEE OVER THE NEXT YEARS WILL EXCEED THAT OF THE PAST 100 YEARS. THOSE WITH SPECIAL NEEDS WILL GAIN ACCESS TO TOOLS WHICH EMPOWER THEM TO IMPROVE THEIR HEALTH. SUMMARY

Healthcare technology is evolving very rapidly. I believe the progress we will see over the next years will exceed that of the past 100 years. The technology will improve information handling for patients, providers, payers, and policymakers. As was the focus of this article, consumers (patients) and those with special needs will gain access to tools which empower them to track their own health and thereby improve their health. In particular, mHealth, 3-D Printing, and robots will change the world for those with special needs. •

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