IS MOBILE THE PRESCRIPTION FOR SUSTAINED BEHAVIOR CHANGE?

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THREE KEY FINDINGS

1 We are at an Inflection Point in Health Behavior Change Understanding and Application

The confluence of three things – *accrued scientific knowledge, unprecedented healthcare and concomitant financial imperatives*, and *the penetration of portable and connected consumer technologies* – provides the opportunity and scope for advancing behavior change. Knowledge gained in both dissecting individual-level interventions to understand the "active ingredients" of effective change efforts, and evaluating multi-level social-environmental interventions has made us more insightful about the complex interplay of social, behavioral, psychological, biological and environmental determinants throughout the change process [37][27]. The rising incidence of lifestyle-driven chronic disease and the unsustainably high cost of health care have expanded the pool of active stakeholders interested in addressing the problems caused by unhealthy behaviors, to include health consumers, insurers, employers and health providers. The dramatic rise of consumer technology adoption, particularly of mobile phones, has afforded us the tools to ground change interventions in the real day-to-day world. The ability to both collect individual data and deliver individualized content holds the promise of more effective behavior interventions as well as access to data for the development of an even better understanding of health-related behaviors.

2 Mobile's Role in Behavior Change is to Enable Personalized and "Just-in-Time" Interventions on a Broad Scale

The impact of mobile technology on behavior change has the potential to be profound, not just in terms of supporting initial change efforts but quite possibly in helping to sustain change over time. Historically, it has not been feasible to frequently assess health-related factors or behaviors in large numbers of people [66]. However, technological advances have made it possible to use assessment tools to gather information on people's daily and even momentary health-enhancing and health-compromising behaviors [66]. Temporal relationships among variables can be explored [66] due to the availability of time-intensive information collected from longitudinal data obtained at an intensive frequency [15]. And these data can be used to develop more personalized interventions tailored for the individual in terms of content, duration and just-in-time delivery.

Such approaches will allow researchers to adapt models to incorporate relatively time-invariant and time-varying characteristics, across multiple levels of assessment and analysis (within and between person, short and long term temporal processes, nested in different social and cultural contexts, etc.)[66]. As technology presents us with opportunities to offer dynamic, interactive and adaptive exchanges with individuals, we need theories that can help guide this paradigm shift in intervention scope and breadth [58]. Mobile will also play a role in the collection of data that can be used to test and strengthen theoretical constructs about behavior so they better reflect the real world [58].

3 A Systems View is Necessary in Order to Make Behavior Change More Effective

Behavior does not take place in a vacuum, and improvements in individual level interventions, though necessary, are not sufficient for sustained change. Smoking reduction being a prime example, where multi-level interventions – both top down and bottom up - that targeted the social, environmental, legislative and individual spheres led to success. Given the reluctance of Government to be seen as a proponent of the "nanny state", technology, again, could provide a way forward. The contextual sensing capabilities of mobile, in combination with social networking and media tracking tools could be used to monitor consenting individuals' exposure to messaging and other environmental cues that lead to behavior; in a manner similar to lifelogging [31] and media monitoring [34]. The resultant data could be used to identify the "active ingredients" leading to behavior that is unhealthy. We know that some of the most effective drivers of change are self-monitoring and feedback, and publicizing these data, at an individual or population level, as a private or public endeavor, could be used to build consensus for action. Interventions could then be crafted that balance the requirements of both free enterprise and promotion of the general welfare. These could include "nudges" (legislative, policy and fiscal changes that guide and enable choice), support for community-based participatory research and action, and public service messaging highly targeted towards at-risk individuals and risky contexts.

Objective of the White Paper

The objectives of the paper are two-fold: (1) to provide attendees at *Consumer-Centric Health: Models for Change '11* with thought starters in advance of the October 12-13th conference and (2) to provide a coalescing and context-setting overview for the 20 perspectives being presented at the meeting. While the paper does offer remarks on historical context, forces at play, theoretical issues, and application challenges and opportunities now and in the future, it is not meant to be a comprehensive survey. Rather, it is an introduction to the in-depth content and discussions of the wide-ranging group of front line experts and thought leaders who will be presenting at the conference.

"It's easy to quit smoking. I've done it hundreds of times."

- Mark Twain

INTRODUCTION

Behavior changes do not last. This is evident as much from our own experiences as from the reports of clinical studies and evaluations of commercial programs [60]. Causes are many and varied – overbuilt expectations, too much reliance on external incentives to initiate change, lack of follow up after initial success, temptations, stressors, difficulty of uprooting entrenched habits, insidiousness of environmental cues, change fatigue, to name several.

Given this somewhat dire state of affairs, why suggest we are on the cusp of inflection?

To put it plainly, we are smarter and more capable and yet, ironically, more desperate, all at the same time. We're smarter because we know more about the effective techniques it takes to get people on the path to changing their behavior (at least after motivation has been stimulated). We're more capable primarily through technological advancements that are woven into the social fabric of our lives. And finally, we're more desperate from being in the midst of a healthcare crisis that threatens to cripple, if not bankrupt the country, and which compels us to act faster and employ methods that are new or previously under-utilized.

Scope of the Document

This paper focuses on Behavior Change Techniques (BCTs) aimed at **improving health**, by changing behaviors that are mediating factors for **chronic diseases**. This restriction in scope is necessary for two reasons: First, to avoid the hurdles introduced by the different lexicons used across disciplines or domains. Second, because there is as yet no common understanding of what BCTs cause what behavior changes, and by what mechanisms. Such an understanding could conceivably, for example, allow BCT practitioners in drug abuse counseling to identify commonalities with their colleagues treating gang violence in the penal system, and so replicate interventions, share and segment data in synergistic ways and understand the causal mechanisms. But, in the absence of such an understanding, mixing across domains adds complexity without shedding light.

Why posit that mobile is part of the inflection and offers the capability to enable sustained change?

Mobile phones offer unprecedented potential as a medium through which behavior change can be supported because they are:

- **ubiquitous** - most people have one, including those who don't have other computers – 234 million mobile phone users, 1/3 smartphone users [10] - allowing for large scale deployment of interventions. And health-related applications are no stranger to mobile users as by one estimate 9,000 consumer health apps are available for download from Apple's AppStore [39].
- **salient** - most people are slaves to them – 2.2 trillion monthly minutes of use [12] and 51% report using mobile for just in time info [50].
- **interactive** – providing information to, and responding to actions from the user; allowing two-way communication, transmission of reminders, mood and motivation assessments, location awareness and more

- **always on** – unlike PCs, laptops or even tablets, users configure their phones to be constantly network-aware

Always On Real Time Access (AORTA) computing, as manifested in mobile phones, holds the potential for enabling a paradigm shift in the information we collect and analyze, the knowledge we gain from the integration and statistical analysis of data, and the interventions that are made possible through these new insights. This is not to say that technology will solve the problems that have plagued long term behavior maintenance. Rather technology will allow behavioral insights and interventions gained from, and applied to, small and controlled groups to be implemented at scale in an affordable manner, and allow additional insights to be gained in real-world settings.

Why the conference?

There is significant activity and interest around behavior change and behavior change techniques (BCTs). However, the activity is taking place, for the most part, in silos (academic, policy, commercial, employer, health provider etc). The Models for Change conference is intended to be the first in a series of programs convened by Health Innoventions to pull together the various domains in order to identify commonalities, share knowledge and generate new insights. Just as importantly, we hope to begin to match problems with solutions and questions with answers and so promote the creation of products, services and changes in behavior.

-------- PERSPECTIVES ON BEHAVIOR CHANGE ----------

Behavior change can reduce the incidence and severity of chronic disease, which is the largest driver of healthcare costs. The cost of healthcare is increasing unsustainably, creating a demand for cost cutting measures, of which behavior change is a necessary component.

Why focus on behavior change?

Simply put, unhealthy behavior got us into this mess, and undertaking healthful behavior is an essential component in digging us out of it. In 1900, the main causes of death were pneumonia/influenza, tuberculosis and gastritis. The practice of Public Health and improvements in the standard of living, diet and scientific medicine led to a reduction in the incidence of infectious diseases. With their decrease, chronic diseases, characterized by (a) non-contagious origin (b) a long period of illness or disability (c) a prolonged latency period between exposure to the risk factors and negative health outcome and (d) multiple causes, became the reasons for premature death. Today, the nation's health care bill, at $2.5 trillion annually [74], is largely driven by the costs for chronic disease care.

While not all entirely preventable, much of chronic disease can be eliminated or mitigated through lifestyle changes. And yet the incidence of obesity is on the rise, with more than 1/3 of Americans obese and nearly 2/3 overweight [76]. Diseases and conditions related to obesity include Type 2 diabetes, hypertension, heart disease, cancer and stroke [8]. Projections from current trends estimate that by 2030, 86% of adults will be overweight or obese; and 51%, obese, at a cost to the healthcare system of between $860 and $956 Billion [76]. While smoking rates and frequency have dropped over the past

five years, still nearly one in five adults smoke, leading to some $96 billion in health insurance costs borne on annual basis [76]. People with diabetes, while only 5% of the insurer-covered population account for 20% of healthcare costs [71].

Studies and wide-ranging analyses have shown the benefit of prevention and wellness efforts. Medical costs fell by about $3.27 for every dollar spent on worksite wellness programs [5]. In another report, employee incentives were shown to lead to fitness-related activities that resulted in 6% lower hospital costs for employees who were inactive and then became active, and 16% lower in those members who were active throughout the study compared to those members who remained inactive [48]. The Institute of Medicine (IOM) issued a clarion call in its seminal 2001 report – *Crossing the Quality Chasm* – acknowledging that the current health care system was bankrupting the country, and reiterating a recommendation from earlier studies that "programs providing counseling, education, information feedback, and other supports (for behavior change) [our emphasis] to patients with common chronic conditions are associated with improved outcomes [26].

The top down perspective – payers and providers.

Each of the major healthcare stakeholders is increasingly looking at behavior change as a way to reduce the drain on resources. The stakeholder with the largest skin in the game is employers, with employer-sponsored health plans accounting for more than 50 percent of health care expenditures [33]. The costs for an employee with a chronic disease can be more than 10 times that of a healthy employee [71]. And this does not factor in the indirect costs to productivity from presenteeism, absenteeism and long-term disability. With healthcare costs outpacing inflation, not to mention healthcare reform looming, employers have been encouraged to take a more active role in implementing "demand-side" strategies. With the intent of reducing demand for services by promoting upfront prevention and wellness activities, employers have instituted tools such as patient incentives and value-based design plans (VBDPs) [33][1]. Based on a recent employer survey, we can anticipate incentives increasingly being tied to particular program outcomes and the potential use of penalties to force healthier behavior [1]. In the meantime, more employers roll out fitness, nutrition and health screening programs such as John Hancock Financial, which invested 1% of its total healthcare expenses in order to reign in total costs [5]. Other companies such as IBM and the Mayo Clinic, in partial recognition of the role that primary care can play in preventive services, have eliminated all out-of-pocket expenses for doctor visits [33].

Insurers have developed and offered new plans designed to give employers opportunities to better manage costs. Consumer-driven health plans (CDHPs) enable this primarily through shifting the onus of higher deductibles, health expense management and better management of their own health to employees. Insurers are also proposing various incentive-based approaches tied to behavior changes, such as cost coverage based on prescription compliance and rewards for healthy behaviors such as diet and exercise and behavior-based methods like health coaching and care counselors. ODS, a Portland, OR.–based health insurer is using the patient activation measure (PAM) - a diagnostic tool to measure a patient's readiness and perceived self-competence to take on an active management role in their own care - to develop tailored coaching interventions that help members with chronic conditions become better at self-management, treatment adherence, and other actions.

Care providers are turning to patient-centric care models aimed at providing better care at lower cost and building in patient behavior change as a key component. The Patient-Centered Medical Home (PCMH) is a delivery model employing a team approach that emphasizes patient engagement, activation

and self-management. Seattle-based Group Health, an early proponent of the PCMH, found that by increasing the amount of doctor-patient visit time as well shifting to more email and phone contact, resulted in significant reductions in emergency room use (30% fewer) and more than 10% fewer preventable hospitalizations [7]. A new evidence-based mode, also developed by Group Health, called TEAMCare, utilizes motivational interviewing and problem-solving techniques to empower patients suffering from multiple chronic diseases and depression. One of the early patient-centric care models, the Chronic Care Model, fostered an informed and activated patient who understood the importance of their role in managing their illness and changed their behavior to do so. Participating physicians were advised to assist in this behavior change by assessing their patients' knowledge, agreeing on goals and arranging follow up visits to provide ongoing self-management support [75].

Hospital administrators have proposed new models that emphasize evidence-base and teamwork. These new models have dramatic impacts on the process, organization and cultural structures of current approaches AND they also demand much of the patient in order to be successful [33].

Another stakeholder bearing a large brunt of the healthcare burden is the government. Veterans Affairs initiated a cultural transformation effort to help indoctrinate its practitioners in its new Patient Aligned Care Team (PACT) model, the department's adaptation of the Patient-Centric Medical Home. Reorienting practitioners is a way to leverage behavior change, as it recognized that care providers can be very influential in changing patient behavior [30]. On a different front, The Center for Medicare and Medicaid (CMS), which handles the 65 years old and over Medicare rolls, recently instituted a reimbursement program for community service organizations to provide care transitions coaching to beneficiaries making the shift from hospitalization to home [14].

The bottom up perspective – health consumers.

Not all of the focus on behavior change comes from the top down. Baby boomers are directly and indirectly one of the biggest users of the healthcare system and have been more vocal than other consumer segments in their rejection of the wasteful costs of healthcare inefficiencies and lack of individual accountability in one's own health. As the incidence of chronic conditions rises with age they have the most to gain from behavior change and the most to lose as they look to work beyond typical retirement years, stretch savings and maintain active, independent lives. Moreover, health management for boomers is not just a personal matter – they are caretakers for chronic disease suffering aging parents who illustrate the need to embrace lifestyle changes for themselves and their boomerang children [18].

With an intent to use people's "observations of daily living" (ODLs) in making patient-clinician relationships more productive, Project HealthDesign was launched in 2010 to capture and utilize sensations, feelings, thoughts, attitudes and behaviors that provide cues about a person's health state [55]. The effort centers on patients and clinicians collaborating to identify the specific ODLs patients value and how they can be tracked and interpreted in order to result in better care. "The good news here is that doctors are beginning to realize how much data their patients generate when out of the office and the value that (these) data can bring to healthcare decision making," says Dr. Joseph Kevdar, director of Connected Health at Harvard Medical School [69].

Perhaps influenced by the technology work world, there is increasing focus on tracking and assessing exercise, sleep patterns, and other activities on overall health. In some respects, life is being viewed as a

project itself, where one can work to make a healthier and more productive and higher performing self (site English-Lueck '04) [16]. While single purpose devices such as Fitbit have helped to support this endeavor, it is the advances in mobile technologies and downloadable applications that have led to a much broader and growing use. Adds Dr. Kevdar, "we are in the midst of a real movement around the collection of data and the use of that data to gain insight about health and affect behavior change, often referred to either as personal informatics or the Quantified Self." [69] Kevdar believes that the power of quantification in chronic disease management is evident, but that there is still a major challenge in getting health care providers to embrace data from self-quantifiers.

Finally, there is the incessant background demand feeding the multi-billion dollar self-improvement industry, demand which at its core, is a desire for behavior change.

Behavior change is not sufficient, but it is essential.

To be clear, behavior change is not the only component required to decrease costs and improve health. Other factors include: changes in payment to encourage accountable and coordinated care, use of evidence-based models, employing process improvement techniques, removing legal obstacles to coordination, and more [77]. Some, or all, are necessary, but they are not sufficient. We contend that the proposed systemic re-architecture requires changes in organizations (payers and providers) comprised of individuals, and individuals themselves (heath consumers) who must all change their behaviors for the other components to be effective.

WHAT WE KNOW ABOUT BEHAVIOR CHANGE

Limitations of existing theoretical models of behavior change and increased focus on making change happen have led to efforts to define the "active ingredients" of interventions. The application of a "systems thinking" approach has placed individual-level interventions in the context of other interdependent and reinforcing interventions (via social, environmental and policy thrusts). Commercial programs, primarily aimed at weight loss illustrate many of the lessons learned.

Behavior change encompasses many diverse theories, models and applications, and is heir to their history and interaction. The following account suggests a linear development of ideas, but in reality this is but one thread in a complex interweaving of ideas, initiatives and policy developments.

Health Belief Model (HBM)

One of the first theories of health behavior developed in the 1950s, it addresses the individual's perceptions of the threat posed by a health problem (susceptibility, severity), the benefits of avoiding the threat, and factors influencing the decision to act (barriers, cues to action, and self-efficacy). The HBM framework puts motivation as its central focus in targeting and reducing problem behaviors. [73]

Our narrative begins with the recognition of lifestyle factors being a major driver in chronic disease, leading to attempts to change behavior at interventions at an individual level. Later, interventionists recognized the importance of environmental factors and adopted models to incorporate those additional forces, also at the individual level. Recent criticism of individual intervention methods

has led to better explanations and identification of active ingredients of intervention. Most recently, researchers and practitioners have begun to apply "systems thinking" to the problem, and expanded beyond the individual to implement multilevel interventions (social messaging, legislation, taxes, as well as individual behavior change techniques).

In parallel with this progress has been the evolution of commercial behavior change methods, primarily for weight loss, and exemplified by Weight Watchers. We discuss the success and approach of this program, and what we know of its components.

We make the distinction between behavior change (interventions to initiate a change) and behavior maintenance (sustaining the change indefinitely) and discuss the latter in the subsequent section.

From identifying risk to doing something about it.

The most significant development in recent behavior change research has been to shift focus from identifying risk and pro-health determinants of health (pre-2000) to applying this knowledge in actually achieving and sustaining behavior change [47]. As a result, researchers and practitioners have fashioned new models, or applied existing ones (model: a simplified description of a system or process, i.e., behavior in order to assist in predictions). These include:

- Self-Regulation Theory
- Operant Conditioning
- Health Belief Model
- Transtheoretical Model
- Theory of Planned Behavior
- Self-Determination Theory
- Relapse Prevention
- Social Cognitive Theory

Relapse Prevention

In the 1970s, Alan Marlatt [32] obtained detailed qualitative information from 70 chronic male alcoholics about the primary situations that led them to drink alcohol during the first 90 days following abstinence treatment. The resulting data were used to create this cognitive-behavioral approach, with the goal of identifying and preventing high-risk situations such as substance abuse, obsessive-compulsive behavior, sexual offending, obesity, and depression.

Transtheoretical Model (TTM)

Also known "Stages of Change," the model was developed in the 1980s for smoking cessation. The model's fundamental premise is that behavior changes occur in five stages: (1) **Precontemplation** – not intending to take action in the next six months. (2) **Contemplation** –intending to change in the next six months. (3) **Preparation** – intending to take action, have taken action in the past year. (4) **Action** –have made specific overt modifications in their life-styles within the past six months. (5) **Maintenance** – working to prevent relapse. The original work measured the **processes** of change (things like self-evaluation and stimulus control) used by smokers who were Long Term Quitters, Recent Quitters, Contemplators, Immotives (pre contemplation) and Relapsers [54].

Social Cognitive Theory (SCT)

According to SCT, three main factors affect the likelihood that a person will change a health behavior: (1) self-efficacy, (2) goals, and (3) outcome expectancies. SCT evolved from research on Social Learning Theory (SLT), which asserts that people learn not only from their own experiences, but by observing the actions of others and the benefits of those actions. Alfred Bandura (1986) updated SLT, adding the construct of self-efficacy and renaming it SCT. SCT integrates concepts and processes from cognitive, behaviorist, and emotional models of behavior change. [73]

All have been used, with varying degrees of success, primarily in controlled interventions, to encourage weight loss, smoking abstinence, physical activity, healthy eating, and other behaviors. On the whole, they concentrate on education, self-management and skill building at an individual level.

Recognizing the role of environmental factors.

Another critical shift is recognition of the importance of interventions beyond the skill-building, and self-management emphasis at the individual level and broadening to include social and environmental barriers or facilitators. [47]. In this context, the social environment is defined more broadly and comprehensively than contemplated in Social Cognitive Theory. So-called ecological theory has been advanced since the late 1990s to explain the highly complex relationships among individuals, society, organizations, the built and natural environments, and personal and population health and well-being [49]. The success of combining environmental, policy, social, and individual intervention strategies to reduce tobacco use [26] has stimulated application in other quarters. Ecological theories posit that health and behavior are influenced at multiple levels, including interpersonal, sociocultural, policy, and physical environmental factors, and that these influences interact with one another," write Patrick et al. [49] "For example, ecological models include an emphasis on characteristics of the built environment, such as architecture and community design, access to elements important to behaviors such as tobacco and healthy or unhealthy food, opportunities for physical activity, and the impact of technologies such as television or other media. At the largest level, these models and theories recognize the effect of natural environmental factors such as geography, weather, and climate on health behavior." [49] The challenge for interventionists is applying it in practice due to its apparent complexity and difficulty [19].

Self-Determination Theory (SDT)

Posits that maintenance of behaviors over time requires that patients internalize values and skills for change, and experience self-determination. The theory further argues that by maximizing the patient's experience of autonomy, competence, and relatedness in health-care settings, the regulation of health-related behaviors are more likely to be internalized, and behavior change will be better maintained [62]

Theory of Planned Behavior (TPB)

Explores the relationship between behavior and beliefs, attitudes, intentions and perceived control. Behavioral intention is influenced by a person's attitude toward performing a behavior, and by beliefs about whether individuals who are important to the person approve or disapprove of the behavior (subjective norm). The TPB includes "perceived behavioral control." For example, despite a group norm about the benefits of recycling, a person may not do so because they feel their behavior will have little impact. [73]

Criticism of existing models.

Questions have arisen from academics and practitioners about existing behavior models. Academic researchers have raised questions about, among other things, the unification of the behavioral theories underlying the models (i.e. the underlying explanation are inconsistent or do not fit together). Practitioners have been frustrated by the absence of actionable recommendations, as well as the complexity and lack of specificity of how recommendations are to be applied.

The Transtheoretical Model (TTM), a stage-based construct and one of the mostly applied models in behavior change, has attracted the most positive and negative attention. Strengths of the theory are that it allows interventions to be targeted towards more stratified needs – people who don't know they need to change, people considering change, etc. – and makes a key distinction between motivational and volitional stages [54]. However, a review of 23 randomized controlled trials, found that "stage based interventions are no more effective than non-stage based interventions or no intervention in changing smoking behavior" [57]. An editorial in the journal *Addiction* criticized the Trans Theoretical Model for (a) arbitrary dividing lines between the stages, (b) assuming that individuals make coherent and stable plans, (c) combining incoherent concepts in the assessment of stages; e.g. time since last quit smoking and past attempts to quit (d) focusing on conscious decision making and planned processes, neglecting the role of reward and punishment and associative learning [78].

Among other influences, Social Cognitive Theory (SCT) brought to the fore the importance of self-efficacy as key mediating variable in behavior change and in this respect alone, has significantly influenced the evolution of health behavior theory generally. However, due to its wide-ranging focus, SCT is difficult to operationalize in practical interventions [40]. Under the lens of ecological theory, SCT is considered to focus mostly on individual factors and therefore, often lacks meaningful evaluation of the potential impact of the full range of environmental determinants of health behavior [49].

The Health Belief Model and The Theory of Planned Behavior, two of the longest standing models, posit that health behavior arises from a formation of intention to change based on a rational assessment of outcomes and barriers. However, both have been criticized for not addressing the important roles of impulsivity, habit, self-control, associative learning, and emotional processing [79].

A review by the UK House of Lords found that although much was known about human behavior from basic research, the applicability at a population level was limited [25]. Similarly, a review of behavior change interventions on care providers found most interventions are effective in some circumstances, but none are effective under all circumstances [20].

"The application of theories to the design of interventions remains a challenge and there is considerable debate concerning the effectiveness and usefulness of theory in informing intervention development." [40] One

Operant Conditioning

A form of learning where an individual modifies his behavior due to the association of the behavior with a stimulus. Operant behavior "operates" on the environment and is maintained by consequences called "reinforcements" and "punishments." They may be "positive" (applied to the organism) or "negative" (removed from the organism). For example, a particular behavior may be encouraged by a Positive Reinforcement (a rewarding stimulus, like soothing music), or a Negative Reinforcement (the removal of an aversive stimulus, like a loud noise).

Self-Regulation Theory (SRT)

This model of behavior is analogous to a feedback loop in a car's cruise control in which information from a **sensor** (the speedometer) is sent to a **comparator** (the on-board computer) which commands an **effector** (the engine) to speed up or slow down in order to maintain a **referent standard** (the desired speed). When applied to human behavior, the model uses language such as goal setting (setting the referent standard), feedback (information used by the comparator) and action planning (acting on the effector). For Carver and Scheier [81], human behavior is organized around a system of feedback loops defined by a hierarchy of goals. This system is controlled or regulated by affective, cognitive and physiological components. Both lower and higher level goals occur simultaneously in behavior.

result is that interventions have been combining theories and using an array of techniques, and yet with still no clear understanding of what are the most effective methods in driving change.

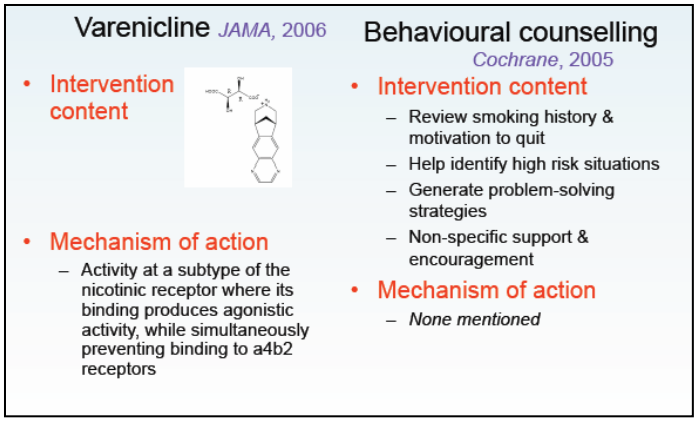
Towards better explanations.

To address the limitations of theory, researchers began to look for improvements. Comparing behavioral interventions to biomedical interventions, Susan Michie [36] pointed out that in the latter the precise mode of interaction of the pharmacological agent is known and described. This line of reasoning naturally led to calls for:

- Well described interventions, including the content of the intervention, characteristics of those delivering the intervention, characteristics of the recipients, characteristics of the setting (e.g., worksite), among other information – to ensure replicability, build an evidence base and be able to test and understand mechanisms of change [38].
- A parsimonious list of conceptually distinct and defined BCTs – to build an understanding of which BCTs are most effective and in what circumstances
- An analysis of which BCTs are the "active ingredients" – to remove superfluous or counteracting interventions

Reporting biomedical vs. behavioral interventions

From Michie [36].



Responding to the calls, Michie et al [35] used expert judges to identify BCTs and match them to behavioral determinants, and came up with a list of 35 techniques in which there was agreement between judges on both the definitions and the links to a theory of behavior (Table 1).

Extending the work, Michie and her colleagues then conducted a meta-analysis of 122 evaluations of interventions targeting increases in healthy eating and physical activity. They found that **self-monitoring**, as any one single technique, had the greatest impact. Furthermore, combining self-monitoring with at least one other technique derived from **self-regulation theory** (based on the work of Carver and Scheier [81]**)** improved the result significantly [37].

The commercial model

Arguably one of the most effective behavioral interventions is the weight loss program developed and offered by Weight Watchers (WW). Originally started in 1961 by a New Jersey housewife who wished to manage her weakness for cookies, the WW program has evolved from a support group emphasizing "empathy, rapport and mutual understanding" to one that incorporates a cocktail of interventions [21]. These include self-monitoring, goal setting, and group support, as well as "business model" driven components intended to keep the business growing. Free lifetime membership is offered to those who can maintain weight within 2 pounds of target, and lifetime members can attend weekly weigh-ins for free. This serves to both support long-term maintenance and provide evidence to existing and prospective customers that the program works.

A Taxonomy of Behavior Change Techniques

From Michie et al [35]

1. Goal/target specified: behavior or outcome	13. Prompts, triggers, cues	22. Experiential: tasks to gain experiences to change motivation
2. Monitoring	14. Environmental changes (e.g., objects to facilitate behavior)	23. Feedback
3. Self-monitoring	15. Social processes of encouragement, pressure, support	24. Self talk
4. Contract	16. Persuasive communication	25. Use of imagery
5. Rewards; incentives (inc self-evaluation)	17. Information regarding behavior, outcome	26. Perform behavior in different settings
6. Graded task, starting with easy tasks	18. Personalized message	27. Shaping of behavior
7. Increasing skills: problem solving, decision making, goal setting	19. Modeling /demonstration of behavior by others	28. Motivational interviewing
8. Stress management	20. Homework	29. Relapse prevention
9. Coping skills	21. Personal experiments, data collection (other than self-monitoring of behavior)	30. Cognitive restructuring
10. Rehearsal of relevant skills		31. Relaxation
11. Role-play		32. Desensitization
12. Planning, implementation		33. Problem solving
		34. Time management
		35. Identify/ prepare for difficult situation/ problems

Table 1.

"The Company presents its program in a series of weekly meetings of approximately one hour in duration. Members provide each other support by sharing their experiences with other people experiencing similar weight management challenges. Group support assists members in dealing with issues, such as emotional eating and finding time to exercise. The Company facilitates this support through interactive meetings. In its meetings, WW's leaders present its program in a manner that combines group support and education with a structured approach to food, activity and lifestyle modification developed by weight management experts." [56]

Given that the content of group meetings changes according to the attendees and leaders, documenting the exact methodology is difficult. None the less, we know:

- The program's pragmatic approach has evolved over many years with input from millions of users, and its emphasis on self-monitoring is consistent with the literature.
- It has been shown to be more effective than other weight loss interventions. A multi-country study demonstrated that Weight Watchers resulted in twice as much weight loss compared to physician delivered interventions [22].
- It maintains results over an extended period of time. By the end of 2 years more than 50% of the WW participants had a body mass weight index (BMI) at least 1 unit below baseline BMI vs. 29% of the self-help group [22]
- The evidence is less clear on behavior change initiation (introducing the idea to someone who has not thought about it to lose weight)
- Or on unsupported behavior maintenance – users are expected to continue to attend weekly meetings, and the drop rate from programs varies between 39% [28] and 29% [22]

The cocktail of methods can be viewed either as a mixture that is flexible enough to meet the needs of a broad population when implemented by trained group leaders, or something that works, but no one

knows exactly how. Relying as it does on experts to implement the recipe; the Weight Watchers process is limited in its ability to scale, and to implement momentary interventions. However, it appears to be one of the most successful programs around, and we would do well to learn from it for other interventions.

Applying systems thinking

As effective as individual-level interventions can become, they are still only one component in a highly complex system of reciprocally-impacting causal relationships. Successful efforts to reduce smoking illustrate a case in point. It has been suggested that social-level interventions were more impactful than individual-level interventions in the reduction of smoking over the past 20 years [24]. "Much of the success has been attributed to changes in social policies such as federal excise taxes, workplace bans on smoking, media campaigns, clean-indoor-air policies, and the enforcement of restrictions on tobacco use by minors," note Hiatt & Breen in The Social Determinants of Cancer [24] Furthermore, "tobacco control is probably the best current model for a systems approach to behavior change, as it has grown from a focus on individual behavior to include the understanding of the genetics of tobacco addiction, the distribution of smoking habits in the population, and how these complex relationships are affected by social policy."

Systems thinking attempts to understand how things influence one another within a whole, and stands in contrast to a reductionist approach of focusing on understanding a thing's constituent parts through separate and isolated evaluation. By putting forth a holistic view, systems thinking attempts to provide the most efficient means of understanding and influencing a complex system, and at the same time avoiding unintended negative consequences. An example of the latter is the emphasis on pricing to control alcohol consumption in Nordic countries, and the concomitant increase in smuggling and illicit production [42].

The recognized need for systems thinking being applied in the public health arena is growing, especially within ecologically minded quarters. "Public health asks of systems science, as it did of sociology 40 years ago that it help us unravel the complexity of causal forces in our varied populations and the ecologically layered community and societal circumstances of public health practice" [19]. We seek a more evidence-based public health practice, but too much of our evidence comes from artificially controlled research that does not fit the realities of practice [19]. Evidence-based solutions, however technically sound, are necessary but not sufficient. Writing about HIV prevention, Elizabeth Pisani notes "...we (also) need to spend more time understanding how behaviour, politics and economics undermine or contribute to success." [53]. For example, condom use and needle exchanges are effective for stopping the transmission of HIV, but the former are unpopular with men, and the latter are unpopular with voters.

In the UK, the British House of Lords Science and Technology Committee applied a systems thinking approach to behavior change in a recent report [25], in which they adopted the "Ladder of Interventions" from the Nuffield Foundation, [44] showing the continuum of interventions from regulatory methods to less coercive "nudges" (see Table 2). We have adapted this to show various "bottom up" behaviors (initiated by individuals), which can be aided or undermined by the various forms of "top down" intervention.

Table of Interventions

	Regulation of the individual		Fiscal measures directed at the individual		Non-regulatory and non-fiscal measures with relation to the individual					
Intervention categories (i)	Eliminate choice	Restrict choice	Guide and enable choice							
			Fiscal disincentive	Fiscal incentive	Non-fiscal incentives and disincentives	Persuasion	Choice architecture ("Nudges")			
							Provision of information	Change to physical environment	Change to the default policy	Use of social norms and salience
Examples (ii)	Prohibiting goods and services e.g. banning certain drugs	Restricting the options available e.g. outlawing smoking in public places	Fiscal behaviors to make behaviors more costly e.g. taxation on cigarettes	Fiscal policies to make behaviors financially beneficial e.g. tax breaks on the purchase of bicycles	Public policies which reward or penalize behaviors e.g. time off work to volunteer	Persuading individuals using arguments e.g. doctors persuading people to drink less, or similar messages from counseling services or marketing campaigns	Providing information e.g. leaflets showing the carbon usage of household appliances Regulation requiring businesses to provide this information	Altering the environment e.g. designing buildings with fewer elevators Regulation requiring businesses to remove candy from checkouts, or the restriction of cigarette advertising	Changing the default option e.g. providing salad as the default side dish	Providing information about what others are doing e.g. information about an individual's energy usage relative to the rest of the street Regulation requiring energy companies to provide this information
Bottom-up behaviors (iii)	*Weight loss *Smoking cessation *Exercise *Healthy diet *Reducing alcohol consumption *Recreational drug use *Medication adherence *Regular dental hygiene *Flu vaccinations									

Table 2. (i) "Top down" Intervention categories, (ii) "top down" interventions examples and, (iii) "bottom up" consumer-initiated behaviors, which may be undermined or strengthened by the "top down" interventions.

The report concluded that "…non-regulatory measures used in isolation, including "nudges", are less likely to be effective. Effective (top down) [our emphasis] policies often use a range of interventions." [25] We take this as circumstantial evidence that applying "bottom up" interventions in the absence of reinforcement by other influences and interventions, if not doomed to failure, at least reduces the odds of success. And, as has been noted earlier, applying one intervention category without reinforcement or consideration of the others increases the chances of inefficacy and unintentional consequences.

A case in point is the employer/employee relationship, where often only financial incentives and disincentives are available or used. But, as Dan Ariely points out "… companies want to benefit from the advantage of social norms (e.g. employees willing to cancel family obligations to achieve an important deadline)… but they are demanding high deductibles in their insurance plans… and reducing the scope of benefits. They are undermining the social contract between the company and the employee and replacing it with the market norm. It's really no surprise that "corporate loyalty" has become an oxymoron." [2]

While the Ladder of Interventions describes the range of possible interventions, it doesn't prescribe how the interventions can work together. Thus, a further request of systems science is to help determine a formula for multiple interventions. Some methods for achieving this objective might include:

- Simulation, as used in other complex systems, like weather forecasting (or Farmville)
- Intervention mapping, which seeks a comprehensive survey before and after, of all elements affected by an intervention [3]

WHAT WE KNOW ABOUT MAINTAINING BEHAVIOR

The two schools of thought about behavior maintenance may be summarized as "more of the same" (of what creates behavior change) and "something different". But despite evidence supporting both, neither has been show to be satisfactory. New techniques, using real time assessment and interventions show some promise, and deserve further investigation.

By way of synopsis, here is what the past decade's efforts tell us about changing and maintaining behavior:

- We can initiate and maintain a variety of new behaviors for at least two years [47].
- Social-environmental models are important due to the highly complex interdependencies impacting behavior [46].
- Incentives can play a role in getting people to initiate change [48].
- Self-monitoring plus other self-regulatory techniques seem to be some of the most active ingredients in getting individuals to initiate change (site Michie) [37].
- A fuller model of the maintenance process is required, one which views maintenance more as a journey than as a destination [47].
- The reality is decay is typical and should be expected over time, and therefore some type of reinforcement is needed over the long haul [47].

- Despite years of efforts, we are still not at the point where we fully understand what leads to sustained behavior [60].

While there is consensus that behavior maintenance, broadly defined, refers to behavior sustained sufficiently and consistently over time to improve health or well being, opinions vary on what it takes to realize a true transfer of change. One school of thought believes that initiation and maintenance are two sides of same process while another believes that initiation and maintenance are conceptually different animals.

Behavior maintenance requires more of the same.

James Prochaska and Carlo DiClemente, originators of the Trans Theoretical Model (TTM), posit that behavior maintenance comes from a successful passing through of change stages. Maintenance is characterized as a distinct culminating stage in the Stages of Change model, driven largely by the same determinants and change processes as drive initiation [59]. Psychologists Richard Ryan and Geoffrey Williams argue that developing self-determination at the outset – from the enabling of a person's sense of autonomy and competence, accompanied by relatedness to the practitioner and/or process - leads to self-internalization of values and skills, and the greater likelihood of ongoing regulation and sustained change [62].

BJ Fogg, head of the Persuasive Technology Lab at Stanford University, advocates for the deconstruction of behavior change into small manageable chunks that can gradually be pieced together into a substantial change [17]. An illustration of this is taking the high level goal of reducing stress and beginning with an actionable target behavior such as stretching for 20 seconds when prompted, small enough for anyone to do and something that can be built on. The Fogg Behavioral Model (B=mat) posits that change occurs at the intersection of motivation, ability and trigger within the same moment. While the Fogg Model has been mostly applied towards initiating change, 5 of his 15 types of behavior change in his behavior grid are "path behaviors" or ones that are intended to lead to lasting change through gradually building habit formation.

Behavior maintenance requires something different.

On the other hand, Alexander Rothman argues that the factors driving initiation and maintenance of change are different. Initiating change is based on desire to achieve certain benefits and outcome expectations on the part of an individual. (In fact, Rothman believes all major models of health behavior espouse a cost/benefit analysis as a common element, but differ in the set of beliefs associated with decision to take action [59]. The key determinants of initiation are attitudes, social norms, self-efficacy and intentions from a reflective standpoint and implicit attitudes and behavior primes from an automatic standpoint. For each area, Rothman suggests different set of interventions. He also maintains that reflective and automatic processes play roles across the spectrum of change.

Maintaining change is about the individual's experience with the actual outcomes and is driven by satisfaction and habit formation. "In this way, maintenance decisions reflect an ongoing assessment of the behavioral, psychological and physiological experiences afforded by the behavior change process." [6] Possible interventions to influence satisfaction are temporal comparisons, salience of outcomes, mindfulness of the change, and expectation management [59]. Possible interventions to influence habit formation are repeated and consistent performance of responses and, potentially most challenging, breaking existing habits, either through self-control or changing environmental cues [59]. From a self-

regulation perspective, maintenance can be considered a function of higher order goals, while behavior initiation a function of the lower order goals that fall under the higher order ones [13].

While these viewpoints raise interesting directions for ongoing research and theorizing, there is no strong empirical evidence that any single one has truly solved the issue of understanding sustained behavior. The most promising comes, once again, from the pragmatic approach of commercial behavior change programs where a combination of role modeling, self-monitoring and social support with some regular frequency may provide long term adherence. This may be the answer, or at least the best answer we currently have. But we shouldn't forget that it would not be in a commercial organization's interests to develop or promote an unsupported solution to sustained behavior change, and if we want to find such a solution we may need to look elsewhere.

A role for the intra-individual orientation.

Perhaps, however, the solution to sustained change may lie outside of the customary methods researchers have used to analyze behavior change factors and determinants. In the common practice of controlled research, target and control group treatments are conducted with the goal of assessing outcome differences between two comparison groups (inter-individual comparisons). This orientation has contributed to our ongoing understanding by evaluating participant characteristics, demographic profiles, and other more or less unvarying attributes with regards to behavior [15].

However, there is some recent evidence to suggest that health-related cognitions and beliefs such as attitudes, self-efficacy, and behavioral intentions, known to be mediating variables in behavior change, can shift over relatively short periods of time [15]. Research also suggests that acute within-person variations in positive and negative affect, anxiety, and anger are related to health behaviors such as caffeine consumption, smoking, and eating patterns across the day [9]. There is growing sentiment suggesting that perhaps the next stage of behavioral change understanding will come from analyzing within-person (intra-individual) differences [15] across different conditions and contexts, and where an individual plays the role of both target and control over time. It is conjectured that this will lead to the amassing of data that can be used to guide and deliver tailored interventions [15], continuously adapted, and based on frequent user and environmental input and changes taking place over the course of the entire intervention.

-------- HOW MOBILE CAN HELP IN SUSTAINGIN BEHAVIOR CHANGE ----------

Technology and ubiquitous connectivity has just begun to impact health behavior and health care. Despite equivocal results, hope is high that behavioral interventions will improve with the use of technology because of the potential to deliver high quality, individualized interventions at lower cost. Mobile offers further enhancements to this paradigm with the use of real time, personalized interventions. However it appears that the capabilities of mobile have outstripped our theoretical underpinnings and practitioners and theorists are scrambling to catch up.

Technology has changed the practice of health care.

The rapid pace of technology innovation and deployment over the past quarter century has had dramatic impact on the dissemination of health information and the practice of health care. Today, nearly 60% of adults use the web to research health information for loved ones and themselves, making it the 3rd most popular online activity (site Pew) [52]. While initially slow to embrace, doctors are now increasingly using the web for email conversations with patients, appointment scheduling and delivery of lab results, fostered by patient-centric care models. Increasingly monitoring of health-critical biometric is taking place via remote technology, devices and systems. Patient community sites let patients share disease-related information with one another and provide social support. 23% of those with chronic disease go online looking to interact with others suffering from same conditions (site Pew) [52]. Spurred on by the promise of efficiency savings, a $27 billion federal government stimulus infusion (HITECH Act), and increasing venture investment, the market for health information technology (HIT) is expected to reach $7.6 billion in 2011 and $17.5 billion by 2016 [4]. By one estimate, the mHealth market on its own is expected to become a $4.6 million market by 2014 [11].

Web-based technologies are also being used for behavior change on an increasing basis. These efforts have been driven by the premise that information and communication technologies combined with the latest behavioral science can deliver individualized and updatable interventions that are not only beneficial to participants but also cost-effective and offer the promise of reaching a larger, more dispersed population. What began as efforts offering limited or no interactivity have now accelerated to more highly interactive programs utilizing assessment, goal-setting, progress tracking and coaching components. With advances in computer human interaction practice across areas more than health, the notion of technology as a tool of persuasion is no longer a marginal concept. “Never before has the ability to automate persuasion been in the hands of so many.” [61].

Subjecting web-based interventions to rigorous clinical trials, however, has resulted in equivocal outcomes [41]. One systematic review of 30 randomized controlled trials concluded that the evidence in favor of computer-tailored interventions for dietary behaviors was strong but there was little evidence for effective computer-based physical activity interventions [29]. Another review concluded that web-based interventions may be no more efficacious than other kinds of interventions, but may provide a public health benefit in reaching a broader population difficult to reach through other methods [43]. A third review on weight loss and maintenance interventions concluded that while some interventions led to weight loss, it was not clear what components of the technology actually influenced this change [41].

Mobile brings further technological capability

Mobile-based interventions provide distinct advantages over those delivered through desktop applications, including:

1. Greater frequency of interaction due to the easy portability, and increasing ubiquity of devices.
2. Providing help when it is most needed due to devices likely being with their owners at any time, and connected to the network.
3. Ability to reach historically hard to reach groups who are disproportionate sufferers of chronic disease due to high penetration of mobile across all socio-economic groups [72].
4. The capability of continuously monitoring an array of information including location, environmental and contextual data.

Furthermore, as computational power and capability aggressively moves more into the environment and eventually to the body, new platforms are also incorporating new functions such as sensing, monitoring, geospatial tracking, location-based knowledge presentation, and a host of other information processes [49].

The notion of extending an intervention into a person's daily life is not new. For years practitioners have been employing tools such as paper diaries to gather data from patients in between sessions and impromptu phone calls for help in time of crisis. When implemented by technology it is known as Ecological Momentary Assessment (EMA), the premise being that crucial data comes from as an individual is living her life, not just when measured or recounted in the doctor's office, laboratory or consultation room. EMAs allow individuals to "report repeatedly on their experiences in real-time, in real-world settings, over time and across contexts." [64]. EMAs are used to capture data both about the person's internal conditions (symptoms, emotions, biometrics) and external conditions (data about the contextual environment such as social and situational variables). EMAs overcome the reported bias handicap of retrospective recall and reconstruction, allow generalization to an individual's real life, get at behaviors that can be difficult to assess in an office visit, and set up the exploration of temporal and contextual relationships between a wide variety of variables [23].

Developing in parallel to EMAs has been Ecological Momentary Interventions (EMIs), which provide a treatment or course of action to follow at moments in the person's daily life. EMI was initially developed to encourage psychotherapy patients to do "homework" in between sessions and were based on Cognitive Behavioral Therapy (CBT). However, it is now being used for behavioral health purposes to provide critical intervention help when an individual needs it during the course of their day or week. An example is a smoking cessation EMI, where a person receives text messages on his mobile phone with tips for dealing with cravings, either self-initiated or at times when the urge to smoke is known to arise. "A prompt promoting immediate action at just the right moment may be more powerful than extensive training that is easily forgotten at the crucial moment." [64].

In smoking cessation interventions, mobile technology-enabled treatments led to quits and improvement of self-efficacy to remain smoke free [23]. In weight loss interventions, participants lost significant more weight when mobile was incorporated [23]. In treating anxiety issues, mobile-enabled interventions led to reduced treatment time, while maintaining similar treatment efficacy [23]. Mobile has also demonstrated the potential of automating less-complex aspects of treatment, thereby freeing up clinicians to focus on the more complex cases (site Heron) [23].

Findings indicate that mobile interventions can be especially effective for the treatment of symptoms and health behaviors with:

- Discrete antecedent states such as cravings or urges prior to eating, substance abuse, risky sexual activity, self-harm behavior [23]
- Events such as anxiety provoking situations, stressors and mealtimes, as these can serve as triggers for delivery of the interventions [23]

Where do we go from here?

Better models.

The content and timing of a specific mobile phone intervention can be driven by a range of variables including (a) the target behavior frequency, duration, or intensity; (b) the effect of prior interventions on

the target behavior; and (c) the current context of the individual (time, location, social environment, psycho-physiological state, etc.). Such interventions require health behavior models that have dynamic, regulatory system components to guide rapid intervention adaptation based on the individual's current and past behavior and situational context [58]. These models must be sophisticated enough to be applied to "time-invariant" characteristics such as genetic attributes and "time-varying" characteristics such as affective and social conditions. Moreover, they need to be applicable across multiple levels of assessment and analysis that include within person, between person, short and long term temporal processes and within the context of different social and cultural environments [66].

Combining EMA and EMI.

Combining EMA (input) and EMI (output) makes them even more powerful, but to date they have largely developed on separate tracks [66]. The future opportunity is in integrating real-time assessment and intervention such that content tailoring is being matched with time tailoring as a function of momentary physiological, behavioral and environmental characteristics [66].

More persuasive delivery formats.

The increasing capability of mobile devices to provide media-rich experiences represents another area of opportunity. While mobile interventions have predominantly utilized the very simple text message format, there is potential within reach to use other formats such as video, image-rich data visualizations and other kinds of dashboards that may provide even greater persuasive appeal.

Personal informatics.

EMAs and EMIs provide the opportunity to assess and treat in the moment, based on the condition of a single individual and within a specific environmental context. Moreover, in combination they provide a wealth of access to ongoing data about dynamic associations and processes that occur over time that can lead to understanding of the highly complex interworking of behavioral barriers and facilitators. This implies a growing field of personal bio and behavioral informatics that can be used to better understand a unique individual and also in aggregate, groups of individuals. As an example, computer algorithms may be able to detect patterns that signal trouble long before a person who is attempting to quit smoking has noticed it, and direct action to avoid or defuse the coming crisis [65].

Better data

On a broader level, they enable the testing of theoretical constructs by the type and way in which they collect information over long periods of time [67]. In turn, the information collected can lead to refinement of existing theory that more accurately reflects the day to day reality of health and behavior [67].

Applying self-regulation theory.

There is also promise that mobile can be very effective at putting into operation the techniques from the self-regulation model where self-monitoring, goal-setting, feedback, etc have shown promise at driving change. It can also be used effectively for cognitive support to aid in coping strategies during the initial and longer term of behavior change [6].

SUMMARY

Behavior change doesn't last and we don't fully understand why. However, we believe we are on the cusp of understanding more than we've ever known because of: the necessity to act spurred on by rising and unsustainable health care costs, increases in what we know about the science, and increases in what we can do with technology.

Health care costs threaten to consume one fifth of our GDP [80] and the majority of the costs are caused by chronic disease, which can be mitigated by behavior change. The increase in what we know includes identification of active ingredients in behavior interventions and the recognition of the effects of societal, environmental, legislative and fiscal issues on individual unhealthy behavior. Increases in what we can do are mediated by the proliferation of AORTA (Always On Real Time Access) technology, as manifested in mobile phones. These allow the collection of data from individuals and the dissemination of individualized and tailored interventions to change behaviors.

To be sure, even some fundamental issues, such as getting people initially engaged in healthful behavior change, require improvement. And we must be careful not to consider technology to be anything more than a tool to enable better and more accurate insights. However, together, the combination of demand, knowledge and technology promises to revolutionize the use and effectiveness of behavior change techniques, in ways that we are just beginning to understand.

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