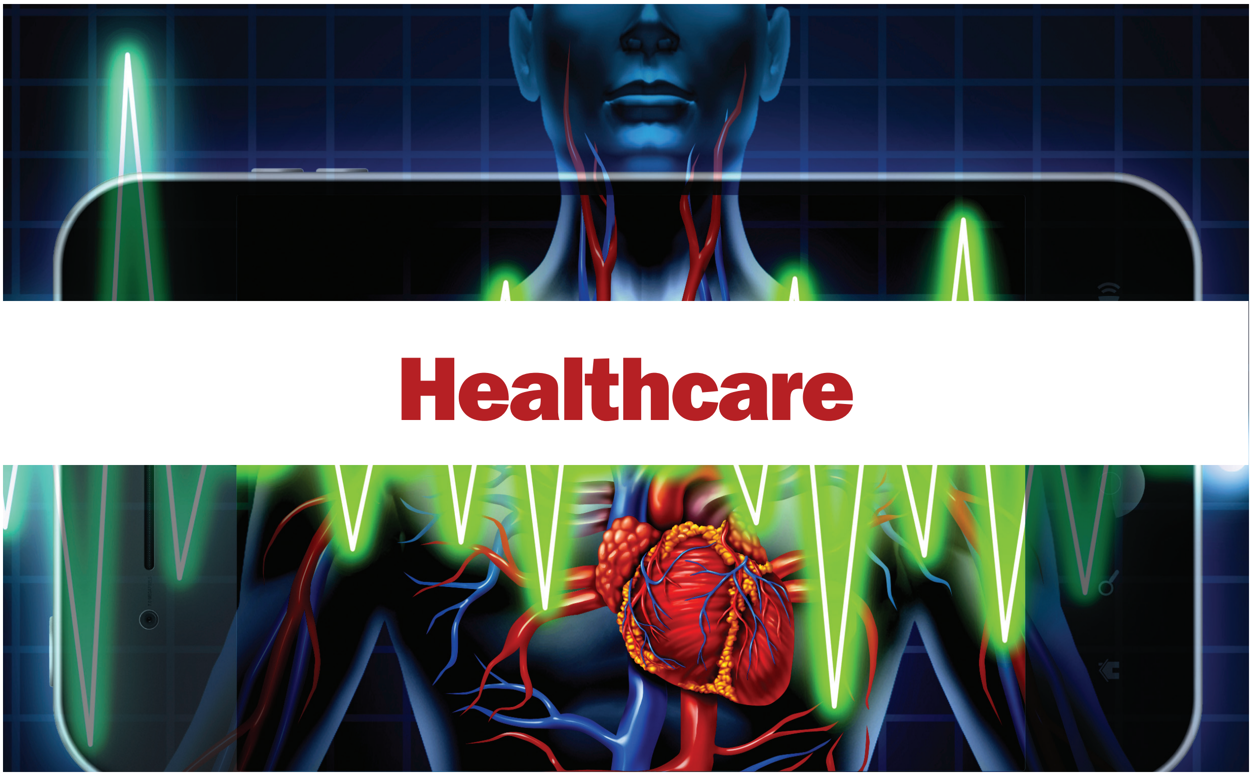
Healthcare



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We're moving closer to realizing pervasive computing devices that can monitor our health status, both individually and as a community. Imagine what doctors could do with ECG data collected on a more regular basis, as people carry on their daily activities. The ability to monitor day-to-day heart data would profoundly affect how the medical community tracks our individual health status.

Likewise, organizations such as the Centers for Disease Control wouldn't have to collect data from reports generated by hospitals and doctor's offices if we could instead collect data about people's behavior directly from the devices they use daily. Furthermore, we could then analyze that data to detect communicable diseases. However, with each such advance and the perceived health benefits, we must consider the related privacy risks and potential for data overload.

The articles in this special issue show us the technological capabilities that might be available to future healthcare providers and how they might be integrated into our daily lives.

Cardiovascular Monitoring

The days of doctors viewing a five-minute snippet of an ECG as part of a routine physical (for people of a certain age) will be viewed as woefully inadequate if two of the technologies highlighted in this special issue pan out.

Sensing with Smartphones

In "Cardiovascular Monitoring Using Earphones and a Mobile Device," Ming-Zher Poh, Kyunghee Kim, Andrew Goessling, Nicholas Swenson, and Rosalind Picard discuss how they modified a set of standard earphones, commonly used with MP3 players and cell phones, to monitor a person's bilateral blood volume. These earphones let doctors monitor patients with carotid artery disease during normal activities using a device that looks almost identical to a music player or cell phone.

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The earphones are the popular intraconcha design, more commonly called "ear buds." The authors added a reflective photosensor on the side of these ear buds that performs the required sensing without interfering with the earphones' primary function.

Unlike previous attempts to use this type of sensing, this work leverages the computational power of the smartphone rather than requiring patients to carry an additional monitoring device. In addition, because the device looks nearly identical to a regular pair of earphones, there's no stigma associated with frequent monitoring during routine activities.

The authors validate their prototype against a standard ECG, monitoring 31 healthy participants while at rest and while performing moderate physical activity. The results show that the system closely matches the data provided by the ECG device, though the authors expect system accuracy to decline when patients perform vigorous activities.

In addition to monitoring patients for cardiovascular disease, the authors also propose using their system as a biofeedback system to help patients identify music that promotes relaxation. They also hypothesize that the modified earphones could help detect carotid artery disease, speculating that bilateral asymmetry is an early indicator of this often-silent disease. However, they have yet to validate this hypothesis.

What's unclear is how this information will be presented to the medical professional. Data overload is a serious challenge, as learned with capsule endoscopy, when the wealth of images provided made interpretation difficult. Researchers also learned through that experience that providers must be trained in how to interpret the new information. As this new technology to monitor bilateral blood volume matures, medical studies will be needed to help correlate the more detailed information with the disease's progression.

Contactless Monitoring

Continuing on the theme of ECG monitoring, in "ECG Monitoring in an Airplane Seat: Appraising the Signal Quality," Johannes Schumm, Bert Arnrich, and Gerhard Tröster explore contactless ECG monitoring in the context of an airplane. Their goal is to measure the ECG signal of a passenger to detect patients with a fear of flying and help reduce their fear during the flight.

Their research has looked at the quality of the ECG signal received from an airplane seat, using a secondary pressure sensor embedded in the seat. They validate their readings against a Mobi ECG, which measures the ECG using wet electrodes attached to the chest.

In their experiments, they compare the results received from their instrumented airline seat against those from the ECG device attached to the participant, who performed routine activities of a long-haul flight. The participants modeled

- relaxing in the airline seat with the seat reclined,
- watching movies on a laptop,
- reading a newspaper,
- eating food, and
- working on a laptop.

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Their results were better during activities that involved less movement, such as relaxing. In addition, the system was able to identify bad signals that shouldn't be used in their calculations, which is important in reducing false positives.

As tempting as it is to envision the many ways we could apply their results, the authors caution that the required signal quality will vary depending on the use. A patient in the operating room undergoing critical surgery requires a higher quality ECG signal than a passenger who is becoming uncomfortable during an airline flight. However, with that caveat, imagine being able to forego the annoying sticky electrodes (and their painful removal!) for a routine ECG test during your next physical because the table on which you're being monitored is similarly instrumented.

This work also presents some significant practical challenges. Any such device will require Federal Aviation Administration approval and buy-in from the airlines. For example, wireless devices were only recently approved on airlines, when the airlines started offering Wi-Fi service. It's also unclear whether this information would help providers treat such anxiety. Follow-up medical studies would be needed to answer this question.

Large-Scale Sensing

Next, we look at healthcare on a larger scale. In "Sensing the 'Health State' of a Community," Anmol Madan, Manuel Cebrian, Sai Moturu, Katayoun Farrahi, and Alex 'Sandy' Pentland explore the use of mobile phones as a mechanism to collect information about the behaviors and opinions of a community. The beauty of their approach is that the mobile device can automatically collect location and proximity information about the places a person has travelled and the people with whom he or she has interacted. In addition, it serves as a device on which to collect survey data about the person's current state and opinions.

With the mobile phone as the platform, the authors explore three questions

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related to behavioral changes, weight-gain influences, and changes in opinion.

Behavioral Changes

The first question explored is whether people's behaviors change when they exhibit symptoms of a cold or the flu. The authors found that a person's behavior does change when ill, and they posit that those behavioral changes can help inform care providers and loved ones that an elderly (or other at-risk person) might need additional care.

In addition to viral illness, the authors also explore behavior associated with stress and depression. An interesting question is whether detecting behaviors associated with depression or increased stress could be used in suicide-prevention programs.

Weight-Gain Influences

The second question the authors explore is whether proximity to people who gain weight leads to weight gain. Again, they used the phone's ability to monitor proximity to other study participants. They also collected the participants' weight periodically. With this data, they showed that a participants' change in BMI was associated with face-to-face interactions with other participants who had also gained weight.

Changes in Opinion

The third and final question that the authors explored was that of how opinions change. In this case, the authors used political opinion as a proxy for a health/wellness opinion. They monitored interactions at different times of day as well as the types of interactions between participants. They observed that people who changed their opinion had face-to-face interactions with non-friends and that they had phone and text messaging activity with people of the opposing viewpoint.

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Drawbacks and Potential

These authors show how cell phones can monitor populations through proximity, behaviors, and locations in ways that can both help and hinder health and wellness. This is an intriguing approach, but it begs the question of whether patients will be comfortable with such information being captured, tracked, and analyzed. For example, Facebook's effort to create "PatientsLikeME" has met with a great deal of skepticism and concern. However, it's possible that, with a generational shift, patients more used to Facebook and Twitter will have fewer concerns.

Perhaps the most interesting potential use is during an influenza outbreak. Imagine public health officials making available an app that could track behaviors. Could the information collected prevent an outbreak from becoming an epidemic or an epidemic from becoming a pandemic?

Privacy Concerns

The next paper focuses on a closely related topic: privacy issues surrounding healthcare technology. In "Aging, Privacy, and Home-Based Computing: Development of a Framework for Design," Kalpana Shankar, L. Jean Camp, Kay H. Connelly, and Lesa Huber examine privacy in the context of home-based computing technologies designed to help elders with security, medication compliance, safety, and activities of daily living.

The authors considered seven different technologies. The first four are prototypes:

- a plant that facilitates connections with remote family members,
- a mirror that reminds elders about appointments and medications,
- a monitor that shows video of the front door when the doorbell rings and shares that video with loved ones, and
- a device connected to the PC to indicate the level of trust of a webpage to be visited.

They also look at three off-the-shelf products:

- a product that provides audio and visual notifications about medication and alerts a care provider or loved one when medications aren't taken,
- a software application designed to promote cognitive functions, and
- a biofeedback application designed to help reduce stress.

They invited elderly residents at a local facility to tour a house in which these devices had been installed and talked with them about the privacy implications of each device. The authors identified factors that determine how the elderly perceive privacy. In short, the elderly evaluated the usefulness of each device and the data granularity it provided. In other words, the elderly wanted to expose only the data that was necessary to maintain their safety and well being.

Based on this feedback, the authors learned several interesting and unexpected lessons about the perception of privacy among elders, and they adjusted their privacy framework accordingly. It will be interesting to see if these attitudes change over time as the elderly population comprises a generation that has used computer technology as part of everyday life. It would also be interesting to see if these findings apply to different age groups, such as those aged 30 to 45.

As pervasive computing technologies take their place in the world of medicine, we'll need to balance the benefits to our health and well-being with the costs to our privacy. We must also consider the dangers of data overload, which could cause our healthcare professionals to miss seeing the forest through the trees.