Report from Dagstuhl Perspectives Workshop 14272

Exploring Interdisciplinary Grand Challenges in ICT Design to Support Proactive Health and Wellbeing

Edited by

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Abstract

There have been significant successes in ICT in eHealth. Examples include deploying mobile devices to improve drug adherence, designing Internet services to extend human expert contact, and developing devices and services that encourage engagement in proactive healthcare activities. From an infrastructure perspective, better supply-chain management has reduced healthcare and patient support costs.

However, we believe that even greater benefits for improved Quality of Life (QoL) can be realized by broadening the eHealth agenda. We advocate moving upstream from medical intervention and healthcare for those already diagnosed as "il" to the design of sociotechnical technologies and systems aimed at fostering Proactive Health and Wellbeing. While not focused on medical health issues specifically, proactive strategies for wellbeing are key to long term health and thus to the reduction of healthcare needs and costs. Through support for lifestyle adjustments to focus more firmly on proactive strategies, we will no doubt achieve reductions in the number of people who become ill in the first place. This will, in turn, reduce the costs of healthcare support at individual, group and societal levels. Good examples are preventable lifestyle conditions such as obesity and heart disease.

Two major challenges are clear, each of which has a number of sub-challenges.

Our first challenge is to map key issues that are tractable in the short, medium and long term. To this end, an interdisciplinary group of researchers from academia and industry, with expertise in sports science, neurology, cardiology, computer science, psychology and sociology met to create a road map for research challenges around developing interactive technologies to support this proactive health and wellbeing agenda. This gathering of research leaders was the Perspectives Workshop on Interdisciplinary Grand Challenges in ICT Design to Support Proactive Health and Wellbeing. Here, we posed the question: What are the key Human Computer Interaction and Computer Science research challenges that need to be addressed for us to support more effective proactive health and wellbeing practices in the long term? We derived five key challenges which we propose to be the foundations for a new research area, "Wellth Sciences": 1) Developing Effective Methodologies, Measures and Metrics for Understanding Proactive Health and Wellbeing; 2) Understanding Motivation and Sensemaking with regard to experiential aspects of a proactive engagement with wellbeing and health; 3) Rethinking Design Practices; 4) Creating New Frameworks and Models; and 5) Rethinking the Phenomenology and Epistemology of "Health". These challenge areas are detailed in the following report, along with landmarks for success at 1, 5 and 10 year periods.

The second major challenge is to foster a dedicated, multi-disciplinary research community focused on these issues. The Perspectives Workshop gave us the first step forward toward addressing this challenge. We offer a proposal for ongoing connection and collaboration between those assembled for the workshop, and for inviting others to address the research areas identified.

Perspectives Workshop June 29 to July 2, 2014 – http://www.dagstuhl.de/14272
1998 ACM Subject Classification H.1.2 User/Machine systems, H.5 Information Interfaces and Presentation

Exploring Interdisciplinary Grand Challenges in ICT Design to Support Proactive Health and Wellbeing, *Dagstuhl Reports*, Vol. 4, Issue 6, pp. 108–123
Editors: m. c. schraefel and Elizabeth F. Churchill

Dagstuhl Reports
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Keywords and phrases Proactive Health, Proactive Wellbeing, eHealth, Wellth, Wellth Creation, Quality of Life, societal impact, interactive design, health, wellness, Computer Science, Human Computer Interaction
Digital Object Identifier 10.4230/DagRep.4.6.108
Edited in cooperation with Adrian Friday

1 Executive Summary

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To date poor health costs billions annually, negatively impacting our nations' GDPs. Costs include provision of healthcare for acute and chronic physical and mental conditions and reductions in productivity resulting from absences from work due to sickness.

Much hope has been placed in the deployment of networked information and communications technologies (ICTs) to improve the health of citizens, engage them in proactive healthcare strategies, and thus reduce the likelihood of illness in the first place. Part of the promise is that ICTs in the form of personal, commercial and infrastructural/ governmental platforms may be deployed ubiquitously, pervasively and more cost-effectively than one-to-one human care.

This perspective draws primarily from advances in mHealth and eHealth in the medical community. The focus in these domains, however, is to see health as a medical condition, focussing on tracking and management of patient records, support for doctor-patient interaction, and technologies for regimen adherence and therapy management. In our view, an excellent complement to this perspective is a focus on Proactive Health and Wellbeing, where the concept of health is broadened from being the absence or management of a medical condition or conditions to include a personal engagement with and understanding of wellbeing. ICT has, so far, delivered less success in this arena[4].

The Perspectives Workshop on Exploring Interdisciplinary Grand Challenges in ICT Design to Support Proactive Health and Wellbeing was convened to engage with these issues. We invited scholars to focus on Proactive Health and to elicit what key challenges we need to address in ICT that, if we were to put in concerted and coordinated effort as a community, would have demonstrable effect. We invited reflection on the promise of ICT in contributing to global health, GDP and wellbeing. Our participants have come from various areas in computer science, principally Human Computer Interaction, Data Science and Information Studies, both from industry and academia. We also had participation from psychology, sociology, sports science, medicine and neural science. While most participants were established research leads, we also reached out to up-and-coming, early career researchers in Computer Science and Human Computer Interaction who have a developing track record on health and wellbeing related topics. These individuals will be the future leads in this emerging field.

Over the three days of our workshop we developed 5 key challenge areas, focusing on the significance of each challenge, success at year 1, 3 and 10, as well as resources required to facilitate success. These areas correspond to data sciences, motivational modeling, design thinking, framework building, and a higher order rethinking of the space of "health":

1. Developing Effective Methodologies, Measures and Metrics for Understanding Proactive Health and Wellbeing. Small and "Big" data need to be captured, cleaned and curated to more effectively reflect hard-to-measure experiential aspects of wellbeing. Qualitative data are needed to better understand what is being captured quantitatively, and to enable a deeper understanding of the diversity of experience and to more deeply investigate what is represented in the data within the "long tail".
2. Understanding Motivation and Sensemaking. New models of motivation and sense making are needed in order to more deeply understand people's aspirations and the contingencies of their everyday lives that enable or prevent personal proactive health and wellbeing practices. A move from imposing normative models of "change" to understanding how sustained motivation and self- and other-persuasion can result in new and innovative technology-enabled programs is needed. .
3. Rethinking Design Practices. We need reflective design practices that focus on the phenomenological aspects of a design to complement designs that focus on intervention and instrumental goal achievement. This arena relates to the need for better motivational models, but addresses the ways in which our design practices mould what we create. How can we more effectively move basic science into applied science and more effective engineering?
4. Creating New Frameworks and Models. We need to develop frameworks and models that take into account unconscious as well as conscious drivers of human behavior, that better connect 'body', 'mind' and 'feeling' experiences, that address emotions as well as cognitive processing, and that acknowledge rhythms of participation and non-participation that are health-positive as well as those that are health negative. This requires a deeper engagement with psychosocial, brain and biological sciences to develop and bring into perspective more holistic frameworks and models.
5. Rethinking the Phenomenology and Epistemology of "Health". Rolling the previous areas up, one of the broader challenges directly addresses how to drive multi disciplinary thinking in regard to proactive wellbeing. A new field of enquiry at the intersection of Human Computer Interaction (HCI) and Computer Science, we need to think about how to motivate and increase engagement from researchers, from designers and engineers, from policy makers, from governmental agencies and from business leaders.

The key outcome of the workshop is an affirmation that a focus on Proactive Health and Wellbeing is both timely and socially necessary, and represents a viable area of research and development. A suite of near-term future activities have been planned and "owned" by participants to drive forward in the coming 6 months. Activities include a follow up Dagstuhl seminar, and workshops, panels, summer schools, invited publications, special issues, and the establishment of an area conference. We have also agreed to explore new ways to engage around experimental design, feedback and collaborative work. We invite potential collaborators to contact us for further discussion and to learn more about our ongoing efforts in this emerging arena of Wellth Sciences.

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3 Key Challenges Identified

All workshop participants

Five key challenge clusters were identified, each having sub-challenges that are likely to lead to targeted research proposals and the need for strategic cross-disciplinary collaboration and applications for resourcing. Our intention is to use these clustered challenge areas to begin to identify key collaborative opportunities, funding sources and opportunities for platforms for further exploration (e. g. conference workshops, sponsored seminars and working groups, etc).

Document Organization

For each challenge, we present an overview of the challenge, and offer a set of associated research challenges, and in many cases, what success at 1, 3 and 10 year points, and our requirements to enable success.

3.1 Challenge 1: Methodologies, Measures and Metrics

3.1.1 Overview

Broadly speaking there are two data related movements within the proactive health and wellbeing arena – quantitative and qualitative data from an input and output mechanism. *Quantitative data* is related to easily computable data (although not necessarily accurate at this time) in individual or aggregate statistical data form garnered from medium to large populations with the intention of communicating trends to individuals or with service providers, monitoring agencies, marketing initiatives, epidemiological and controlled comparative studies and so on. Quantitative data can be input (e. g. I swam for 20 minutes; my heart rate is 152), analyzed, and output (e. g. you walked 9,573 steps today). *Qualitative data* from an input perspective is related to the lived experiences of individuals and can cover everything from one's culture, stories, and rich multimedia/sensor experiences (e. g. a video of one's experience in a specific context). Qualitative output is broadly defined as reflecting on one's lived experiences (e. g. listening to one's favorite experiences) or viewing abstracted quantitative data (e. g. a light color that is colored based on how long one spent outside).

For Quantitative Data, statistical information is derived and manipulated to understand the relationship between behaviors, demographics or other kinds of antecedents and health outcomes. Indeed, health science traditionally relies on statistical information from large populations to understand the relationship between behaviors, demographics or other kinds of antecedents and health outcomes. This information is then used to offer prescriptive or corrective advice to achieve some goal. However, these statistical tests generally only offer reliable information when there are fairly large groupings of people that are similar in a given distribution. That is, we can offer good advice to people when they fall in the "body" of the distribution – the middle 60–80% of the population for a given variable (e. g. age, race, gender, diet, exercise regimen, body type, BMI, resting heart rate, etc.). However, this fails for those in the "tails" of the distribution, those who fall on either side of the middle clump

of people. It also fails when the distribution is more evenly distributed, or flat. This is even more complicated because most people fall in the middle of a distribution on some factors, but out in the tails on others. Thus, on person might be very similar to most other people, but respond very differently from those others in the remedies that are prescribed. Someone else might be like most people on both of these factors, but for some reason find it very easy to maintain a reasonable BMI with very little exercise. Health science has traditionally been very useful for people when they fall in the body of the distribution, but when they are in the tails, it can recommend advice that just doesn't work (or is even harmful).

This is where recent advances in data science can be very helpful. By exploring very large data sets of many people, signals in the tails become understandable. Machine learning and information visualization techniques allow us to make sense of large number of features (different factors) and how they relate to each other to result in meaningful classifications & groupings at an individual level. The classic example of this in other domains is personalization in shopping or entertainment (Amazon, Netflix, Google, etc.). There is an opportunity to innovate in similar techniques to make huge strides in how we understand wellness information on a personal level based on the aggregate data of millions of other people each providing vast amounts of individual data from new sensors and other sources. Naturally, there are serious obstacles to work through. For example, the data in this case is very sensitive and so guarding privacy is very important.

The second important format for data is personal data, as in the kinds of data available through personal fitness and body monitoring device. Examples include the Fitbit and Nike FuelBand. Much has been covered in this arena by members of the Quantified Self movement, and recent years have seen an enormous amount of investment in this space from venture capitalists and those who are keen to link these personal data 'pools' to the aforementioned large scale predictive modelling efforts.

Quantitative data are excellent for supporting decision-making around activity engagement and program change. They enable us to understand whether our health is improving by offering a baseline and or a standard against which we can measure ourselves. However, there are challenges in helping people understand what their personal data mean – as noted above individuals vary considerably and there is no one size fits all measure. It is hard to help people understand what is reasonable change over time. Health regimens are notoriously poor for maintenance when the focus is on quantitative measures of change and "improvement". We need to develop better methods for aiding individuals to make more effective use of their data. Researchers and industry have abstracted quantitative into qualitative visualizations (e. g. a flower growing on a fitbit) to assist lay people understand the impact of their everyday activities on their health, however we need a better understanding of what these visualizations should look like to assist people make better real time and post-reflective decisions. In addition, we need to develop flexible systems where people can decide how they want this feedback as they go throughout their lives – maybe during the week when one is working, they need a subtle, vibrotactile reminder that they are sitting too long, however during the weekend when activities are more varied and include other people, maybe something more ambient and attention getting is needed.

In addition to abstraction, qualitative data can take the form of narrations and lived experiences. The qualitative data that help us understand and interpret the quantitative datasets are essential for developing understanding. The most successful fitness and wellbeing applications and services are those that are social, where people are able to account and narrate their activities. These are not successful, however, when people are made to be accountable to an imposed regimen of improvement. They are successful when they are focus

on experience rather than outcome. In addition, designers can gain a rich understanding of one's life through these qualitative narratives such as recent work that has been done investigating youtube videos.

Quantitative data are about monitoring, and are easy to generate. Qualitative experiences are somewhat easier to collect, however they are harder to design for and are difficult to measure. We will return to this point in outlining another challenge, below.

Within the space of data capture, we also have a particular opportunity to consider the long tail in new ways.

3.1.2 Key Research Challenges

- The more automated quantitative and qualitative data collection methods become, the less we burden users, however they may also be less likely to think about the data and reflect on it. How do we design low burden, but high reflection health and wellness tools that empower people to take action in their everyday lives?
- Today's health and wellness technology is largely still created for majority groups (typically middle to high socioeconomic, knowledgeable and/or enthusiastic about technology with access to relevant information resources, and often male). How can we integrate more diversity into the stakeholder design space (e. g. children, people with low literacy and/or numeracy and fewer economic and other resources)?
- Social interactions are a key component in motivating people to maintain health lifestyles – once we diversify the stakeholder design space, how should the research community address the power relationships within these social interactions (e. g. child – parent; patient-healthcare provider)?
- Quantitative data is relatively easy to collect (e. g. accelerometers), however difficult to visualize. How should we effectively visualize quantitative data for a diverse population user group?
- Qualitative data is easy to collect, however difficult to process and reflect on (in large quantities). For collection, how can we make it easy to collect while maintaining others privacy expectations? For reflection, how can we make it easy to reflect on large sets of qualitative and derive appropriate results (e. g. no confirmation biases)?

3.2 Challenge 2: Understanding Motivation and Sensemaking

The individual is a critical agent in proactive health. While ICTs are enablers for successful participation, the decision to participate rests with the individual. Thus, we need to understand how to motivate the individual to participate in his or her health. Since *proactive health* requires a life-long commitment, the time dimension is critical in addressing motivation, as we know that people's commitment will wax and wane over time. Thus, we need improved models of how motivation operates over *it's lifecycle*, that is, how to initially involve people in proactive health, how to maintain their commitment and how to enable them to return to proactive health activities should their commitment wane.

The large body of literature that has investigated motivation is a testament to the complexity of the topic. Increasingly researchers are adopting ecological theories (e. g. the work of Uri Bronfenbrenner on Ecological Systems Theory) to organize the interdependency of individual determinants of behavior (psychodynamic factors) with those derived from social (e. g. emotional and pragmatic support within the family), organizational levels and

cultural levels (e. g. socioeconomic factors such as poverty, social opportunity) to understand how to better support an individual to make positive behavioral decisions.

We propose to augment existing theoretical approaches to motivation with a heavily data-driven approach to understand the operation of motivation across the lifecycle with regards to the individual's involvement in proactive health activities. The goal of this work stream is to devise a method for using behavioral data collected in the course of normal activities to refine initial estimates of the "motivational equation" for an individual that were defined on the basis of theoretical constructs. Some basic research questions include the following. Is it possible to consider normal activities in the course of an individual's life to be small "experiments" that provide data to be used to refine the set of "proactive health experiences" initially offered to an individual based on a categorization guided by theories of motivation? What kind of infrastructure might be needed to collect data to support such data-driven refinements of proactive health experiences? What data is useful for making initial theory-based classifications of people? What results on in-the-wild experiments would be informative for updating the scripting of future proactive health experiences?

3.3 Challenge 3: Rethinking Design Practices

One challenge facing designers of health and wellness systems is which goals they should support or encourage and how heavy-handed they should be in their promotion of them. Fit4Life [3], an elegant paper by researchers at Cornell, describes a future in which people succeed at creating an engaging system that monitors and provides feedback/instructions on what to do to achieve an optimal state of health and fitness, as determined by the application's designers or health professionals. This future, however, is dystopian. Wearers of the system are shamed into compliance, and it becomes clear that the system allows little to no room for other forms or definitions of wellness or well-being.

Researchers and consumer device manufacturers have been rapidly developing the capabilities described in the Fit4Life paper. These include persistent, ubiquitous sensing capabilities for a variety of biomarkers and activity indicators, techniques that can identify patterns in this data, and a variety of real-time feedback techniques to promote healthier behaviors. If taken to their logical extreme, current trends in personal informatics may approach or even achieve Fit4Life.

We argue, however, we should strive not to achieve this future. Over-optimizing for certain health outcomes or focusing overly on specific numbers may come at the expensive of individual autonomy or other forms of wellbeing.

3.3.1 Key Research Challenge

Our community should identify, embrace, and further develop design strategies that help balance these tradeoffs for a specific situation. While we generally argue for design of systems that respect people's wishes and autonomy, we can quickly identify situations when more persuasive systems, or even coercive systems, may be appropriate (consider, for example, someone who is anorexic, or parents encouraging their child to eat vegetables). We also agree that people should not always be so focused on their health and wellness that they are unable to enjoy a delicious meal or simply just be in a moment without worrying about the consequences of each small decision, but we also agree that some amount of mindfulness and reflection is appropriate or necessary. There are also many questions about whether and how

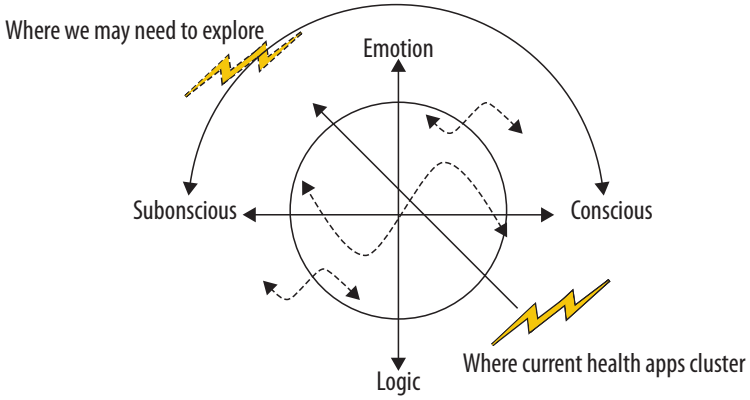

Figure 1 Design dimensions for proactive wellbeing.

to engage people who are not motivated to change their health and wellness behavior, but for whom health providers or others in society generally believe changes would be beneficial.

Determining guidelines for ethical design and deployment of proactive health and wellness technologies, or even how one even goes about identifying such guidelines, is a grand challenge for the next decade. It is imperative that our communities begin work on this before we create systems that create a future that most people would not want, and that we revisit guidelines as new systems reach the market and technological advances make new interactions possible.

3.3.2 Success markers in 1, 3, and 5 years

As an **immediate goal**, our research community should identify one or more measures of quality of life that go beyond specific health outcomes and be considering them for use in future studies. Many quality of life scales exist; it is outside of our current expertise to identify those that are most suitable or changes that would make them more appropriate.

Similarly, our community should adopt and promote the development of design strategies that help designers and policy makers identify a full range of individuals' motivations, goals, and priorities, and design to be inclusive and respectful of those. In particular, we think that health and wellness intervention designers would benefit from more exposure to and training in Value Sensitive Design [1].

3.4 Challenge 4: Creating New Frameworks and Models

Of central import is the emerging design space of proactive wellbeing; a first attempt to outline this design space is shown in Figure 1.

Our thesis is that behaviour change interventions typically target the conscious self, appealing to us as rational beings: it's good for us, therefore we will of course integrate wellbeing into our lives. Only we often don't. Wellbeing is often not prioritised, i. e. is subsumed and subjugated by pressures of work and home, or constraints of the infrastructure of our everyday lives. Consequently, those needing wellbeing the most are least likely to action towards it. A marked social inequality in wellbeing at work also exists, i. e. those with the lowest paid and most strenuous jobs are least likely to call for actions towards wellbeing.

Our horizontal axis takes the focus of our designs from the conscious and rational, which is still an important target, towards the unconscious. This is partly motivated by technologies that speak to the unconscious brain, e. g. training aides while sleeping; but is also in our deeply rooted autonomous actions: our primitive brain is trying to gain energy quickly and optimise and store energy in case we need it (fight or flight). In order to understand these domains, we must take our conscious and subconscious perception into account. Some foods have an unconscious appeal (the burger is always more tempting than the carrot) – how can we start to design to support making wellbeing less conscious and rational? How can the technology be used to nudge us towards healthier behavior?

The vertical axis appeals to our senses and emotions. Humans inherently make choices that are instantaneously rewarding: dopamine release is pleasant, rather than rewarding in the long-term. We are envisioning the future where we incorporate all the human senses; how we perceive our world is dependent on how we perceive our sensory stimulus and its interplay with our emotions and memories. Can we design technologies that filter or augment our perception of the world (AR, BCI) to make wellbeing more appealing at an emotional level. We might for example, offer stimulation and rewards, e. g. that "back of neck feeling", to reward health promoting behaviours. The nascent argument being that we are emotional creatures, and that our hearts will rule our rational heads. Along this axis we would include social technologies that promote and share positive reinforcement to make proactive wellbeing more normatively acceptable, and to gain support from others.

By understanding, appealing or even manipulating our subconscious reasoning and perception, we might find new ways to encourage wellbeing in our lives. However, broadening out from the individual, we must also recognise that we are not typically unconstrained or free to act in our rational or even irrational choices. We act in a context constrained by rules, relationships, policy and infrastructures of both of our home and work lives, and of the wider social norms and expectations of our peer groups and of society.

This opens up in important 'intentional design' concept 'proactive wellbeing by design': in which policies that promote wellbeing become embedded in the socio-technical systems, tools and technologies that surround us and support our lives. Applying this concept to conventional workplace systems, we use the example of a company meeting strategy in which the calendaring tool deliberately suggests 'walking meetings' or books rooms that are *deliberately less convenient* to encourage exercise. All this done in a fashion that seems appealing and meaningful to the employees rather than annoying. Similarly, a route planner might leave a transit system early to give you with a short walk at the end of your route, while still ensuring you arrive on time. Here, we might think of 'deliberate inconvenience' that promote new experiences related to wellbeing in order to break down preconceptions and gain new competencies [2].

We also note the trends toward 'quantified self' technologies for reflecting on and motivating exercise (e. g. step counters, smart watches, and so on). While such technologies clearly focus on benefit to the individual, we believe a significant opportunity space exists for exploiting this information collectively 'en masse': beyond the quantified self (as individual), we might think of the quantified workforce (as collective), i. e. how can we leverage aggregate measures of the self in and beyond the self to help make strong empirical cases on the positive impact of wellbeing technologies and strategies to powerful actors controlling such infrastructures (e. g. employers, town planners, politicians). These data and new tools to analyse and visualise it, could help start powerful changes to the environments, facilities, and policies that surround us, and thus enable practices that reshape workplace and social norms towards proactive wellbeing.

3.5 Challenge 4, Part 2: Scenarios for Exploration

For each individual, long-term health and wellbeing depends greatly on maintaining healthy behaviors and reducing habitual unhealthy ones. It seems appropriate to take a step back when designing health behavior change technology and aim to really understand the daily contexts before we commit to programs of proactive health intervention. For example, a 'go-to-the-gym' app on your smartphone does not make sense if you live in an area where there is no gym around. But what might make sense in this circumstance is if you knew that your elderly neighbor would be happy if you would walk her dog twice a week. How would one be able to integrate highly contextual personal and interpersonal understandings in relation to the more quotidian aspects of our life. How do we identify and seamlessly mesh the many specifics of context in order that one might develop systems that take advantage of such contextual understandings? We believe it is essential that we get people involved in proactive health design. We would like to believe that people could democratically engage in the developments of systems that might have an impact on their own life. We would also like people to explore the notion of tools for self-design tools in respect to proactive health and personal behavioural adaptation. We would also like to look at the social dynamics of such situations - who gets empowered, who can get impact, who says what intervention is right? In aiming for adaptation and adoption of proactive health behavior change there needs to be a degree of understanding that comes directly from the user in order that any change can be maintained and sustained. Therefore, we would argue that there needs to be flexibility in proactive systems and that such flexibility needs to be transparent, intelligible, and a subject of ongoing conversation.

3.5.1 Key Research Challenges

- Our first specific challenge in designing health behavior change technology is to understand the daily contexts of people's lives before we commit to building specific interventions. For example, a go-to-gym-app does not make sense if you live in an area where there is no gym around but your elderly neighbor would be happy if you walk her dog twice a week.
- With specific regard to the role of technology infrastructure that would be required to support behavior change applications we seek to create and/or engage with venues and platforms for creation and accretion of knowledge and motivational resources around nudging people to be healthier in their daily lives.
  - We can see other examples of such platforms in open source software projects and repositories, Massive open online course, and Wikipedia to name a few.
  - The domain of application is specific behavior change to mitigate long-term healthcare costs due to correctable behaviors, e. g. reduce preventable health inhibitor such as workplace conditions that contribute to lost productivity in the workplace (e. g. joint and back pain and other strength and posture related conditions) and increased healthcare cost in the long term because of emergent diseases (e. g. diabetes, deterioration of the spine)
  - We envision creating or participating in one or more marketplaces or other economic mechanisms for those involved in content production and management and in service provision related specific proactive healthcare interventions and contexts. i. e. Host specific behavior change applications that arise from and/or integrate to the platform
  - We further seek to empower interested stakeholders to be involved in self-design tools for health behavior change. This goal arises from working in the margins of official Healthcare systems

3.6 Challenge 5: Rethinking the Phenomenology and Epistemology of "Health", A Meta Challenge for Computer Science and Wellth Science – framing a new discipline

We are inspired by Ben Shneiderman's Science 2.0 that shows great science can come from exploring real and practical problems [5]. Our health, wellbeing, quality of life are all in the space of such real problems. This document has presented a suite of key challenges that require Computer Science expertise to help solve.

Within Computer Science

Many computer scientists will immediately see opportunities from these research questions to help advance our knowledge into delivering support from infrastructure to interaction to have social benefit. This immediacy is truly exciting: it gives us real footholds to make progress, and offers opportunities for applications from domains that may not have considered they have anything to offer these domains.

Some example computer science domains/challenges driven by our interaction-oriented Wellth questions include:

- *Systems and Semantics*: collecting diverse personal health data sources into a unified database, while preserving individual privacy and ensuring high data quality. Developing standards for data interchange, and metadata annotation rules to ensure compatibility.
- *User interface*: Enabling users with diverse skills to understand and manage their own personal health data. .
- *NLP/text analytics*: extracting health/wellth signals from social media streams (improved Google Flu Trends) search terms, or blog posts.
- *Big Data analytics*: Researchers, public health professionals, and others need visual and statistical tools to sift through the high volume of data, clean out erroneous values, build models, present correlations, develop causal hypotheses, refine theories, and propose practical guidelines.
- *Personal Informatics and Machine Learning*: integration of personal data sets, from calendars, to social interactions, to content creation, to physical sensor data. There are opportunities to look for patterns to help surface connections and correlations to help inform practice.
- *Information Visualization*: Visualization to provide comprehensibility of these patterns not as histograms but as answers to questions: where am I relative to temporal changes, comparisons with similar people, and geographic patterns.
- *Computed Security and Computed Policy*: We need to create dynamic policies for data that may not be stored but generated by queries on personal information.

There are terrific opportunities for the challenges in this report to drive fundamental computer science research, where we need innovative infrastructure to support trustable, safe data interactions on our behalf. Driven by the human requirements for better normal, we see such profound challenges for fundamental computer science to help optimize performance for what we can do to be useful and usable in people's hands and contexts.

With Computer Science – Gaining New Expertise

We have deep within-discipline opportunities to support these challenges as Computer Scientists and HCI researchers. To deliver on the challenges identified throughout this report, particularly in terms of understanding exactly what we may wish to begin to design, however,

we see an opportunity to develop new expertise beyond Computer Science and HCI. For instance, as largely computer scientists, few of us have the skills and knowledge necessary to design tools to support, for instance, coaching in general or coaching nutrition practice in particular. A usual approach may be to collaborate with domain experts, and design tools relying on their insights. Wellth Science and Engineering as it may become known, however, also offers opportunities to consider what expertise do we want to hold personally to be Wellth Scientists.

The knowledge challenges this domain presents about for instance how does the state of the body influence the state of the mind, we hope will become part of Wellth Science general education. Our bias in this workshop is that many of our societal challenges for which we are endeavoring to develop ICT health and wellbeing solutions exist due to a profound lack of knowledge about how our bodies (and brains as part of our bodies) perform. As a result of this knowledge gap we have a consequent lack of skills and experience on how to operationalize and sustain personal and social good practice.

We strongly recommend that computer scientists interested in designing for Wellth Creation become themselves literate about the body-brain connection. We suggest that this expertise development to be a Wellth Scientist and Engineer is a meta challenge within this domain. We need to consider the curriculum that would be optimal for such a researcher and design practitioner.

Fortunately, such domain curriculum consideration is a familiar experience for computer science, itself a domain hybrid from math. omputational linguistics draws on the formalisms of computer science machine learning and linguistics, largely based in the humanities. New international programs in support of "biologically inspired computing" has blended domain expertise in molecular biology, computation and devices. Human Computer Interaction itself brings psychology, sociology and human factors to blend into effective and efficient interactive designs to help enhance people's lives, from the workplace to the home. We suggest that given the scope of the issues around our health, wellbeing and quality of life, we need to consider the benefit of developing similar interdisciplinary Computer Science programs around Wellth Science.

In the CS/HCI space in formal Health Care, we already see examples of researchers spending time from their existing degree program or post grad research efforts, to gain considerable knowledge and expertise about medical practice to have meaningful conversations with the professionals in this space. These undertakings, however, have been largely ad hoc and individual, where that individual has often had to negotiate through degree timelines or research project support to be able to have the time to gain this level of expertise. We suggest that by being more deliberate about the kinds of knowledge students, researchers, practitioners need as part of our training to be effective in a timely way in Wellth Science, that we consider the benefit of incorporating these studies as part of a Wellth Science Design and Engineering program from the outset.

3.7 Challenge 5, Part 2: Framing a Domain Epistemology

The next one to three years will be key to shaping the concept of the Wellth Sciences. A key question throughout the workshop compared traditional HCI ways of knowing and asserting knowledge via short, small participant sample evaluations with the medical model of large randomized control trials. Into this mix we proposed the new and exciting opportunities to run large scale n=1 experiments remotely. This is an accepted model of evaluation neither

in HCI nor other human oriented sciences, and yet it seems particularly apt for exploring effect when one wants to consider practice interventions.

Similarly, new models of collaboration and of impact are needed. For example, we propose the sharing of experimental protocols before experiments are run (similar to medical sciences). This would enable scientists to gain comments on a proposed protocol and also encourage new ways of running experiments such as co-running distributed interventions and creation of new data sets that can themselves be shared.

Current models of practice in HCI in particular were critiqued. Questions were raised whether our nascent community's focus might not be better spent on live meetings for networking and sharing work in progress towards solving problems, and using journals for more complete work, rather than the current dominant computer science paradigm of main publications at conferences, where the publication is the key mechanism to demonstrate impact. The critique was to ask what kind of impact is it to have a paper accepted at a conference, when we truly want to see research having an impact not only for our co-researchers, but in the community.

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DOI: 10.1126/science.1153539

Acknowledgements. We thank all the participants who attended the Perspectives Workshop. We also thank all our collaborators for their insightful comments and edits to this report.

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