Ubiquitous Computing Technology for Just-in-Time Motivation of Behavior Change

Stephen S. Intille

House_n: the MIT Home of the Future Consortium
Massachusetts Institute of Technology
1 Cambridge Center, 4FL
Cambridge, MA 02142 USA
intille@mit.edu

1 Introduction

There is an emerging opportunity for ubicomp researchers: the development of proactive healthcare technologies that use "just-in-time" information to motivate and sustain and behavior change. My group is developing and testing sensors and user interface systems that determine when to present messages to motivate healthy behaviors.

The U.S. medical system and those in other countries face an impending crisis: how to pay for the care of an aging population. This growth combined with governmental health care shortfalls and the rising cost of medical procedures will place an enormous strain on the worldwide health care industry in the next 10 years.

Three ways to address this problem are to (1) increase governmental expenditure and taxation, (2) ration care, and (3) develop effective preventive systems that help people stay healthy and living independently of the medical system as long as possible. Options and 1 and 2 are inevitable, at least in the U.S. My group is focused on option 3. Applications for proactive health care can be grouped as follows:

Systems that detect a crisis. Detecting a crisis generally requires a few good sensors, typically biometric sensors worn on the body. Commercial cardiac monitors, for example, continuously monitor people for heart conditions that indicate immediate medical care is necessary.

Systems that detect declines in health. Detecting a gradual change in health status will generally require multiple, multi-modal sensors. For instance, based on interviews with medical professionals, we developed a prototype system to automatically monitor an individual in the home for congestive heart failure using input from sensors in the environment or placed on the person [12]. That prototype used context-sensitive self-report, where the user is asked questions about health at moments when those questions provide the most diagnostic information. Context can be inferred from sensors in the home. Our group is currently developing ubiquitous sensing technology for homes and mobile computing devices to detect activities of daily living and other common domestic activities [2, 15]. A sensor system that can detect changes in everyday activity in the home would enable a new generation of home-based and institutionally-based services for the aging [16]. Changes in everyday activity often precede declines in health.

Systems that *motivate* healthy behavior. If a computer can identify everyday activity, then it can not only monitor for changes but it can also proactively present information that may lead to behavior changes that help people stay healthy [10]. This is a primary focus of our current work. In some cases the ubiquitous computer system may increase self-awareness of health care in fun and entertaining ways by presenting information. In others, the computer system may present information at specific times and places to purposefully influence behavior.

2 Just-in-time messaging and motivating behavior change

My group is prototyping and testing technology that can motivate behavior change. Some of the tools we have developed for measuring behavior change, which consist of ubiquitous sensors for the home setting and context-sensitive wearable tools, will be described at the Ubicomp conference [13]. At the workshop I would describe how we are using these tools for activity recognition and our current work on context-sensitive messaging.

Although people are often skeptical at first that a computer system might motivate them to change their behavior, researchers in a variety of non-IT fields have convincingly demonstrated the power of point-of-decision messaging to motivate behavior change (e.g. improving safety in the workplace [14, 9], encouraging seat belt use [7], increasing public recycling [7, 8], reducing electricity consumption [19, 18], and encouraging exercise in public spaces [4], among others [6]). Although the systems only work for some of the people, some of the time, studies have consistently shown that context-sensitive information presentation can make a difference (e.g. doubling the number of people who take stairs [4], reducing air conditioner use by 15% [18]).

There are four components to an effective strategy to motivate behavior change:

1. Present a simple message that is easy to understand
2. At just the right time
3. At just the right place
4. In a non-annoying way.

To present messages at just the right time requires computational sensing that can infer context from sensor data. To present messages at just the right place requires an output mechanism wherever the user is. This can be achieved using either mobile computers (e.g. PDA/cellular phone hybrids) or “augmented reality” Everywhere Display technology that can place information directly onto objects in a home [17]. We are investigating both approaches. Finally, to present information in a non-annoying way means the information must be relevant given the context, and the presentation of information must not disrupt ongoing activity. Careful attention must be paid to user interface design. For instance, it may be better to present more subtle information that the user is receptive to rather than blatantly attempting to command the user what to do. For example, a computer that detects when a user took an unusually long walk and provides positive reinforcement by informing the user of the health benefits is likely to be perceived as less annoying than a computer that continuously tells the user he/she should take a long walk because no walk has occurred in a while.

My group is exploring how non-intrusive, "just-in-time" messaging can be conveyed as people are in their homes, workplaces, and communities. To demonstrate such systems work, in some cases we are building tools to measure how effective such messages might be [11, 13]. We are interested in three points in time: the point of decision, the point of behavior, and point of consequence [5]. Our work on activity recognition aimed at using sensors to automatically detect these specific (and sometimes fleeting) moments in time [2, 15].

3 Evaluation

Despite extensive evidence of the power of just-in-time information from behavioral science, my group faces a challenge in convincing the medical community of the great potential of ubiquitous computing technology to detect the right moment to present information and to customize it to the situation.

Therefore, in addition to developing prototypes and core activity recognition technology, we have ongoing projects in exercise and diet aimed at evaluation. One of our projects is determining how technology that places messages at points of decision can be used to motivate behavior changes in public spaces. The work is motivated by 20 years of research in behavioral science on the power of point of decision messaging for motivating exercise in public spaces [1, 3, 4].

Stair motivation studies have consistently found that simple signs that convey health and weight-related messages at the point of decision can dramatically increase the number of people taking the stairs versus the escalator or elevator in public spaces (e.g. [1]). In one study a simple sign ("Your heart needs exercise ... here's your chance") displayed for three weeks had a residual effect on stair use of commuters after the sign was removed for up to *3 months* [4]. Others have found similar results.

We have created an inexpensive system that can *automatically* estimate the *relative* numbers of people using the stairs versus the escalator using computer vision. It can also project a just-in-time message. We are currently investigating the impact of various types of messages on stair use at three public transit sites. Figure 1 shows one of our systems.

4 Expectations for the workshop

My goals at the UbiHealth workshop would be to meet other researchers interested in the application of ubiquitous computing to healthcare. I would prefer

Figure 1: Image of one of three systems being used to measure the impact of just-in-time messaging in transit stations to motivate physical activity. The box contains a computer vision people counting system for measuring sign impact and a projector.

a format with brief presentations on current research followed by exercises that encourage critique and discussion aimed at helping to foster collaboration. Issues I am particularly interested in discussing are how we can (1) obtain funding for ubiquitous computing research for proactive healthcare given that funding agencies often specialize in either technology or public health, (2) provide the public with convincing demonstrations of what might be possible, and (3) convince the medical community of the value of technology that promotes proactive healthcare using ubiquitous computing technologies.

5 Bio

Stephen Intille is a Research Scientist and Technology Director of the Changing Places / House_n: MIT Home of the Future Project based out of the MIT School of Architecture and Planning. His research interests are focused on the development of context-recognition algorithms and interface design strategies for ubiquitous computing environments. Of special focus is the challenge of creating spaces and devices that motivate behavior change over long periods of time, particularly as applied to preventive health care. He received his Ph.D. from MIT in 1999 working on computational vision at the MIT Media Laboratory, an S.M. from MIT in 1994, and a B.S.E. degree in Computer Science and Engineering from the University of Pennsylvania in 1992. He has published research on large-occlusion computational stereo depth recovery, multi-agent tracking, realtime tracking, multi-agent action recognition, and perceptually-based interactive environments. He always takes the stairs.[1]

[1] Jacob Hyman developed the stair monitoring system. The proactive health work of my group is supported in part by the NSF (#0112900), the Robert Wood Johnson Foundation, and the House_*n* Research Consortium.

References

1. R.E. Andersen, S.C. Franckowiak, J. Snyder, S.J. Bartlett, and K.R. Fontaine. Can inexpensive signs encourage the use of stairs? Results from a community intervention. *Annals of Internal Medicine*, 129:363–9, 1998.
2. L. Bau. *Physical Activity Recognition from Acceleration Data under Semi-Naturalistic Conditions*. M.Eng. Thesis, Massachusetts Institute of Technology, 2003.
3. A. Blamey, N.M. N, and T. Aitchison. Health promotion by encouraged use of stairs. *British Medical Journal*, pages 289–90, 1995.
4. K.D. Brownell, A.J. Stunkard, and J.M. Albaum. Evaluation and modification of exercise patterns in the natural environment. *American Journal of Psychiatry*, 137:1540–5, 1980.
5. B.J. Fogg. Persuasive technologies and netsmart devices. In E. Bergman, editor, *Information Appliances and Beyond*, pages 335–360. 2000.
6. G.T. Gardner and P.C. Stern. *Environmental Problems and Human Behavior*. Allyn and Bacon, Boston, 1996.
7. E.S. Geller. A delayed reward strategy for large-scale motivation of safety belt use: a test of long-term impact. *Accid. Anal. and Prev.*, 16:457–463, 1984.
8. E.S. Geller, R.A. Winett, and P.B. Everett. *Saving the Environment*. New York, 1982.
9. S.J. Guastello. Do we really know how well our occupational accident prevention programs work? *Safety Science*, 16:445–463, 1993.
10. S.S. Intille. Designing a home of the future. *IEEE Pervasive Computing*, April-June:80–86, 2002.
11. S.S. Intille, C. Kukla, R. Farzanfar, and W. Bakr. Just-in-time technology to encourage incremental, dietary behavior change. In *Proceedings of the AMIA 2003 Symposium*. 2003.
12. S.S. Intille, K. Larson, and C. Kukla. Just-in-time context-sensitive questioning for preventative health care. In *Proceedings of the AAAI 2002 Workshop on Automation as Caregiver: The Role of Intelligent Technology in Elder Care*, AAAI Technical Report WS-02-02. AAAI Press, Menlo Park, CA, 2002.
13. S.S. Intille, E. Munguia Tapia, J. Rondoni, J. Beaudin, C. Kukla, S. Agarwal, L. Bao, and K. Larson. Tools for studying behavior and technology in natural settings. In *Proceedings of UBICOMP 2003*. Springer-Verlag, 2003.
14. J. Komaki, K.D. Barwick, and L.R. Scott. A behavioral approach to occupational safety: pinpointing and reinforcing safe performance in a food manufacturing plant. *J. Appl. Psychol.*, 63:434–445, 1978.
15. E. Munguia Tapia. *Activity Recognition in the Home Setting Using Simple and Ubiquitous Sensors*. S.M. Thesis, Massachusetts Institute of Technology, 2003.
16. B.D. Mynatt and W.A. Rogers. Developing technology to support the functional independence of older adults. *Aging International*, 27(1):24–41, 2002.
17. C. Pinhanez. The Everywhere Displays Projector: A device to create ubiquitous graphical interfaces. In G.D. Abowd, B. Brumitt, and S.A.N. Shafer, editors, *Proceedings of the Conference on Ubiquitous Computing*, LNCS 2201, pages 315–331. Berlin Heidelberg, 2001.
18. C. Seligman, L. Becker, and J.M. Darley. Behavioral approaches to residential energy conservation. *Energy and Building*, 1978.
19. R.C. Winkler and R.A. Winett. Behavioural interventions in resource management: A systems approach based on behavioral economics. *American Psychologist*, 1982.