Viewpoint Paper ■

Healthy Living with Persuasive Technologies: Framework, Issues, and Challenges

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Abstract While our Y2K worries about old computers "retiring" at midnight captured the television and news media attention, a more significant "old age" phenomenon snuck onto the scene with hardly a headline: the dawn of the age of the aged.[1] The over burdened health care system will face a worldwide wave of retirees who will live longer, cost more to treat, and demand new goods and services to help them stay healthy, active, and independent. Research in persuasive technologies and the associated usage of a computing system, device, or application intentionally designed to change a person's attitude or behavior in a predetermined way is showing the potential to assist in improving healthy living, reduce the costs on the health care system, and allow the aged to maintain a more independent life. This article gives a deeper insight into the evolution of persuasive technologies and presents a framework that can guide a researcher or practitioner in comprehending more effectively the work being done in this novel research field. It also provides categories of domains within health care in which these technologies are used and surveys exemplars from published literature. The article's goal is to provide greater understanding by addressing the challenges that lie ahead for all key stakeholders that design and/or use persuasive technologies in health care.

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Introduction

Of the more than 1.7 trillion dollars spent nationally every year in health care, less than 4% is spent on prevention and public health. The growing rate of chronic diseases such as diabetes, hypertension, trauma, back problems, heart disease, and cardiovascular disease accounts for more than half of the overall growth of health care costs. Prevention services such as screening and disease management that address populations at-risk, along with primary prevention with an emphasis on improving the environments where people live, work, play, and go to school, are receiving increasing attention and helping to reduce the costs on the health care system.[2]

This paper reviews persuasive technologies, an area of research that has the potential to assist in health related prevention services. Persuasive computing technology is a computing system, device, or application intentionally designed to change a person's attitude or behavior in a predetermined way.[3] In the decade since 1998, several emerging devices, applications, and experimental projects have appeared in the market. The point here, however, is not to list them; instead, we want to offer a deeper insight into the evolution of these technologies and ideas. We present a framework that can guide both novice and experienced researchers to comprehend more effectively the work that is being conducted in this field, provide categories of domains within health care in which these technologies are being used, and show exemplars of persuasive research projects that are successful. Our goal is to provide insights by addressing the challenges that lie ahead for all key stakeholders that design and/or use persuasive technologies in health care.

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A Framework

B. J. Fogg[3] defines persuasive technology as any interactive computing system designed to change people's attitudes and/or behaviors. The emergence of the Internet has led to a proliferation of web sites designed to persuade or motivate people to change their attitudes and behavior. Amazon.com doesn't just process orders, it attempts to persuade people to purchase more products. It does so by offering suggestions based on user preferences during previous visits, analysis of click-stream patterns, and feedback from other buyers. Similarly, the auction site eBay® has developed an online exchange system with enough credibility that users are persuaded to make financial transactions and divulge personal information. Beyond the web, we see persuasive technologies expanding to other fields including environment, business marketing, education, and of course health care.

Figure 1 shows a simple framework that exemplifies how persuasive technologies can impact health care. The three circles represent: (1) technology that is the driver for persuasive change and has to be selected or designed carefully to impact health care; (2) persuasion strategies that must be employed with an intent to change behavior, attitudes, or motivation; and (3) the subdomains within health care where we see potential applications bounded by disease, lifestyle, or the natural cycle from birth to death. The size of

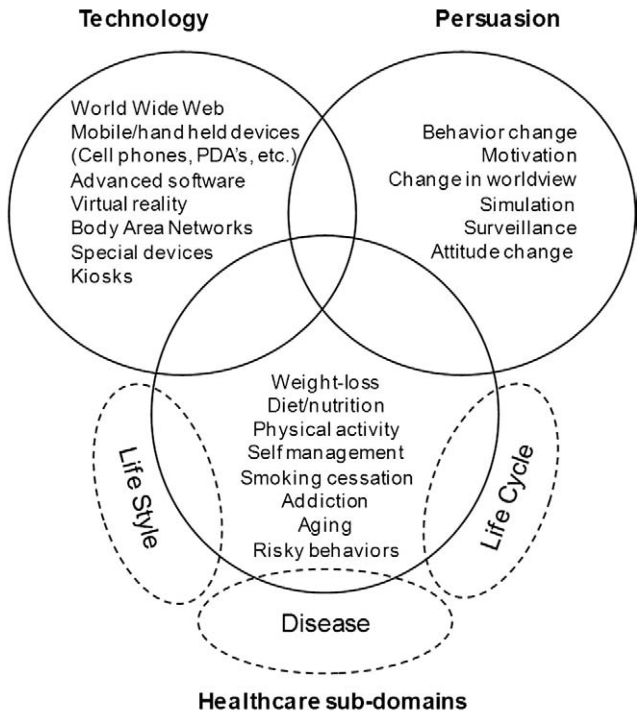

Figure 1. Simple Framework.

the intersecting field within the three domains is not well understood, but given evidence of its growth from both academic literature and the media, it is expected to continue to grow quickly.

In his seminal work,[3] B.J. Fogg addresses the functional triad that forms a framework for thinking about the roles played by computing products from the perspective of the user. According to Fogg, interactive computing technologies can play three roles: as tools, as media, and as social actors. As a tool, interactive computing technologies can be persuasive by making target behavior easier, leading people through a process, or performing calculations/measurements that motivate. As a medium, interactive computing technologies can be persuasive by allowing people to explore cause-and-effect relationships, providing people with experiences that motivate, or helping people to rehearse a behavior. As a social actor, interactive computing technologies can be persuasive by rewarding people with positive feedback, modeling a target behavior or attitude, and providing a social network of support. Within the health care field, we anticipate that interactive technologies will be deployed to take on more than one role at a time. For example, a simple tool can measure calories while also giving a reward upon attainment of a personal goal. If several people are connected to a server through the Internet, then social support can be leveraged, which has been shown to impact motivation and behavior change.

Persuasion, Modes, and Strategies

While philosophers and scholars have been examining persuasion for years, there is no single universal agreement on what the term really means. For this paper, persuasion is a deliberate attempt to change attitudes and/or behaviors. Note, however, that deliberate for this paper means intended and not accidental. Also, it does not connote coercion or deception. Coercion implies force; while it may change behavior, it is not the same as persuasion—which implies voluntary change.[3]

In order to design effective persuasive-based computing technology (PBCT), it is important to understand the different strategies that a researcher can employ when setting the role of a PBCT as a tool, a media, or a social actor. In Table 1, we list some persuasion strategies that may be used by a researcher or a practitioner.

In Fig. 2, we present a roadmap to show how persuasive-based computing technologies have evolved over the years. At the top level, we divide the available technologies into four generations. First generation (G1) systems that we call prescriptive systems started in the late 1960s and 70s and fundamentally dealt with human one-on-one persuasion with a physician or health care provider trying to convince a patient to take care of their health. In terms of technology, telephones were widely used and a computer-generated brochure (or CD-ROM) containing additional information about a disease or health condition was often given to a patient.

Second generation (G2) systems are what we call descriptive systems. With the popularity of the Internet, we see web-based systems being designed to provide information and educational content (such as http://www.webmd.com) delivered to users first through PC's and later through cell-phones. The content shared was more than text; multimedia data such as images, audio, and video became commonly used.

Table 1 ■ Computing System Roles and Corresponding Persuasion Strategies

Persuasive-Based Computing Technology Role	Persuasion Technique or Strategy
As tools	Reduction—simplify by making target behaviors easier by reducing the complexity of activity
	Tunneling—lead users through a step-by-step sequence of actions or events getting them highly engaged in the process
	Tailoring—provide customized information that is relevant
	Suggestion—intervene at the right time and place
As media	Simulate cause-and-effect scenarios—provide the ability to convey the effects in a vivid and credible way
	Simulate environments—create new and immersive environments for user engagement
	Simulate objects—provide tangible context that fits into a person's every day life
As social actors	Influencing via physical cues
	Psychological influence—support feelings, empathy, emotions, etc.
	Social dynamics—support taking turns, praise for good work, answering questions, reciprocity, etc.
	Social roles—support various roles (e.g., doctor, nurse, rehabilitator, teacher, coach, guide, etc.)

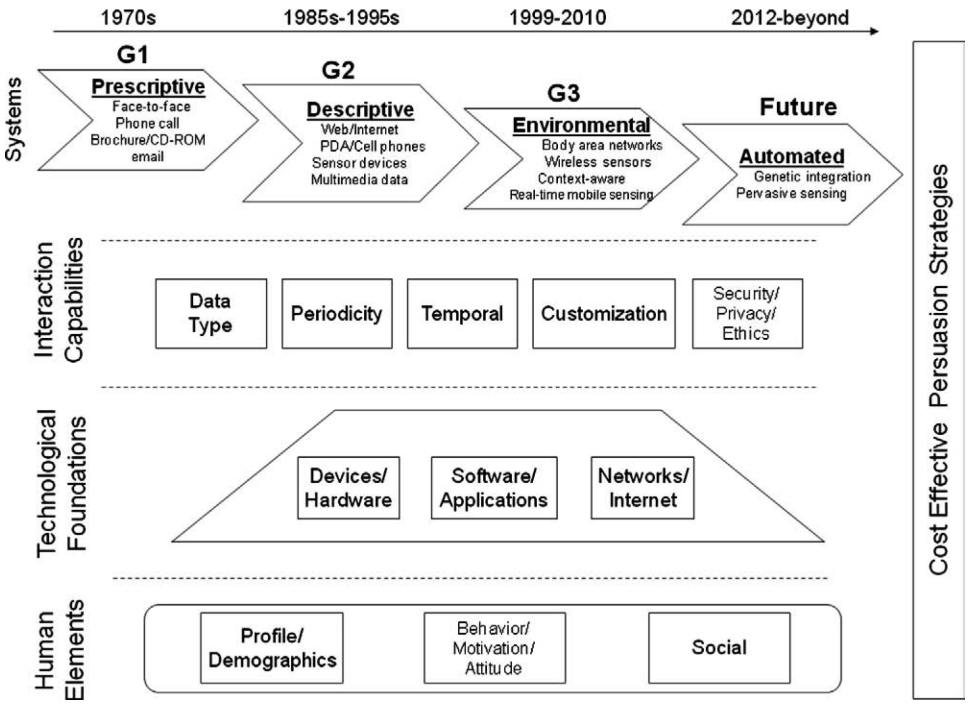

Figure 2. A Roadmap showing the Evolution of Persuasive Technologies.

Third generation (G3) systems that we call environmental systems dominate the marketplace in 2008. Three characteristics distinguish these systems from their predecessors: (1) use of body-wearable sensors that collect, store, and share relevant data; (2) use of context-aware technologies that attempt to infer a subject's present state and use that information to impact change; and (3) real-time exchange of information giving rise to such concepts as "just-in-time" motivational messages delivered over a wide variety of devices.[4] The trend is toward the use of mobile devices such as cell-phones and PDA's.

Lastly, innovations that follow G3 systems represent the future systems of persuasive technologies. They are characterized by advanced automation techniques in which human intervention is minimal. These systems rely on extensive pervasive sensing of the users environment and they provide the ability of powerful software engines that can process, mine, and send suggestions in a completely automated way. Such technologies will leverage the advances in pervasive computing, sensor technology, and agent technology.[5,6]

In order to understand how these generational systems have evolved and how new systems can be designed, built, and deployed, we show in the roadmap three additional layers on which these technologies rest. The first layer is called "Human Elements" and must address human aspects that include profile/demographics, behavior/motivation/attitude, and social elements to have an impact by PBCTs. Understanding human behavior change theories is critical.[7] We increasingly see an affinity for social networks and predict that the next generation systems will capitalize on the social networking phenomenon and will provide incentives for baby boomers to adopt PBCTs as they age with technology.

The second layer is called "Technology Foundations." This layer is an enabler and delivers the technology to the end-user. The three important components of this layer include:

- Devices/hardware—we envision several different kinds of devices and hardware platforms to be used in designing such systems. They will include PC's, laptops, mobile phones, PDA's, Apple iPods,® specialized tablet computers, game consoles such as the Nintendo Wii, and various sensors like the ones shown in Table 2.
- Software/applications—we envision a range of applications that will be designed to leverage the variety of hardware for which these systems are developed. There are critical challenges in software design which we will address later.
- Networks/Internet—we envision new network technologies that will function as the glue to make ubiquitous PBCTs a reality. The TCP/IP protocol will become the de facto protocol to be used in such systems. The use of the mobile Internet will continue to grow, bandwidth will be a valuable commodity, and latency issues will continue to impact performance.

The third and last layer is termed "Interaction Capabilities." The three generation systems differ in their *data types*. G1 systems are predominantly text-based while later generation systems are multimedia, using audio, video, images, and high resolution multimedia data types. They also differ in their *periodicity* of sending and updating messages. Earlier systems had very low periodicity of exchange. Typical

Table 2 ■ List of Medical Sensors and Devices

Invasive or Implantable Sensors	Non-Invasive Sensors
Glucose sensors	Blood pressure sensors
Blood gas sensors	Environmental sensors
Artificial pacemakers	Pedometers
Enzymatic sensors	iPod+Nike sports kit
Retinal implants	Electrocardiography (ECG)
Cochlear implants	SmartPill GI Monitoring System
Intracranial pressure sensors	Ultrasound, X-rays, MRI, etc.

Table 3 ▪ List of Exemplary Research that Fits Each Generation

Reference	Generation	Health care sub-Domains	Persuasion Goal	Supporting Technologies	Study Outcomes
Piette J, Kraemer F, Weinberger M, and McPhee S. Impact of automated calls with nurse follow-up on diabetes treatment outcomes in a department of Veterans Arrairs Health Care System. Diab Care 2001;24:202–8.[9]	G1	Diabetes treatment	Behaviour change	Automated telephone messages Personal and live follow-up communications	Intervention patients reported more frequent glucose self-monitoring and foot inspections, completion of a cholesterol test, fewer symptoms of poor glycemic control, and greater satisfaction with their health care than the control patients
Friedman R, Stollerman J, Mahoney D, and Rozenblyum L. The virtual visit: using telecommunications technology to take care of patients. Journal of the American Medical Informatics Association 1997;(4)413–425.[10]	G1	Chronic disease monitoring Patient counselling Home caregiver support of patients with disabling conditions Diet/nutrition Physical activity	Improved health management and outcomes Behaviour change	Automated telephone system	Program participants showed higher medicine adherence, lower diastolic blood pressure readings, greater health awareness, lower total cholesterol readings, and greater physical activity than control group
Irvine AB, Ary DV, Grove DA, Gilfillan-Morton L. The effectiveness of an interactive multimedia program to influence eating habits. Health Educ Res 2004;19:290–305.[11]	G1, G2	Weight loss Diet/nutrition	Behaviour change	Custom-created educational multimedia (IMM programming) and PC driven on healthy eating strategies Non-Internet based	Interactive multimedia programming (IMM) has a positive impact on behavior change (e.g., reduction in fats and increase in fruits and vegetables)
Kroeze W, Werkman A, and Brug J. A systematic review of randomized trials on the effectiveness of computer-tailored education on physical activity and dietary behaviors. Ann Behav Med 2006;31:205–33.[12]	G1, G2	Diet/nutrition Physical activity	Behaviour change Attitude change	Computer-based systems/interactive multimedia programs	Strong evidence that computer-tailored nutritional education impacts behavior but weakness exist with short-time frame of studies
Lenert L, Munoz R, Perez J, Bansod A. Automated e-mail messaging as a tool for improving quit rates in an Internet smoking cessation intervention. Journal of the American Medical Informatics Association 2004;11: 235–240.[13]	G1, G2	Smoking cessation	Behaviour change Motivation Attitude change	e-mail Education-only Web sites	Individually timed educational messages (ITEM) group showed higher quit date establishment, intent-to-treat quit rates, and increase in odds-to-quit ratio than non-item group
Tate DF, Wing RR, Winett RA. Using Internet technology to deliver a behavioral weight loss program. JAMA 2007;285: 1172–1177.[14]	G2	Weight loss	Behaviour change	Computer/Internet Web-based diaries Web-based information on diet, exercise, other resources Weekly e-mails (personalized) to IBT group	IBT group lost more body weight and reduced their waist circumference over control group
Atkinson N, and Gold R. The promise and challenge of eHealth interventions. Am J Health Behav 2002;26: 494–503.	G2	Various	Behaviour change	Message tailoring/ Intervention tailoring	eHealth intervention shows promise in changing behavior

Table 3 ▪ continued

Reference	Generation	Health care sub-Domains	Persuasion Goal	Supporting Technologies	Study Outcomes
Baranowski T, Baranowski J, Cullen K, Marsh T, Islam N, Zakeri I, Hones-Morreale L, and Demoor C. Squire's Quest! Dietary outcome evaluation of a multimedia game. American J Prev Med 2003;24:52–61.[15]	G2	Diet/nutrition	Behaviour change Attitude change	Psychoeducational, multimedia game	Program participants increased their fruit, juice, and vegetable consumption over nonparticipation group
Obermayer J, Riley W, Asif O, and Jean-Mary J. College smoking-cessation using cell phone text messaging. J Am Coll Health 2004;53–71–78.[16]	G2	Smoking cessation	Behaviour change Motivation Attitude change	Web and cell phone technologies (text messages)	Support shown for using text messages in the aid to reduce smoking rates
Hurling R, Catt M, de boni M, Fairly B, Hurst T, Murray P, Richardson A, and Sodhi J. Using Internet and Mobile phone technology to deliver an Automated Physical Activity Program. J Med Internet Res 2007;9(2):e7.[17]	G2	Diet/nutrition Physical activity	Behaviour change Motivation	Sensor and Internet technologies	Test group reported a significant greater increase over the control group
Chen D, Yang J, Malkin R, and Wactlar H. Detecting social interactions of the elderly in a nursing home environment. ACM transactions on multimedia computing, Communications and Applications 2007;3(1).[18]	G3	Physical activity Aging Habitat monitoring	Behaviour change Surveillance Attitude change	Multimedia processing Simulation and modeling Wireless sensor networks	Detection of social interaction patterns is possible and can be used to predict changes in physical and behavioral states
Eriksson H, and Timpka T. The potential of smart homes for injury prevention among the elderly. Inj Control Saf Promot 2007;9(2).[19]	G3	Physical activity Habitat monitoring	Various	Wireless sensors IP-based networks	Literature review on the use of wireless sensor networks and smart homes and the four components needed—sensors, communication network, computational components, and actuators—for injury detection and activity monitoring
Jovanov E, Milenkovic A, Otto C, and De Groen P. A wireless body network of intelligent motion sensors for computer assisted physical rehabilitation. J J Neuroengineering Rehab 2005;2(6).[20]	G3	Physical activity	Behaviour change Motivation	Wireless body area network (WBAN) Physiological sensors	WBAN's can support unobtrusive and unsupervised ambulatory monitoring of physical activity and health states and provide feedback messages to promote change persuasion

interactions might be daily, weekly, or monthly. Later generation systems have a higher periodicity of data exchange that might be seconds, minutes, or less than an hour. In real-time G3 systems, data are continuously sent to a context-aware server and relevant feedback is sent back immediately.[8] Real-time data collection in itself is a big research challenge.

The generational systems also differ in their *temporal* nature of interaction, with time being measured in discrete units or in real time. *Customization* also differentiates these systems. In early generation systems, information was more generic and not suited to the context or situation in which the subject was placed. Newer systems have a high level of customization so the right message and content can be delivered at the right time and place. Web-based systems now provide customization capabilities and can learn and adapt to the user's changing requirements.

Survey of Exemplars of Persuasive Technologies from Published Literature

The use of technologies to persuade and motivate behavior change has been an active domain for research. Table 3 provides a list of exemplary research that fits each generation as outlined in this paper. While not inclusive of all work done in the use of technologies to support healthy living, it does provide the reader with a survey of current research activity.

The research literature highlights the evolution of technologies used to impact health care and the changes in information flow between patient and health care provider. G1 systems are characterized by the prescriptive nature of information flow from physician, health care provider, or technology-based system to a health care recipient with most research outcomes over the years yielding the conclusion that phone-based or simple messaging technologies can improve the quality of health care management and clinical outcomes.

G2 systems are characterized by the descriptive nature of information interaction between a user and the persuasive technologies. These include interactive Web sites, personal data assistants (PDAs) that allow activity recording, and simple sensors that record and report basic health parameters. G2 systems allow for richer information dissemination over G1 systems with multimedia content that can be audio or visual, and text messages that combine to build systems that allow the user to become immersed in the operating space.

G2 technologies move beyond G1 technologies that are often limited to simple messaging and one-size-fits-all approaches and support persuasive interventions that are tailored or adapted for various and changing states of behavior change readiness among the targeted recipients. This design paradigm of "deliver the right message at the right time" requires "multiple forms of communication delivery and variation in the content of messages delivered"[21] and is made possible with computers, advances in sensor technologies, and the global reach of the Internet.

The use of G2 systems to change behavior is well documented in research settings. Sensor technologies vis-à-vis wrist-worn accelerometers to monitor physical activity, mobile phones that allow users to record workouts and determine caloric expenditures, and other monitoring devices like the *BodyMedia*'s *BodyBugg*[22] that resides on a users arm and uses physiological sensors and data modeling to measure health routines are leveraged in the studies to support the change.

While most of the research studies cite custom technological applications and designs, commercial products do exist that provide personal awareness of activity level or determination of health state. The Kogan GPS watch allows an owner to monitor heart rate.[23] Omron manufactures pedometers that allow a user to track step-counts and several models support activity tracking and analysis via health management software.[24] For the runner, the Nike+ iPod® uses an accelerometer embedded in a shoe and communicates with an Apple iPod® to report workout states (e.g., the distance and pace of a walk or run) and also provides positive feedback for goal-oriented workouts with pre-recorded congratulation messages provided by Lance Armstrong, Tiger Woods, and Paula Radcliffe at the achievement of a workout milestone.[25] Each of these commercial products further exemplifies G2 technologies that drive persuasion ideology to impact various health care subdomains.

G3 systems extend G2 capabilities by the inclusion of body-wearable sensors that support advanced health monitoring, use of context-aware computing that can use information of a person's location within their environment and the determination of their activity at the moment of measurement, and real-time exchange of information to support "just in time" messaging.

Supporting technologies in G3 systems leverage the recent advances in microchip fabrication and wireless networking, and the integration of embedded microcontrollers, physical sensors, and radio interfaces on a single battery-powered chip allows for new medical applications not available in past generations. These miniature, wireless, and wearable sensor nodes can be placed on a patient to allow for the untethered measurement and monitoring of various health factors including high blood pressure, irregular heartbeats, or physical conditions tied to diabetes or obesity. Non-evasive and invasive sensors are used to monitor these medical parameters and report alerts to the user and/or health care provider. Various real-time patient monitoring projects have been developed, including UbiMon (Ubiquitous Monitoring Environment for Wearable and Implantable Sensors), whose goal is to provide continuous and unobtrusive patient monitoring for the capture of life threatening events, and CodeBlue,® a wireless sensor network model that supports a range of medical applications including hospital monitoring, stroke patient rehabilitation, and *Disaster* response.[26]

According to Mukhopadhyay et al.,[27] "Sensor networks permit data gathering and computation to be deeply embedded into the environment." These technologies can manifest context-aware systems that deduce a person's activity from their environmental state. Context-aware systems are exemplified in work done by Hassan and Chatterjee[8,28] and are being used in assisted-living complexes in monitoring the health states of their occupants. With the rise in the number of baby boomers (it is predicted that those aged 65–85+ will make up more than 18% of the population of the United States by the year 2025[29]), research is being conducted on in-residence elderly monitoring that can provide several benefits, including providing peace of mind for adult children who can remotely monitor their loved ones, collecting real-time logs of physical activities and health parameters for examination by health professionals located at distant sites, and the detection of anomalous patterns in behavior or physical conditions that may forewarn of an impending health problem.[30] These smart homes can assist the aged in maintaining a more independent life.

Several exemplars of smart homes are noted in literature: CAST—Center for Aging Services Technology—have developed several projects, including a home that integrates various

Table 4 ■ Challenges, Critical Issues, and Prediction/Implications for Persuasive Technologies

Challenges	Critical Issues	Predictions and Implications for Persuasive Technology Designers
Consideration of disparate stakeholders?	How can persuasive technologies support the four primary stakeholders of PBCTs: patients and general population, system designers, health care network (physicians, nurses and medical professionals) and payers?	It is important to note that two modes that will evolve: 1. ***Self-care*** in which end-user interacts with automated persuasive technologies and 2. ***Network-care*** in which end-users get feedback and help that involves health-care professionals.
Adoption of persuasive technologies?	How to design solutions that can work on mobile platforms and have increased adoption rates?	Keeping in mind that consumer product success depends on (1) the willingness to pay and (2) the technology must have very low *threshold of indignation*.[32]
Engagement of persuasive technologies and experiences?	How can persuasive technologies engage its users? The user's attention span is fragile, easily lost if not stimulated.	Designing engaging mobile experiences require three principles: (1) context must be relevant, (2) support guided engagement and navigation, and (3) provide differentiation as a critical feature.[33]
Ethics of persuasion and privacy?	How can persuasive technologies be grounded on ethical principles? Persuaders have always stood on uneasy ethical grounds. Lack of privacy and big brother issues are critical.	Persuasive technology creators must adhere to the golden rule: "Persuasive technology creators should never seek to persuade a person or persons of something they themselves would not consent to be persuaded to do."[34]
Payment by insurance companies, HMOs/PPOs, and third party payers?	How will the cost of persuasive technologies be covered? The most vexing question is who will pay for it?	Understand that prevention is better than treatment. Therefore, it is in the interest of the "payers" to cover all or part of the cost as in the long run they will lower their overall health care cost.
Integration of persuasive technologies with personal health records?	How can persuasive technologies integrate with personal health records? PHR systems capture health data entered by individuals and provide information related to the care of those individuals.	PHR's are ideal candidates to include decision-support capabilities that can assist patients in managing their health condition. When adoption of PHR systems grows, we will see persuasion alerts and behavior change modules being embedded into them.

sensors into its environment to monitor movement to help debilitated aged people track their normal activity and to provide alerts when non-normal living is detected, and a sensor-based bed that will track sleep patterns for later evaluation of possible diseases; the Center for Future Health has built a five room house with various infrared sensors, monitoring devices, and biosensors with the goal to provide users with the data they need to manage their health and to forecast changes in their living that could be the signs of an immediate or future health issue; and the MobiHealth© project at Georgia Tech is working on a system for the remote collection of body signals, thereby allowing health professionals to more easily monitor patients in their homes.[31]

Challenges Ahead

While persuasive technologies have promise, formidable challenges lie ahead. Table 4 addresses the most common challenges.

The Future of Persuasive Technology in Health Care

The study of attitudes and persuasion remains a defining characteristic of contemporary social psychology.[35] Over the last 70 years, attitude still remains a "most distinctive and indispensable" concept and "a prime factor that must be considered when reflecting on persuasion . . . Most accept the view that an attitude represents an evaluative integration of cognitions and affects experienced in relation to an object. Attitudes are the evaluative judgments that integrate and summarize these cognitive/affective reactions. These evaluative abstractions vary in strength, which in turn has implications for persistence, resistance, and attitude-behavior consistency."[35]

Designers have to understand that processes of attitude formation and change are not identical, nor are their outcomes. Factors that do affect attitude change have been a staple of social psychology from its earliest days. The fundamental premise of attitude change says that messages are presented, processed, and if successful, move recipients attitudes toward the advocated position. The revised attitude, in turn, may influence subsequent behavior under appropriate conditions. The well-known dual-process model says that message reception can lead to attitude change and then behavior change. If receivers are able and properly motivated, they will elaborate, or systematically analyze, persuasive messages. If the message is well reasoned, data based, and logical (i.e., strong), it will persuade; if it is not, it will fail.

With the latest advancements in Internet and mobile communications technology, a number of avenues are available to help designers promote adoption of persuasive applications and technologies to their intended end-users. The success of the adoption of these technologies will depend on the grounded understanding of the theories above. This should become a fertile ground for providing persuasion toward healthy living. The time is right. Are the researchers, designers, health care providers, and patients ready for it?

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