This forum is dedicated to personal health in all its many facets: decision-making, goal setting, celebration, discovery, reflection, and coordination, among others. We look at innovations in interactive technologies and how they help address current critical healthcare challenges. **— Gillian R. Hayes, Editor**

Managing Health with Mobile Technology

Predrag Klasnja, University of Michigan
Wanda Pratt, University of Washington

Nearly two-thirds of all U.S. adults now have smartphones—powerful personal computers that are always with their owners, are continuously connected to the Internet, are capable of running sophisticated applications, can know where their owners are and what they are doing, and can connect to a wide range of other devices, from wearable sensors to car entertainment systems.

The growth of smartphones has far-reaching implications for healthcare. Simply put, smartphones and other mobile technologies might be the single most promising avenue we have to help individuals manage their health, and to do so at scale. From encouraging physical activity to assisting cancer patients with the management of chemotherapy side effects, mobile health (mHealth) is increasingly becoming a key platform for delivering health interventions.

The recent explosion of work in mHealth has come from both the commercial sector and research in health sciences and human-computer interaction. Commercial fitness devices, such as Fitbit and Nike+ Fuelband, have brought mHealth into the mainstream, while HCI and health researchers are continuing to develop new ways to support people's efforts to manage their health and to test the efficacy of the resulting interventions. In broad terms, this recent work has fallen into two categories: wellness management and health behavior change, and patient care outside the clinic. Here we briefly review the main approaches that have been taken to support these goals and discuss where we think the field of mHealth needs to move next.

WELLNESS AND HEALTH BEHAVIOR CHANGE

A key focus of mHealth research and development in the past few years has been on helping individuals to adopt and sustain healthy lifestyles. Physical inactivity, poor diets, smoking, and other behavioral risk factors are key contributors to an epidemic of chronic conditions—including obesity, diabetes, and heart disease—with immense costs in terms of human suffering and healthcare expenditures. Yet these conditions are largely preventable, and many recent mHealth technologies have aimed to help individuals improve their health by adopting healthier habits. mHealth applications use four main strategies to encourage healthy behaviors: tracking and feedback, goal setting, social influence, and gamification.

Insights

→ Mobile technology is a promising tool for timely and scalable support of wellness activities and continuity of patient care outside the clinic.

→ Wellness strategies include tracking and feedback, goal setting, social influence, and gamification.

→ Patient-care strategies include symptom monitoring, self-management coaching, and automated decision support.

The core features of nearly all mHealth applications are tracking of health-related behaviors and providing feedback on those behaviors. This process, called *self-monitoring*, has been used to support health behavior change since the early 1970s and can be effective for changing a broad range of behaviors, from physical activity to obsessive rumination. mHealth applications are making self-monitoring more powerful and practical by easing the collection of behavioral data and by providing users with real-time feedback on how they are doing with respect to their behavior-change goals.

Physical-activity trackers (e.g., Fitbit), digital scales, Bluetooth-equipped heart-rate monitors, and other emerging sensors are making it possible for mHealth applications to track information about users' activities and states with minimal burden, greatly easing the process of self-monitoring. Even for activities that cannot be captured automatically, such as diet or emotion, mHealth researchers have developed logging interfaces that substantially reduce the burden of tracking. For instance, PAM—a recent project by Pollak and colleagues at Cornell [1]—enables users to record how they feel simply by tapping on one of 16 photographs that best represents their current emotional state. Pollak et al. have shown that PAM correlates well with the much more laborious gold-standard measures of affect. Similarly, category-based journaling of food intake, which asks users to report only what types of food they consumed

(e.g., "dark-green vegetables" or "low-carb meal") rather than exactly what they ate, is making it easier for people to track their diets long-term. Although category-based journaling is less accurate than traditional food diaries, simplified diet tracking can still help with the adoption of healthier eating habits. Early studies of mHealth applications that used this approach have found that study participants increased their consumption of fruit and vegetables [2], and that the resulting data could even be used to automatically calculate correlations between users' food intake and their other health-related behaviors, such as sleep [3].

Nearly all wellness applications also provide feedback, often in the form of daily and weekly views of tracked activities. Some, like Jawbone UP, even offer charts of multiple types of activities, enabling users to look for patterns in their data and formulate hypotheses about how their activities are related to one another. Nor does feedback stop with charts. For instance, UbiFit [4], a mobile-phone application for encouraging physical activity, provides users with feedback in the form of a flower garden on the phone's wallpaper, enabling them to see how active they have been that week every time they use their phone. And many mHealth applications provide feedback directly on the sensing device (e.g., Nike+), enabling users to quickly see how they are doing without reaching for their phones. Such improvements to tracking and feedback are helping individuals to monitor their health activities more effectively, more easily, and over longer periods of time.

Tracking support enables mHealth applications to employ a number of other strategies for encouraging healthy activities. One common strategy is goal setting. In many mHealth applications, individuals are able to set goals and to track how they are progressing toward those goals. Recent applications explore how to set such health-behavior goals most effectively. For instance, GoalPost [5] enables users to set two physical-activity goals, a main goal and a backup goal. The addition of the backup goal can help individuals to stay motivated and active even during periods when they are too busy to reach their primary goal. Such innovations can help people deal with the messiness of everyday life, which makes perfectly consistent routines difficult even for those with the best of intentions.

Social influence is another strategy commonly used by mHealth applications to encourage healthy behaviors. Fitbit allows users to friend one another, to create challenges, and to post their achievements and activities on Facebook and Twitter,

inviting supportive feedback. Jawbone UP lets users form teams to work toward common goals, and Nike+ has a sophisticated system for creating challenges and staging competitions among users. Research applications have explored social influence as well. For example, VERA [6] allows users to document a wide variety of health-related activities and to engage in conversations around these posts, exchanging tips and generating ideas for other healthy activities. What the optimal forms of social influence are in mHealth applications is still an open research question, but there is a shared belief among researchers that mobile technology can help create social structures that can facilitate the effective adoption of healthy behaviors and pursue their health goals.

Finally, recent work has begun to incorporate video game principles into mHealth applications. The efforts in this direction vary greatly in complexity and sophistication. At the simple end of the spectrum, many commercial applications, such as Fitbit, now offer badges for goal attainment and active application use. On the complex end, researchers are creating *exergames*, full-blown video games that incorporate real-world physical activity as part of the gameplay. iFitQuest [7], for instance, is a set of iPhone-based games aimed at adolescents that require players to exercise to move their in-game characters, interact with other characters, or collect items, such as coins. iFitQuest uses the iPhone's GPS and compass to detect players' activities, which are converted into actions within the game, such as escaping a ghost who is pursuing the player's character. How to make such games effective for changing behavior is an exciting research area.

Beyond the strategies we described above, technological advancements are creating opportunities for supporting wellness in ways that we are only beginning to explore. Phone sensors, combined with environmental sensing and cloud computing, are making it increasingly possible to dynamically model how a person's health behaviors are influenced by her environment, social interactions, daily routines, and other behaviors.

Such models can be used to create effective just-in-time interventions, enabling individuals to get the right kind of support at just the right moment—for instance, when a person is deciding whether to go to the gym or settle in for the night with a pizza and a movie. Similarly, personalized models of health behaviors will make it possible to optimize interventions by targeting behaviors and aspects of the environment that have the

PAM's simple mood-tracking interface.

greatest influence on the behavior a person is trying to change. Such advancements could greatly increase the effectiveness of wellness and behavior-change technologies.

PATIENT CARE OUTSIDE THE CLINIC

In addition to encouraging healthier habits, mHealth applications have tremendous potential to support patient care outside the clinic,

mHealth apps can help health professionals teach patients how to successfully manage their conditions.

where, ultimately, patients manage their health and where most health problems occur. Much of the work in this area has focused on three strategies: symptom monitoring, self-management coaching, and automated decision support.

Management of many conditions requires that patients' symptoms are regularly monitored, so that a deterioration in the patient's state is promptly detected and treated. mHealth technologies make it possible to monitor symptoms continuously using sensors or frequent self-report, increasing the likelihood that a worsening condition will be dealt with in a timely manner. Scherr and colleagues [8] used this approach to remotely monitor patients with heart failure. By monitoring daily data on patients' weight and blood pressure, Scherr et al. were able to show that they could significantly reduce monitored patients' rates of hospitalization, and that the length of hospitalization was significantly shorter when a patient had to be admitted. Symptom-monitoring applications can help patients get care when the need first arises, giving them peace of mind and helping prevent serious, even fatal, health events.

In addition to supporting symptom monitoring, mHealth applications can help health professionals teach patients the strategies they need to successfully manage their conditions. MAHI [9], for instance, enables patients with diabetes to record their glucose levels throughout the day, along with the information about the context or activities that could have influenced the glucose readings, such as what they ate. This information is uploaded to a secure website, where it is reviewed by a diabetes educator, who then coaches the patients in diabetes-management strategies based on the patients' data. By focusing the coaching around patients' own data, mHealth applications can ensure that patients learn strategies that are relevant to their specific life circumstances.

Finally, mHealth applications can contain clinical knowledge and provide patients with immediate decision support whenever it's needed, regardless of whether a healthcare

provider is available. An application for management of chemotherapy side effects [10], for instance, gives patients tailored management plans for their reported symptoms. If they experience diarrhea, patients might be told to drink fluids, use rehydration sachets, or take medication, depending on the reported severity. Such decision-support applications can detect when a patient's condition is getting worse and provide immediate advice on what the patient should do, increasing the chances that the symptoms are dealt with in an appropriate and timely fashion.

The promise of mHealth for outpatient care goes beyond symptom monitoring and coaching, however. The emergence of portable medical instruments that connect to mobile phones, such as ultrasound devices and electrocardiograms, makes it possible to significantly increase access to high-quality care in rural and underprivileged communities. Equipped with a smartphone and a few pocket-size instruments, and connected to a regional medical center via a video call, community health workers can act as eyes and ears for highly skilled physicians in areas where access to specialty care is limited. If implemented at scale, such models could help close the divide in access to care faced by many communities around the country and the world.

A LOOK AHEAD
For the promise of mHealth to be fully realized, many problems still need to be solved—problems that HCI researchers and practitioners are well equipped to tackle. From investigating how to provide optimal social support for health behavior change to determining how to summarize large sets of sensor data so clinicians can quickly understand how their patients' behaviors and conditions have changed, HCI researchers and practitioners can significantly contribute to making mHealth technologies even more effective and better integrated into people's lives and in clinical care.

Just as important, we believe that HCI can play a key role in the development of the next generation of mHealth technologies. We envision two classes of applications: adaptive systems that take into account an individual's changing health goals, abilities, and circumstances to provide support that is finely tuned to the user's current needs; and life-companion applications that accompany users over many years and devices, helping them reach the goals they care about the most. Such life-companion apps would motivate health behaviors by framing them in terms of users' overarching goals and values, making it more likely that health activities will become intrinsically motivated and maintained long-term. At the same time, due to the richness of the data they would collect about their users over time, such life-companion apps could become an integral part of a learning health system, enabling clinicians to personalize treatment based on a deep understanding of the patient's history, and advancing our knowledge about how behavior and context interact with genetic factors to cause disease or maintain health. The HCI community should be at the forefront of that next wave of mHealth innovation.

ENDNOTES
1. Pollak, J.P., Adams, P., and Gay, G. PAM: A photographic affect meter for frequent, in situ measurement of affect. *Proc. of the 2011 Annual Conference on Human Factors in Computing Systems.* ACM, 2011, 725–734.
2. Arsand, E., Tatara, N., Ostengen, G., and Hartvigsen, G. Mobile phone-based self-management tools for Type 2 diabetes: The Few Touch application. *Journal of Diabetes Science and Technology 4,* 2 (2010), 328–336.
3. Tollmar, K., Bentley, F., and Viedma, C. Mobile health mashups: Making sense of multiple streams of wellbeing and contextual data for presentation on a mobile device. *Proc. of Pervasive Health '12.* 2012, 65–72.
4. Consolvo, S., McDonald, D.W., Toscos, T., Chen, M.Y., Froehlich, J., Harrison, B., Klasnja, P., LaMarca, A., LeGrand, L., Libby, R., Smith, I., and Landay, J.A. Activity sensing in the wild: A field trial of UbiFit garden. *Proc. of the 26th Annual SIGCHI Conference on Human factors in Computing Systems.* ACM, 2008, 1797–1806.
5. Munson, S.A. and Consolvo, S. Exploring goal-setting, rewards, self-monitoring, and sharing to motivate physical activity. *Proc. of the 6th International Conference on Pervasive Computing Technologies for Healthcare.* 2012, 25–32.
6. Baumer, E.P., Katz, S.J., Freeman, J.E., Adams, P., Gonzales, A.L., Pollak, J.P., Retelny, D., Niderdeppe, J., Olson, C.M., and Gay, G.K. Prescriptive persuasion and open-ended social awareness: Expanding the design space of mobile health. *Proc. of the ACM 2012 Conference on Computer Supported Cooperative Work.* 2012, 475–484.
7. Macvean, A. and Robertson, J. iFitQuest: A school based study of a mobile location-aware exergame for adolescents. *Proc. of the 14th International Conference on Human-Computer Interaction with Mobile Devices and Services.* ACM, 2012, 359–368.
8. Scherr, D., Kastner, P., Kollmann, A., Hallas, A., Auer, J., Krappinger, H., Schuchlenz, H., Stark, G., Grander, W., Jakl, G., Schreier, G., and Fruhwald, F.M. Effect of home-based telemonitoring using mobile phone technology on the outcome of heart failure patients after an episode of acute decompensation: Randomized controlled trial. *Journal of Medical Internet Research 11,* 3 (2009).
9. Mamykina, L., Mynatt, E., Davidson, P., and Greenblatt, D. MAHI: Investigation of social scaffolding for reflective thinking in diabetes management. *Proc. of the 26th Annual SIGCHI Conference on Human factors in Computing Systems.* ACM, 2008, 477–486.
10. Weaver, A., Young, A.M., Rowntree, J., Townsend, N., Pearson, S., Smith, J., Gibson, O., Cobern, W., Larsen, M., and Tarassenko, L. Application of mobile phone technology for managing chemotherapy-associated side-effects. *Annals of Oncology: Official Journal of the European Society for Medical Oncology 18,* 11 (2007), 1887–1892.

⬤ **Predrag "Pedja" Klasnja** is an assistant professor in the School of Information and the Department of Health Behavior and Health Education at the University of Michigan. He studies how technology can help people to better manage their health in everyday life and to more effectively communicate with their healthcare providers.
→ klasnja@umich.edu

⬤ **Wanda Pratt** is a professor in the Information School and the Medical School at the University of Washington. Her research focuses on deeply understanding patients' needs and then designing as well as evaluating new technologies to address those needs. She is a fellow of the American College of Medical Informatics.
→ wpratt@uw.edu