








# Wearables and the Internet of Things for Health

Wearable, interconnected devices promise more efficient and comprehensive health care.

By David Metcalf,  
Sharlin T.J. Milliard,  
Melinda Gomez,  
and Michael Schwartz



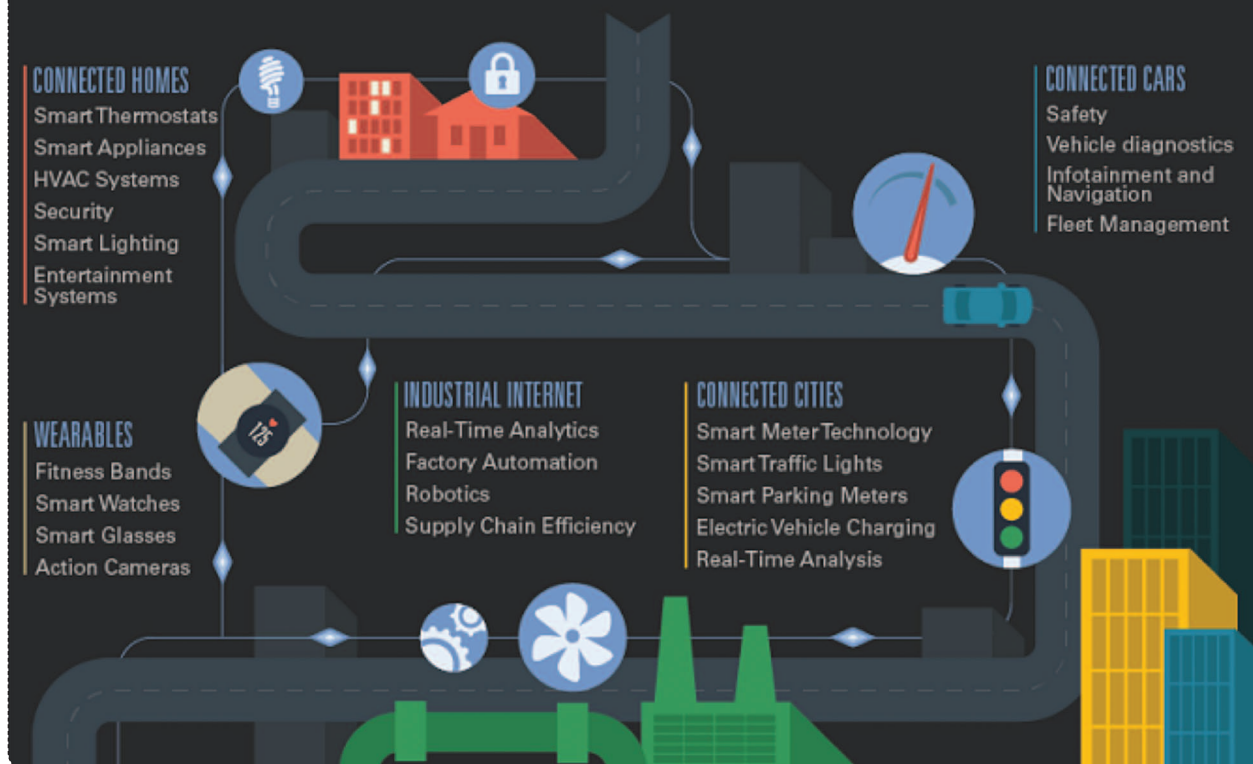
In our recent book *Health-e Everything: Wearables and the Internet of Things for Health*, we capture in an interactive e-book format some global thought-leader perspectives as well as early examples of case studies and novel innovations that are driving this emerging technology domain. Here, we provide a brief snapshot of key findings related to these novel technologies and use cases, which are driving both health care practitioners and health consumers (patients). As technologists, having a firm understanding of customer-driven innovation and the actual user



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# WHAT IS THE INTERNET OF THINGS?

The Internet of Things connects devices such as everyday consumer objects and industrial equipment onto the network, enabling information gathering and management of these devices via software to increase efficiency, enable new services, or achieve other health, safety, or environmental benefits.



**FIGURE 1** The IoT capabilities. (Image courtesy of Goldman Sachs, retrieved from <http://www.goldmansachs.com/our-thinking/pages/iot-infographic.html>.)

benefits of interconnective devices for health will help us engineer better solutions that are more targeted to the triple aim of better, faster, and cheaper health solutions.

## The Internet of Things and Health

The Internet of Things (IoT) is an emerging paradigm for the range of new capabilities brought about by pervasive connectivity. The concept involves situations where network connectivity and computing capability expand to objects, sensors, and everyday items that exchange data with little to no human involvement (see Figure 1). The premise of the IoT is to build, operate, and manage the physical world by means of pervasive smart networking, data collection, predictive analytics, deep optimization, machine-to-machine methods, and other solutions. Its potential benefits can impact how individuals live and work. In the near future, corporate and government organizations, such as the U.S. Department of Defense, may be challenged by the inevitable addition of IoT devices

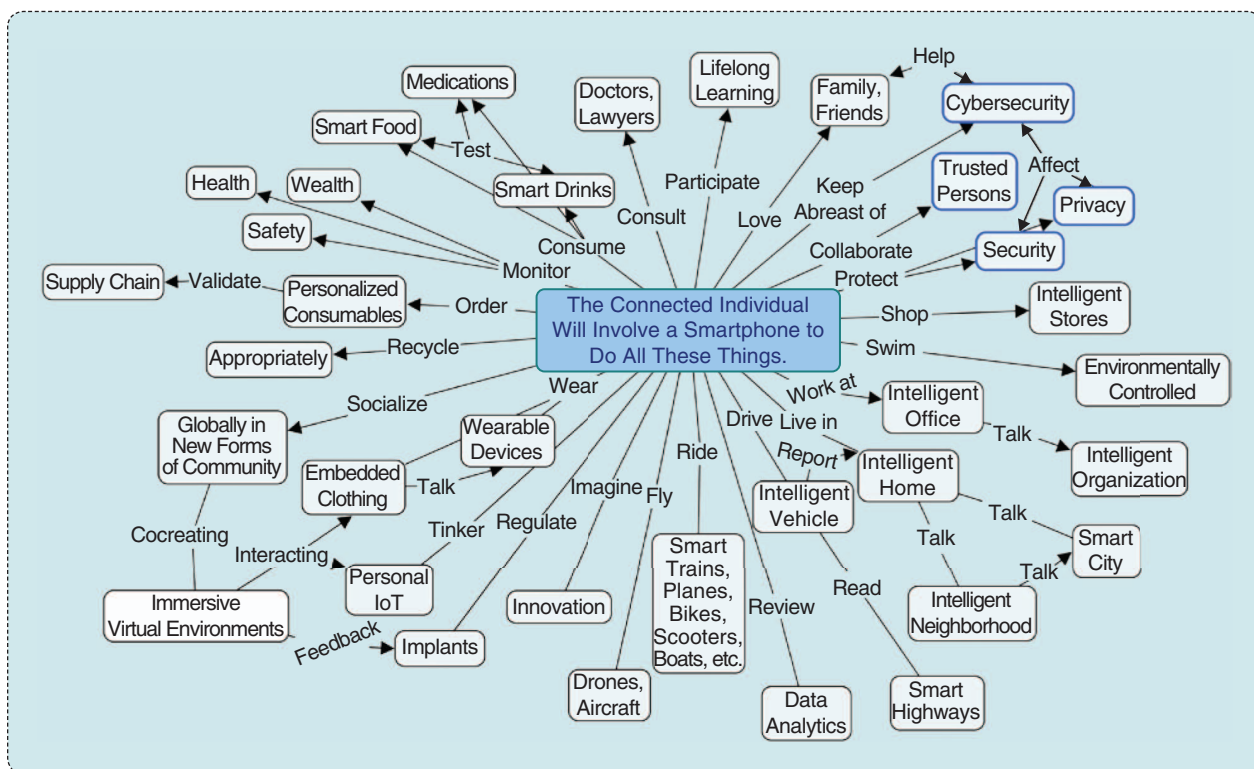
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to their networks and connected systems. This notion will serve as a source of innovative decision making.

The IoT allows for virtually endless opportunities and connections to take place. Connected homes, wearable devices (including embeddables), the industrial Internet, connected cities, and connected cars are some of the domains that can be added and adapted, as needed, to explore current IoT capabilities. These innovations are not only used to capture and display information, but are connected and controlled through smart devices. Growth builds on existing computing devices, such as personal computers, tablets, and smartphones,

which play a large role in this new user-focused IoT development (see Figure 2).

This user-focused perspective is particularly evident in the health care domain, in which the IoT is changing the way care is provided and managed via data and information exchange between connected and wearable devices. The IoT is enabling a



**FIGURE 2** A schematic of the connected-individual taxonomy. (Image courtesy of Barbara Truman, Institute of Simulation and Technology.)

more personalized form of care where consumers are self-managing and self-monitoring their own health and providers are able to improve the experience of care.

Modern wearable devices (e.g., the Fitbit health monitor, Pebble smartwatch, and Google Glass) inspire new ways of thinking about the IoT for the body and even beyond. These play an important role in facilitating self-management and self-monitoring. They are being integrated with, for example, electronic health records and office systems by means of their sensors and data transmitters, which are the prime movers of the IoT. When asked how the IoT and wearables have impacted his work, Dr. Eric Topol says, “The fact that you can take care of a patient or a passenger at 30,000 feet with all types of digital medical devices bespeaks that we have a different capability today. And not only that, all those devices can even be used by patients or anyone because they have algorithms that give you the answer. So this is a whole different look” [1].

## How Are Wearables Being Used in Health Care?

Wearable technology has made significant progress in recent years, with millions of devices being sold to consumers and steady advances being made in technological capabilities. Although the form and function of contemporary wearables have changed from Shannon and Thorpe's 1961 experiment, many of the same conflicting design issues have to be taken

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into consideration when developing modern technologies that are intended to be worn. Although wearables have benefited from advances in mobile technologies, functionality remains limited compared to smartphones. Additionally, smartphones do not need to be comfortable to wear while in motion, are less restricted by weight and size requirements, and have more well-defined aesthetic requirements. However, wearables present a tremendous opportunity for capturing a continuous stream of data about our physiology and kinesiology, which can empower consumers with self-knowledge.

Human health and fitness are areas in which wearables can offer insights that smartphones cannot. This is evident from the immense popularity of fitness trackers (e.g., the Fitbit Blaze, Jawbone UP, and Nike+ FuelBand) and smartwatches (e.g., the Apple Watch and Samsung Gear) being used by consumers to self-monitor physical activity. Additionally, wearables are being used for self-monitoring and preventing health conditions such as hypertension and stress. Donald Jones with the Scripps Translational Science Institute says, “My favorite wearables today are those that measure blood pressure and that can be used to impute stress. I think these are some of the most interesting areas of feedback that we have today. Hypertension is a cause of many illnesses, and stress is obviously a big contributor” [1].

Research continues to explore how wearables can help patients and physicians before, during, and after medical procedures, such



as surgery [2]. For example, telemedicine can be performed by on-site paramedics wearing Google Glass, a head-mounted display with a camera and microphone, and communicating with off-site medical doctors to provide expert care during disaster relief efforts [3]. Additionally, wearables can provide a more expedient means of monitoring a patient's vital signs during surgical procedures by reducing the size of equipment and the number of wires leading to external devices. Such applications could improve the quality of medical care a patient receives by shortening the transition time between ambulances and emergency rooms and so reducing the complications that may arise during these transitions. Wearable technology can help hospitals become safer and more efficient. Products such as Leaf Technology, a wearable patient sensor, can help prevent complications that may arise during a hospital stay (e.g., pressure ulcers from inadequate turning), thus improving patient outcomes and reducing medical costs.

Even so, many issues need to be taken into consideration when deploying wearables for general health care. For example, John Feland, chief executive officer of Argus Insights, says, "People get tired of the fitness bands and throw them in the sock drawer. They stop being useful, people lose their fitness momentum. ..." [4]. Furthermore, data security and privacy are primary concerns for both patients and hospitals. Therefore, new technologies need to be integrated with devices and systems already in place, and approval by regulatory agencies can take years and millions of dollars before benefits are realized.

### The IoT and Wearables in Action

Wearables are steadily becoming the most prevalent personal devices, offering users the ability to interact with other tools and physical objects around them. Once the IoT becomes more widely adopted—creating a truly hyper-connected world—common interactions via the Internet and connected objects may shift to more active engagement of content and environment, specifically in health care. Let's take a look at a few case studies that showcase how wearables and other technologies integrate to form an IoT solution in different domains.

#### Augmented Reality Wearables for Medical Education

The IoT, augmented reality (AR), and wearables can create new paradigms that may potentially change the way people experience the world. In all aspects of life, AR is an emerging technology that can be implemented as a system of interac-



FIGURE 3 The Lake Nona intelligent home living laboratory.

tions to better serve human needs, especially in the field of health. For example, medical students from Case Western Reserve University and the Cleveland Clinic are using Microsoft HoloLens, a holographic, head-worn computer that enables learners interacting with high-definition holograms to better understand the body's organs and systems. These students examine and become familiar with details of the heart and specific functions of the body through a three-dimensional projection instead of in traditional,

cadaver-filled laboratories. Through the combination of AR, wearable technology, and the IoT, environments will become more responsive and digitally manipulable.

#### Humber River Hospital: An All-Digital Hospital

Humber River Hospital in Toronto, Canada, opened its doors in 2015 and is the first state-of-the-art, all-digital hospital in North America. Humber River uses the IoT to provide high-tech patient-centered care in a manner that is more efficient with regard to costs and operations. The IoT has been integrated as a solution to provide faster care and consequently reduce patient stays, provide more accurate diagnoses, improve the link between medical records and medical practitioners, and automate more than three-fourths of its supply chain.

The all-digital hospital experience begins with online appointment scheduling and check-in. Patients are empowered with bedside access to their medical records via monitors, and they can communicate with doctors, nurses, and family members using video chat and instant messaging. The hospital employs patient wristbands featuring real-time location technology for tracking wandering patients and improving security to prevent infant abduction. Additionally, Humber River has medical devices that automatically capture and store patient health metrics, which enables doctors and nurses to have a real-time view of a patient's health status from a distance. The hospital uses robots to mix drugs and transport goods; machines also process blood samples in minutes, then transmit the results electronically.

#### Lake Nona Intelligent Home Living Laboratory

The Lake Nona Institute in Orlando, Florida, provides a range simulator as an intelligent home, cosponsored by Johnson and Johnson, Cisco, General Electric, Healthcare Information and Management Systems, and the Florida Blue health insurer (see Figure 3). The intelligent home is designed with multiple connected interfaces, devices, and appliances. It provides an environment that models how individuals and health care

Networked wearable devices and apps play an integral role, serving as the foundation to the ever-evolving practice of the IoT in health care.

providers can work together to fashion a home that will improve and maintain the overall health and well-being of its dwellers.

As Robert Wachter of the University of California–San Francisco Medical Center said, “You can think of a future world where not only is the scale smart and saying to the heart-failure patient: ‘you’ve gained a few pounds, you should cut down on the salt.’ But it’s also about locking the salt shaker...” [5]. The home connects health monitoring, tele-medicine, digital health coaching, advanced air and water purification systems, and circadian lighting strategies. Its lighting, temperature, window shades, energy, utility, and media management can be controlled through a smart mobile device from anywhere via the Internet as much as 200 times faster than what is commonly found in the average home.

## Conclusions

The IoT is a potential emerging solution that consists of interconnected devices. These networked devices offer better, faster, and cheaper customer-driven innovations in health care consumption as well as provision. Networked wearable devices and apps play an integral role, serving as the foundation to the ever-evolving practice of the IoT in health care.

Daniel Kraft of the Aspen Institute believes that apps and their IoT connections may begin supporting clinicians’ workflow. He says, “As the incentives are aligning and value-based care comes together, the future will be the IoT that blends with wearable devices, apps, and smart analytics on top of data. This is so the clinician and care team can get the right insights from the data at the right time and not be overwhelmed. Smart preventative decisions can be made for a more proactive individualized care and therapy” [1]. With the wearables market still in its early phases of expansion and the IoT continuously changing, communications and electronic engineers will be at the forefront of building next-generation solutions.

There may be a substantial increase in things like embeddables—small and easily powered microchip implants that can be placed anywhere within a person’s body. In terms of the health care sector, they may be able to measure vital signs without invasive surgery. Embeddables, such as electronic tattoos, for example, may be equipped with sensors that can transmit through wireless technology. Also, three-dimensional printed medical devices are very promising additions to the IoT, in that every object implanted in the human body may be scannable or trackable through networks.

Similar to what we see in science fiction movies, wearable devices that have electrostatic properties connected to various wireless systems could create new user experiences with the added capacity of artificial intelligence, making our future devices truly smart. With all of these looming innovations, the future seems to be very bright and electric.

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**David Metcalf** ([dmetcalf@ist.ucf.edu](mailto:dmetcalf@ist.ucf.edu)) is the director of the Mixed Emerging Technology Integration Lab at the University of Central Florida's Institute for Simulation and Training. **Sharlin T.J. Milliard** ([smilliar@ist.ucf.edu](mailto:smilliar@ist.ucf.edu)) is a research assistant with the Mixed Emerging Technology Integration Lab at the University of Central Florida's Institute for Simulation and Training. **Melinda Gomez** ([mgomez@ist.ucf.edu](mailto:mgomez@ist.ucf.edu)) is an instructional systems design research assistant with the Mixed Emerging Technology Integration Lab at the University of Central Florida's Institute for Simulation and Training. **Michael Schwartz** ([mschwartz@ist.ucf.edu](mailto:mschwartz@ist.ucf.edu)) is a graduate research assistant with the Mixed Emerging Technology Integration Lab at the University of Central Florida's Institute for Simulation and Training.

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