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Consumer Informatics and Digital Health

Solutions for Health and Health Care

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Chapter 12
Improving Self-Management and Care Coordination with Person-Generated Health Data and Mobile Health

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The Rise of Person-Generated Health Data and Mobile Health Applications

Person-generated health data (PGHD) is information about a person relevant to health that is purposefully created by the individual, observed by her, or passively collected by devices about her. Examples of common forms of PGHD in the past include forms for gathering individual's health and family history, screening tools for symptoms and moods, or logs tracking medication use.

In the last decade, we have witnessed a rapid convergence of interest and use of mobile health (mHealth) (Miller & West, 2009). With the availability of inexpensive wireless sensor networks (Alemdar & Ersoy, 2010; Varshney, 2005), increasingly available connectivity, and consumer-adoption of smartphones, opportunities abound for improvements in health management. Paper tools have been replaced by online tools and mobile applications. The diversity and depth of biometric PGHD that can be captured has grown with the availability of devices such as wearable fitness monitors and smartphone accelerometers. These devices can capture data on physical activity, sleep patterns, and heart rate.

Other health data that were customarily collected in clinical settings are today more easily generated by individuals via personal-use devices such as mobile electrocardiograms for detecting heart rhythm, glucose meters for measuring diet related blood glucose levels, and blood pressure cuffs. In addition, environmental sensors offer highly localized and in-home measures. For example, motion sensors detect an individual's movement around a home. Sensors in a bed or chair can collect mobility data and ambient sensors in the home can measure exposure to air pollution.

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Remote monitoring through PGHD presents one possibility for providing timely and precisely targeted health interventions that reduce the need for costly and burdensome hospital-based services (PricewaterhouseCoopers, 2015). Recent surveys revealed that the public acknowledges the value of PGHD for maintaining their own health: 33% of United States (US) residents are using health-tracking mobile apps and 21% using wearable devices (Gownder et al., 2015).

In the last two decades, the bulk of research in mHealth has been related to demonstrating data collection and display of PGHD to individuals for self-monitoring. One of the first systematic reviews of cell phone voice and text messaging use for health management identified 25 studies showing moderate improvements in medication taking, symptoms, smoking cessation rates, and self-efficacy across 13 different health conditions (Krishna, Boren, & Balas, 2009).

An extensive review of randomized controlled trials (RCTs) involving consumer health informatics applications showed that the key technologies employed were computer applications or web-based applications (Gibbons et al., 2011). Even though the studies used a variety of methodological approaches and varied in quality, they provided preliminary evidence that consumer-oriented technology improved health outcomes in mental health, diet/physical activity, breast cancer, obesity, diabetes, asthma, Alzheimer's disease, and HIV/AIDS.

The advent of readily available consumer smartphones in the form of iPhones (2007) and Android operating system phones (2008) launched a dramatic rise in interest in mobile applications or "apps." The field of mHealth research began to grow substantially, as evidenced by the increase in published scientific literature.

As the number of peer-reviewed papers increased, systematic reviews also began to appear that focus on mHealth apps for single conditions. A recent review of mental health apps found eight papers involving five apps associated with significant reductions in depression, stress, and substance abuse (Donker et al., 2013). Four of these apps involved support by a mental health professional.

In studies of heart failure, Creber et al. found that only 3 out of 34 apps that centered on symptom monitoring and self-care in peer-reviewed publications had been evaluated (Creber et al., 2016). In their review of 21 studies using mobile phones for type 1 diabetes, Holtz and Lauckner (2012) found that some showed evidence of improved self-efficacy, hemoglobin A1c, and self-management, with study limitations including insufficient sample sizes and short intervention periods. Similarly, a review of mobile apps for behavior change through self-monitoring found evidence of user acceptance of apps, although most studies involved small sample sizes (Payne, Lister, West, & Bernhardt, 2015).

A body of evidence is also accumulating in cancer care. In a review assessing behavior change techniques utilized in cancer apps. Dahlke et al. found that among 68 apps and games the majority of iOS apps (67%) and about a third of Android apps (38%) used theory-based behavior change techniques (Dahlke et al., 2015). Another review found 594 papers related to 295 cancer apps found in app stores for four major smartphone platforms (Bender, Yue, To, Deacken, & Jadad, 2013).

These reviews reflect the rapid growth in the number of health-focused apps and increasing interest among mHealth researchers in identifying and assessing applications with potential to health people with particular health conditions. However, most of the apps have not yet been evaluated systematically. There are significant ongoing challenges in understanding what measures were important in the selection and evaluation of apps, e.g., features and functions, behavior change, or health outcomes, in order to build the evidence base that supports what apps work for which conditions and populations.

The Evolution of Self-Monitoring Tools: Examples from Type 2 Diabetes

Type 2 diabetes (T2D) is a chronic condition that affects the way the body metabolizes sugar (glucose), which is the body's primary energy source. T2D is currently one of the world's fastest growing diseases; the prevalence of T2D rose from 171 million affected in 2000 to 415 million affected in 2015 worldwide (International Diabetes Federation, 2017). The total annual global health expenditure for diabetes in 2015 was $673 billion in US dollars, accounting for 12% of the world's total health expenditures. As of 2016, the total global cost is $825 billion per year (Harvard School of Public Health, 2016).

People with T2D either have a resistance to the effects of insulin, a hormone produced by the pancreas that regulates the flow of sugar into your cells, or aren't able to produce enough insulin to maintain a normal blood glucose level (mayoclinic.org). While there may be a genetic component to T2D, there is clear evidence that environmental factors such as excess weight and sedentary lifestyle are contributors.

Individuals living with T2D often need a complex set of services and support including daily glucose monitoring, insulin and other medication management, lab tests, foot exams, and regular medical check-ups. Intensive management of blood glucose levels, through medical intervention or lifestyle adaptations (improved diet and increased exercise), can reduce complications in T2D.

Health information technologies have been used in T2D management since 1990. New technologies emerge rapidly in the consumer market. However, technologies that are applied in US healthcare or medicine must go through regulated testing and evaluation processes, including clinical trials such as those required by the US Food and Drug Administration (FDA) agency in order to be approved for clinical use. For this reason, this section focuses on tools for T2D that were evaluated in randomized clinical trials (RCTs).

Technologies used and evaluated in RCTs of T2D over the last two decades range from basic technologies where patients and clinicians communicate through phone, email, or SMS (short message service) text to advanced web-based frameworks that require connection to the Internet and mobile devices (Jalil, Myers, & Atkinson, 2015). In the 1990s before the Internet, widely available technologies included glucometer modem transfer of data followed by graphical report generation (Shultz, Bauman, Hayward, Rodbard, & Holzman, 1991). Three primary types of technology were reviewed by Jalil et al. (2015): telephone-based, computer-based, and handheld (see Fig. 12.1).

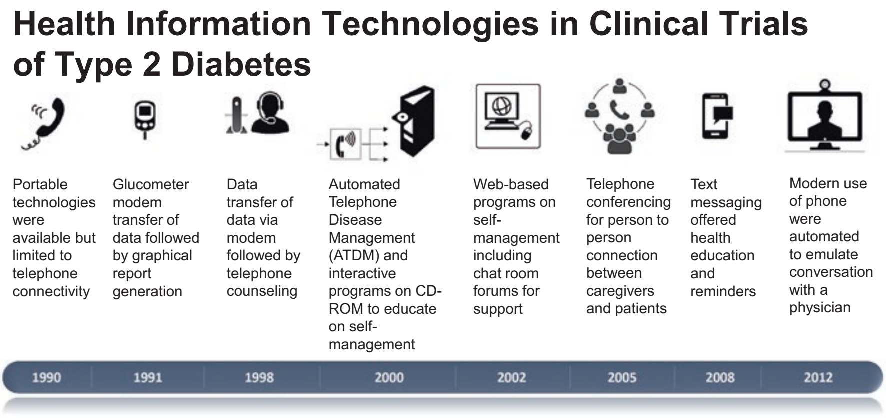

Fig. 12.1 Health information technologies used in type 2 diabetes have evolved over two decades. Source: Katherine K. Kim

Telephone-Based Monitoring Tools

Telephones have been used in many different ways for T2D management. Two early examples are data entry using touch tone telephones followed by voice messages from clinicians (Meneghini, Albisser, Goldberg, & Mintz, 1998) and the transfer of data via modem followed by telephone counseling (Biermann, Dietrich, & Standl, 2000). Another example is the Automated Telephone Disease Management (ATDM)—a telephone-based system where patients received calls at predetermined times and listened to self-management tips navigated via the telephone keypad (Piette et al., 2000).

After the year 2000, non-automated telephone services were also used with basic conferencing via teleconferencing, using person to person telephone connections between caregivers and patients (Izquierdo et al., 2003). Further variation of telephone-mediated and proactive call center treatment support was seen in a telephone-based system where patients spoke with trained non-medical operators (Young et al., 2005). More recently, an RCT used automated phone calls to emulate conversations with a physician (Williams et al., 2012).

Computer-Based Monitoring Tools

While the majority of the clinical trials in mobile health have evaluated telephone-based technologies, some involved computer-based tools particularly in the pre-Internet era. One early example used interactive programs on CD-ROM to educate consumers on self-management of type 2 diabetes (Glasgow & Toobert, 2000). The post-Internet era saw the emergence of web-based programs on self-management including chat room forums for support (McKay, Glasgow, Feil, Boles, & Barrera, 2002), computer appliances that integrated data from devices such as iCare and the Health Buddy device (Cherry, Moffatt, Rodriguez, & Dryden, 2002), web-based diabetes management systems (Montori et al., 2002), and the Internet Based Glucose Monitoring System (Cho et al., 2006).

Handheld Monitoring Tools

For more than 20 years, handheld portable devices have allowed for patient mobility and convenience in recording time, date, and blood glucose levels (Rutten, Van Eijk, de Nobel, Beek, & Van der Velden, 1990; Tsang et al., 2001). Text messaging using mobile phones then began to offer health education and reminders such as "Please, decrease the long acting insulin by two units," "Please add one tablet of sulfonylurea in the evening," "Lack of exercise may be the cause of the aggravated glucose level," and "Your glucose control seems to be good" (Kim & Kim, 2008).

Mobile Applications in Clinical Trials

Mobile applications ("apps") are software programs installed on mobile devices such as smartphones and tablets with a mobile operating system such as iOS or Android. These apps are equipped with computing and connectivity capability. With the rapid growth in wireless connectivity and smartphone sales, users have access to many different health apps. In the iTunes App Store for iOS and Google Play for Android apps, diabetes is one of the top-ranked categories with more than 1100 different apps available for download (Wu et al., 2017).

However, there is a dearth of evidence about their efficacy or effectiveness. A recent systemic review (Whitehead & Seaton, 2016) showed there were only five randomized controlled trials assessing apps in diabetes self-management. Yet, there is great interest and hope that apps can help people manage their condition. The American Diabetes Association (ADA) guideline states that apps may be a useful element of effective lifestyle modification to prevent diabetes (American Diabetes Association, 2017).

As technologies have evolved in the consumer market, health researchers have begun to study these new technologies and evaluate clinical outcomes. This section reports only T2D health information technologies that were reviewed through clinical trials. The contrast between the number of commercially available apps and the number of RCTs of apps demonstrates a clear need for additional research to help individuals and clinicians and patients determine whether to use apps and how to choose safe and effective ones among the thousands that are available.

Early Research on PGHD and Mobile Health: Examples from Project HealthDesign

One major effort to move mHealth and PGHD forward was Project HealthDesign: Rethinking the Power and Potential of Personal Health Records, which began in 2006 (Robert Wood Johnson Foundation, 2015). Project HealthDesign sought to stimulate innovation and expand the use of technologies to put actionable health information into the hands of patients by awarding $9.4 million to 14 interdisciplinary teams. This initiative introduced the term "observations of daily living" (ODLs), which indicated that much of the data for health decisions was generated by and used by patients themselves in their daily activities, and consequently lack of ODLs might hamper patients' ability to optimize their health (Brennan, Downs, & Casper, 2010).

The Project HealthDesign teams demonstrated innovations that addressed the needs of diverse populations. Here are four examples.

The Estrellita project sought to enable self-monitoring of the health of premature infants and their mothers and deliver those ODLs to clinicians (Cheng, Hayes, Hirano, Nagel, & Baker, 2015).

The Living Profiles: Transmedia Personal Health Record Systems for Young Adults project used principles of design thinking to understand the needs of adolescents with chronic illness related to health information display (Park, Chira, Miller, & Nugent, 2015).

Dwellsense demonstrated how aggregated data from sensors on furniture and pill bottles could provide insights to elderly people about potential cognitive impairment and medication adherence, as well as offer early warning signs to their healthcare teams (Lee & Dey, 2015).

iN Touch demonstrated the value of an application for self-tracking for youth with overweight/obesity and at risk for depression within a health coaching program (Kim, Logan, Young, & Sabee, 2015). The next section provides an in-depth description of iN Touch.

iN Touch: A Mobile Self-Monitoring System and Health Coaching Program

Obesity is a pressing issue that exacerbates the development and ongoing management of chronic conditions and health disparities. Innovative approaches in prevention, treatment, and self-management are needed to stem the rise of these negative health impacts on population health. Obesity disproportionately affects low income and minority teens (Rossen & Schoendorf, 2012; Skelton, Cook, Auinger, Klein, & Barlow, 2009). Adolescent depression is also a risk factor for development and persistence of obesity (Goodman & Whitaker, 2002).

Motivational interviewing-based health coaching shows promise as a method of supporting self-management in chronic illness and its risk factors, such as overweight/obesity (Lindner, Menzies, Kelly, Taylor, & Shearer, 2003). For youth, coaching and coping skills training can impact metabolic risk associated with type 2 diabetes (Grey et al., 2009). Several studies suggest that adolescents find goal setting, action plans, and self-monitoring to be attractive features of a web-based or in-person health coach (Appel et al., 2011; Olsen & Nesbitt, 2010; Thompson, Cullen, Boushey, & Konzelmann, 2012. In addition, there is a growing body of literature indicating that computer-based and mobile behavioral interventions show moderate impacts on diet, exercise, and weight in youth (Cushing & Steele, 2010; Nollen et al., 2013).

Kim et al. report on the iN Touch study, whose purpose was to evaluate acceptance of a mobile self-management application and health coaching by low-income youth with overweight/obesity and assessing the potential for the intervention to affect health outcomes (Kim et al., 2015). The iN Touch application and intervention strategy were developed with participatory methods engaging a ten-member youth advisory board. A 6-month pre-post pilot study was conducted. Urban youths age 13–24 who were overweight or obese, and identified from three clinics in San Francisco (two clinics in the same hospital and one school clinic) that serve primarily low-income patients, were recruited for the study. Participants were provided an iPod Touch with trackers for exercise, food, mood, and socializing, supplemented by photos and notes, (Fig. 12.2) and they met with a health coach.

Summative evaluation of iN Touch encompassed both technology and health domains, see Table 12.1.

These results suggest that technology was accepted by participants who reported that both the application and health coaching are useful for self-management. Health impact based on waist measures and PAM were positive.

Sarah's Story (Box 12.1) offers one example of the broader impact this program had on participants.

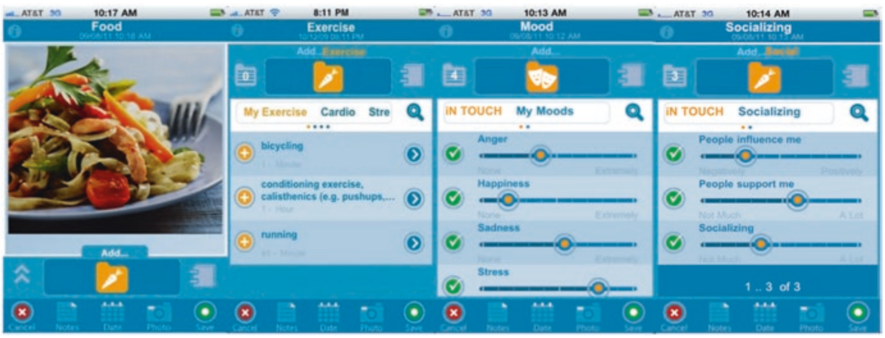

Fig. 12.2 Screenshots of iN Touch self-tracking application supports in the moment awareness of observations of daily living. Source: Katherine K. Kim

Table 12.1 Evaluation of the iN Touch study examines multiple health and technology domains (Katherine K. Kim)

Domain	Evaluation	Significant results
Waist circumference	Paired *t*-test of pre- and post-measure	$M = -1.21$ in., SD = 2.62; $t(22) = -2.21$, $p = 0$
Patient activation measure (PAM)	Paired *t*-test of pre- and post-measure	$M = 0.42$, SD = 0.93; $t(24) = 2.20$, $p = 0.04$
Application usage	Number of ODLs recorded	2117 total over 6 months ODLs/participant/day, $M = 3.11$
Application usefulness	Rating on scale of 1 = low to 5 = high	$M = 3.50$, SD = 1.18
Ease of use of application	Rating on scale of 1 = low to 5 = high	$M = 3.83$, SD = 1.27
Perception that application had an impact on health	Rating on scale of 1 = low to 5 = high	$M = 3.50$, SD = 1.18
Usefulness of application without health coach	Rating on scale of 1 = low to 5 = high	$M = 2.83$, SD = 1.19
Usefulness of health coach without application	Rating on scale of 1 = low to 5 = high	$M = 3.13$, SD = 1.19

Box 12.1: Sarah's Story

Sarah (a pseudonym) was a 214-pound, pre-diabetic high school student who hated comments her peers made about her appearance. When she first met the iN Touch health coach, Sarah shared that she regularly ate fast food, drank soda, and cut class. She wanted to focus on eating healthier and exercising. Sarah and the coach discussed different types of exercises and worked together to create backup plans in case she was unable to do her intended exercise.

Sarah planned to record her observations of daily living (ODLs) about her food, exercise, socializing, and mood in the iN Touch application a few times a week. She began recording her ODLs and found it was easy enough to do. She also used the notes section to intensively journal about her path to a healthier life. Sarah texted the health coach and took advantage of in-person coaching visits to talk about her challenges, strategies, and progress. She also continued to see her regular physicians and nurses.

By the third month of participation she reported that she was cutting fewer classes. She now regularly power walks with hand weights and started taking dance classes over the summer. She has eliminated fast food, chips, and sodas from her diet. Instead, she carries healthy snacks in her purse and drinks only water. At the end of 6 months of participation, Sarah has lost more than 20 pounds.

Sarah's size is not the only change. "I have confidence," she says, "I feel this is my year. Now if people want to come at me with drama, I'm just like, 'I don't care.' I'm going across that stage. I'm going to a 4-year college. Twelfth grade is my serious year."

Source: Kim (2011). Reprinted with permission of author.

Project HealthDesign provided a corpus of studies at the leading edge of science in PGHD and mHealth as it related to observations purposefully collected by individuals about their health. Learnings from these studies demonstrated impacts on health, technology adoption, and feasibility of integration into patient–clinician interactions.

PGHD and Mobile Health for Care Coordination

As mHealth has burgeoned, so has the amount of PGHD available for use by individuals and their healthcare teams. Alongside this growth has been increasing interest in how PGHD can be combined with clinical data to support collaboration among individuals and their healthcare teams and develop new insights to improve care.

The value of PGHD for individuals can be enhanced by leveraging it to enable care coordination across multiple conditions. Care for individuals with chronic conditions such as diabetes or heart disease, or conditions requiring life-long surveillance such as cancer, is complicated and fragmented. Individuals frequently transition between settings: from home to physician office, clinic, outpatient service, emergency department, inpatient hospital, and community-based services.

Due to lack of integration by the healthcare system, the burden of coordinating between the healthcare teams attending each of these settings often falls to the patient, their family members, and close friends (family team). Examples of care coordination activities that family teams conduct are numerous. They may keep copies of important medical records such as consultation reports, recent lab or imaging results, and hospital discharge summaries to share with other clinicians because those records may not be available by the time of subsequent visits. The family team may keep a calendar of appointments and contact list of healthcare providers and facilities in paper or on their phones to facilitate scheduling and rapid communication among the family team members. Finally, they may keep an ongoing list of questions and concerns about medication interactions or side effects, dietary restrictions, or treatment plans without being certain which of their clinicians can offer the answer.

The community-wide care coordination conceptual framework seeks to elaborate the context surrounding an individual's health journey (Kim, Bell, Reed, & Whitney, 2016). This framework shows that there are dynamic relationships and workflows among different teams involved in care of an individual—family teams, healthcare teams, and community teams—and over time (see Fig. 12.3). Different teams, represented by the multi-colored spheres, are involved with an individual (large oval) throughout their health lifecycle. The size of the spheres indicates the magnitude of involvement in any particular stage. Finally, where spheres touch or overlap represents a "point of need" at which coordination is required to synchronize and share information, organize activity, hand-off responsibility, or make

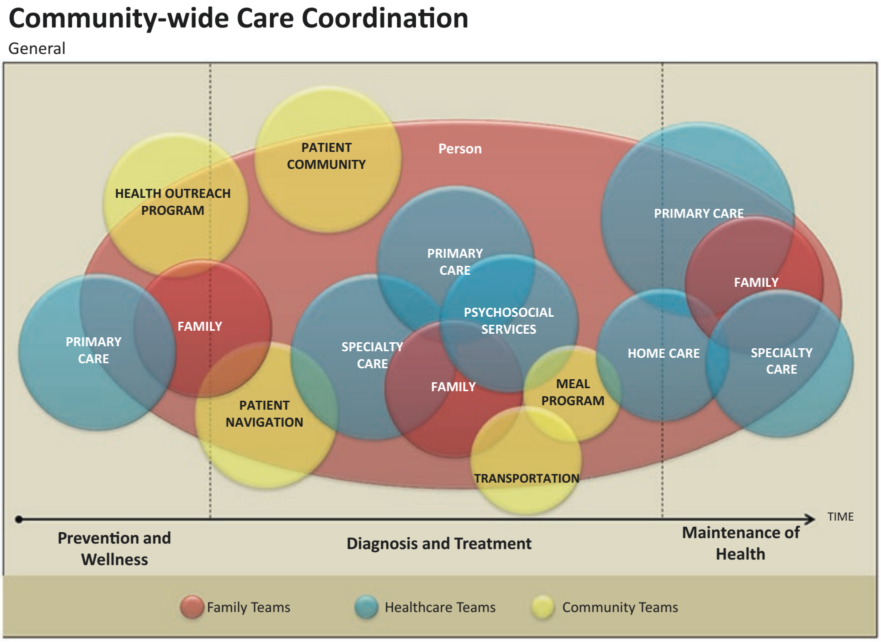

Fig. 12.3 A conceptual frame for community-wide care coordination offers a broad view of a person's health journey. Source: Katherine K. Kim

shared decisions about health. Points of need are broader and more diverse than the points of care where healthcare services are provided.

A shared care plan (SCP) is defined as a comprehensive, evidence-based plan of care that is collaboratively developed with participation of the patient, family, and health care team (Osborn, Squires, Doty, Sarnak, & Schneider, 2016). The SCP is a key tool for care coordination by serving as a means of compiling who, what, when, where, and how care will be accomplished for an individual and communicating that to all parties involved, thus offering a means of assuring that important activities are accomplished. While there is no consensus about the optimal SCP, a starting point for its construction based on a review of published literature identifies both PGHD and clinically generated information (see Table 12.2) (Hsueh et al., 2017).

Few examples of SCPs or other care coordination systems exist for chronic illness or cancer that engage healthcare teams across multiple practice settings with individuals and family teams exist (Kim, Bell, Bold, et al., 2016). The Personal Health Network (PHN) is one example from the authors' research that seeks to demonstrate the value of a mobile technology to enable community-wide care coordination. The PHN is a personalized social network built around a patient for collaboration with clinicians, care team members, carers, and others designated by a patient, to enable patient-centered health and healthcare activities across a relevant community. User-centered design methods were used in several phases of work to

Table 12.2 Informational elements of a shared care plan suggest any types and purposes for person-generated health data

Content categories	Person-generated health data	Clinical data
Contact information	• Patient preferred contacts.	• Responsible clinician. • Number(s) to call for results.
Health history	• Detailed health concerns. • Allergies.	• Conditions, diagnoses. • Health status evaluation populated with computable, standardized data.
Goals and preferences	• Patient's goals. • Expectations of care. • Challenges and concerns. • Self-management capabilities. • Family or caregiver resources. • Patient-reported health status. • Advanced directives. • Patient likes and dislikes.	• Problem list. • Clinical goals. • Treatment plans.
Actions	• Self-tracking measures (e.g., blood glucose, weight). • Tracking of observations of daily living. • Patient self-management plan/behavior change action plan. • Side effects and symptoms. • Tracking SCP items.	• Appointments. • Interventions and treatments. • Test results. • Tests and orders pending at discharge/transfer. • Responsible individual for follow-up. • Evidence-based guidelines. • Tracking SCP items.
Health education	• Identified learner for education if patient is unable to receive it. • Information about health condition.	• Clinical instructions given to patient.
Medications	• Medication concordance and adherence plan and tracking. • Over the counter medications. • Medications that are not being taken.	• Prescribed medications. • Medications during hospitalization. • Pre-admission medication list. • New discharge medications with start date, duration, route, dose, frequency, date, indication.

conceptualize the application, develop the system, and conduct early evaluation of its usability (Kim et al., 2014; Kim, Bell, Bold, et al., 2016).

The resulting PHN system offers both PGHD (proactive symptom assessments, person-reported outcomes, ad hoc questions sent as secure messages, personal notes) and data generated by the healthcare team (appointments, referrals, team member contacts, results of symptom assessments after nurse review, patient education library linked to results of symptom assessments,) allowing for whole person-centered care and collaboration among teams. Figure 12.4 shows several screens from the functioning application rendered on a tablet computer.

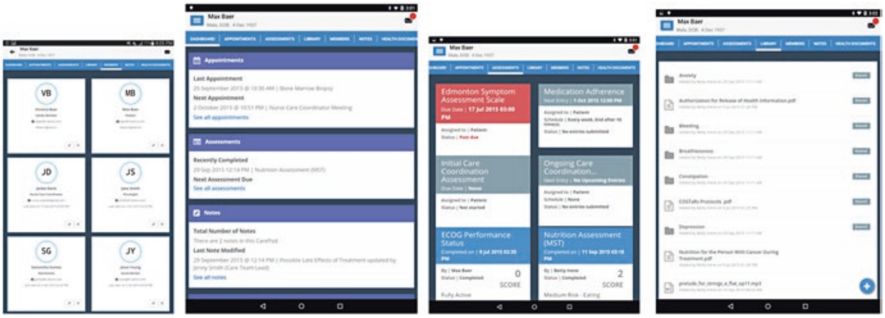

Fig. 12.4 The personal health network mobile application v2.0 integrates PGHD and clinical data including members, patient dashboard (overall care plan), symptom assessments, and patient-reported outcomes. Source: Patient Education Library in Kim, Bell, Bold, et al. (2016)

To meet the needs of a dynamic health journey, the PHN is easily configurable to add/hide individual team members. The instruments used for structured PGHD collection are also easily revised or replaced and can be scheduled at intervals or set for one-time collection. The library can include both educational materials selected by the healthcare team or customized with resources uploaded by the person. Finally, an individual can maintain his or her own notes, upload health records, and share these with others to foster communication across teams.

The PHN is being tested in a randomized clinical trial with evaluation that includes impacts on utilization (ED use and admissions), quality of life (e.g., pain and symptoms), and technology acceptance and use. Although care coordination is not new, the use of PGHD and mHealth to enable care coordination is an emerging area ripe for innovation, adoption, and investigation.

Growth of Persuasive Technology Research

Persuasive technologies (PT) are designed to influence attitudes, behaviors, and choices. This emerging, multidisciplinary field expands on evidence from behavioral sciences, cognitive science, and behavioral economics and uses smartphones, social media, and other digital technologies to influence personal decisions in a variety of areas, including health and wellness.

A recent empirical review of PT research (Orji & Moffatt, 2018) shows that researchers in 21 countries have studied a variety of health behaviors. There is a substantial corpus of research on design of persuasive technology interventions for motivating healthy eating habits (Orji, Mandryk, & Vassileva, 2012; Orji, Vassileva, & Mandryk, 2013). Some examples of serious games using persuasive strategies include: video games for health (Thompson et al., 2008), mobile games to help adults choose healthy meals (Grimes, Kantroo, & Grinter, 2010), LunchTime—a goal-based slow-casual game that educates players on how to make healthier meal choices (Orji et al., 2013), and Squire's Quest targeted at fourth grade students to influence fruit and vegetable consumption (Cullen, Watson, Baranowski, Baranowski, & Zakeri, 2005).

The effectiveness of PT is variable across health and wellness behaviors and attitudes and includes studies promoting healthy, desirable behaviors and changing undesirable ones (Orji & Moffatt, 2018). However, there is great potential in using PT to improve healthy living, reduce health care costs, and support independent living for older adults (Chatterjee & Price, 2009). By ethically engaging in collaborative design with end-users, and evaluating and refining technologies through user experience testing, we believe PT is very promising and should be further studied.

One promising area for persuasive technology intervention in telemedicine is beneficial for diseases like T2D where behavioral management is key. People living with diabetes need strict control of their blood glucose levels by balancing food, exercise, and insulin (or medication) (Kanstrup, Bertelsen, Glasemann, & Boye, 2008). To teach and motivate changes in eating behavior the persuasive techniques could be an initial recommendation to inform diabetes patients of good food and food to avoid. Motivation and awareness to build better habits for exercise and medication could also be accomplished through persuasion.

For example, just-in time messages or triggers can be set up with the appropriate device reminders to take insulin injection or medication. Persuasive in-home monitoring can make the management of blood glucose levels timely and provide an efficient day-to-day management of diabetes to prevent complicated stages. HIT interventions for behavior change have been identified as a major cornerstone for changing dietary behaviors (Lau et al., 2007). A study in the USA of over 17,000 patients enrolled in a home telehealth program reported a 20% reduction in hospital admissions and 25% reduction in bed days of care for chronic health condition management (Darkins et al., 2008). Recent work has theoretically explored the promises of persuasion techniques if added in existing telemedicine type 2 diabetes in-home monitoring interventions (Jalil, 2013). Research in Australia also has shown promises of integration of persuasive technology with health information technologies (Jalil & Orji, 2016).

Challenges and Recommendations

As the use of PGHD and mHealth continues to expand and evolve, we face several key challenges to adoption.

Challenge: Behavioral Models for mHealth

mHealth itself is a health intervention. The technology and data cannot be divorced from the behavioral model underlying the intervention.

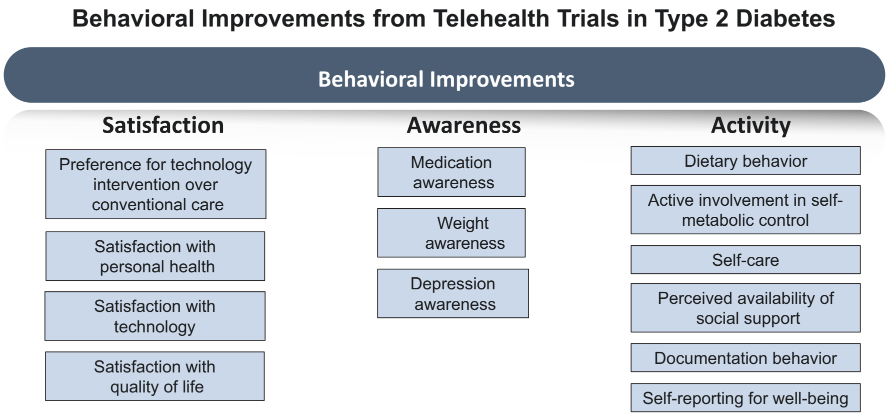

Fig. 12.5 Behavioral improvements from telehealth trials in type 2 diabetes suggest outcome measures. Source: Katherine K. Kim

A major challenge exists in understanding and building technology that is concordant with an appropriate behavioral model and care delivery model. These models help to elucidate not only *what* works to improve health but also *why and how* those impacts are accomplished, thus contributing knowledge that can further enhance the field.

The trials in T2D described in the previous section concluded that technology supports positive behavioral change which may then lead to desirable health outcomes. Three specific behavioral improvements of the patients were seen in these trials: activity improvement, awareness, and satisfaction (see Fig. 12.5) (Jalil et al., 2015). *Activity improvement* refers to activities that the patients adopted due to the technology intervention. *Awareness improvement* refers to the informed state-of-mind about living with T2D that the patients achieved after using the telemedicine intervention. *Satisfaction* refers to the participants' pleasure and fulfillment from using the technology intervention.

These categories of behavioral outcomes help specify *what* the intervention is seeking to improve and also drive the selection of measures of effectiveness. They also contribute to a model through which we can test whether and how these variables contribute to the end goal of improving health.

Recommendation: Understand and Apply Behavior Change Theory

It has been widely reported that health interventions are more effective when based on behavior theory (Ammerman, Lindquist, Lohr, & Hersey, 2002; Glanz & Bishop, 2010; Glanz, Rimer, & Viswanath, 2008; Noar, Benac, & Harris, 2007). For example, Webb, Joseph, Yardley, and Michie (2010) conducted a systematic review and assessed the use of theory in 85 randomized trials of Internet interventions. The review showed that overall, theory-based Internet interventions showed very small but statistically significant improvements in health outcomes over those not based on theory.

By applying a "use of theory" score calculated as an aggregate of 11 intervention-related items, Michie and Prestwich (2010) found that greater use of theory to select or develop intervention techniques, to select constructs, or to select participants was associated with larger effect size in post-intervention behavior differences. The most frequently used theories in this review were Theory of Planned Behavior (TPB), Transtheoretical Model (TTM), and Social Cognitive Theory (SCT).

In sum, mHealth interventions that seek to change behavior and impact health should leverage the large body of knowledge on health behavior that has been generated in the fields of psychology, public health, and clinical health research.

Challenges: How to Understand and Apply Persuasive Technology Strategies

The study of how to design technology to motivate behavioral change has been of increased interest to researchers and industrial practitioners due to the widespread uses of technology such as computers, mobile phones, and iPad. Fogg (2002) led the way to persuasive technology as "a computing system, device, or application designed to change a person's attitude or behavior in a certain way" without using coercion or deception. Oinas-Kukkonen extended the idea that technology is never neutral; it influences users in one way or another (Oinas-Kukkonen & Harjumaa, 2009). However, the influences occur as "side effects" of technology use, rather than the planned effect of the technology design (Fogg, 2002).

On the contrary, persuasive technology is designed to intentionally target a specific behavioral change of the users. The persuasive system design model (Oinas-Kukkonen & Harjumaa, 2009) posits that a multitude of aspects need to be recognized when designing persuasive systems: responsiveness, error-freeness, ease of access, ease of use, convenience, information quality, positive user experience, attractiveness, user loyalty, and simplicity, to name a few. This model also addressed precise requirements to translate the ideas from theory to the system design of the technology.

Even though the use of PT is not effective at all times, there is an increasing interest and investments to develop and use technology to promote health and wellness. Researchers, practitioners, governments, technology designers, public health agencies are all working towards similar goals and deploying technologies for health and well-being. PT research has a great potential to be one of the solutions for a healthy world.

Recommendation: Design the Right Solution

We must design solutions well to meet users' needs and accomplish their health objectives. However, it can be challenging to understand in detail what users' needs are and translate those needs into system requirements. Research on how to design technology to influence a behavioral change has been of increased interest to researchers and industrial practitioners due to the widespread uses of technology such as computers, mobile phones, and tablets. In order to accept mHealth, at a minimum, users must perceive mHealth technology to be reliable for health purposes.

Technical challenges such as lost messages (Holtz & Lauckner, 2012), poor battery life, freezing of apps, and connectivity challenges that are not tolerable in general consumer-facing apps are also unacceptable in mHealth (Donker et al., 2013). Technology is not neutral; it influences users in one way or another (Oinas-Kukkonen & Harjumaa, 2009). Unreliability due to technical issues may have a negative influence on adoption for obvious reasons.

Given the dynamic and inter-connected nature of health, team communication and features for discretion in sensitive health-related communications are necessary but all too often neglected (Bender et al., 2013; Donker et al., 2013; Payne et al., 2015). We need methods to leverage technology as a positive influencer and tool for individuals to improve health.

Challenge: How to Promote Technology Adoption

Understanding how the content, system, and service of an intervention are used and experienced may be the key to understanding why HITs suffer from large non-adherence rates. Efficacy and effectiveness studies through randomized trials are important, but they should be complemented by, for example, qualitative methods or measures of the usage of HIT interventions to be able to understand why and how these interventions do or do not achieve the desired effects.

Despite the proliferation of mHealth in the past decade, research on the effectiveness, utility, and technical and financial feasibility in real-life clinical settings is still lacking (Holtz & Lauckner, 2012; Krishna et al., 2009). There are numerous challenges related to implementation such as keeping up with technology, accommodating technology, competing priorities, technical compatibility, patient privacy, complicated partnerships, complicated technologies, clinician resistance, fitting technologies into clinical practice were challenges identified with personal health records (Brennan et al., 2010).

In a systematic review focusing on patients' acceptance of telehealth technologies, Dinesen et al. (2016) concluded that focusing on patient factors alone was not sufficient for understanding the degree of patients' interest (or lack of interest) in using telehealth technologies. Yet, existing literature focuses largely on patient-related factors such as sociodemographic characteristics, health- and treatment-related variables, and prior experience or exposure to computer/health technology.

Studies rarely examine the impact of social and task factors on acceptance or the effects of organizational or environmental factors on acceptance (Or & Karsh, 2009).

PGHD and mHealth appear promising for improving health. But the hoped for impacts will not be realized unless these new interventions and enabling technologies are adopted by the intended users.

Recommendation: Understand and Apply Technology Adoption Models

Several models for technology adoption with measurement scales can be helpful in design and implementation of mHealth. One of the foundational instruments for technology adoption is the ten-item Computer Self-Efficacy Scale (CSES) developed by Compeau and Higgins (1995) which focuses on beliefs of employees about ability to competently use computers.

The Technology Adoption Model which combines technology acceptance (Davis, 1985) and technology motivation (Davis, Bagozzi, & Warshaw, 1992) probes a person's belief in their ability to respond to situations and deal with obstacles in the process of accepting technology in a workplace setting (Venkatesh, Speier, & Morris, 2002). Recent work by several researchers has adapted the Technology Adoption Model to understand consumers' and patients' use of technology (Or et al., 2011; Venkatesh, Thong, & Xu, 2012). Venkatesh's instrument specifies constructs that may help pinpoint problems that deter adoption or levers that improve adoption (see Table 12.3).

Table 12.3 Emerging technology acceptance and use constructs focus on interaction of people and tools

Construct	Definition
Performance expectancy	Perceived benefit: Degree to which using a technology will provide benefits to consumers in performing certain activities. Concept of utility/extrinsic motivation. Strongest predictor of intention (Venkatesh, Morris, Davis, & Davis, 2003)
Effort expectancy	Perceived ease of use: Degree of ease associated with consumers' use of technology (Venkatesh et al., 2003)
Social influence	Extent to which consumers perceive that important others (family and friends) believe they should use a particular technology. More important in mandatory settings (Venkatesh et al., 2003)
Facilitating conditions	Consumers' perceptions of the resources and support available to perform a behavior (Venkatesh et al., 2003)
Hedonic motivation	The fun or pleasure derived from using a technology (Brown & Venkatesh, 2005) intrinsic motivation
Price value	Consumers' cognitive trade-off between perceived benefits of the applications and (their own, not third party) monetary cost for using them (Dodds, Monroe, & Grewal, 1991)
Habit	Extent to which individual believes behavior to be automatic (Limayem & Hirt, 2003). Construct important to use rather than initial acceptance

Technology adoption encompasses more than just usability. How the technology is implemented within a clinical trial or a health intervention is crucial to its potential acceptance. Investigations of interactions between the patient and the technology are important because failure to use a technology by patients or an adverse response to the technology from patients can cause patients to withdraw from a clinical trial. With the advent of several models and their associated instruments, there are tools to assist in more deeply understanding individuals' use of health technologies.

Conclusions

Technology is not a goal in and of itself. Rather technology is complementary to and increasingly necessary for a health delivery model that takes into account what individuals value and how they behave.

There are many unexplored questions in the quest to design and evaluate efficacious and effective health interventions enabled by PGHD and mHealth. The challenges outlined in this chapter may seem daunting and the breadth of expertise needed begs for unprecedented collaboration across fields both within and outside of health. However, there are innovative approaches that have emerged that are ripe to be applied to these challenges.

Behavioral models and behavior change theory have been extensively studied in health psychology-related disciplines but have not been well-integrated with mHealth. Technology adoption models help us to understand the interaction of the person with the environment and context of use while persuasive technology approaches inform the design of the technology. Learning from the work of pioneers and early researchers who have integrated behavioral models with technology adoption and persuasive technology are illustrative of the caliber of work and resulting innovations that are possible from interdisciplinary systems thinking.

Contributions from numerous fields can benefit the conceptualization, design, development, and implementation of PGHD and mHealth solutions and optimize the potential for accomplishing health objectives. Teams representing expertise from human factors and computer engineering, human computer interaction, design, health informatics, healthcare practice, community health, behavior change should collaborate with potential users and stakeholders in the success of these technologies. The opportunities for innovation through these teams abound not only for new researchers but also for practitioners who will bring solutions into our health institutions and the communities where people live.

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