Understanding and Changing Behavior

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People routinely engage in relationships whereby they influence and are influenced by other humans. In the near future, we envision people confronting machines that can support such relationships as well. B.J. Fogg refers to these machines as *persuasive systems*.[1]

A notable difference between persuasion in human-machine interaction—as opposed to human-human interaction—is the limited (if any) ability of machines to have a real-time understanding of people's individual traits, activities, and social dynamics. Most persuasive systems are designed offline and subsequently lack the flexibility required to personalize or adapt messages to the usage context. This can only be remedied by real-time analysis of human behavior during interactions.

New technology and algorithms for human behavior analysis are giving computers an awareness that lets them attribute meaning to users' attitudes, preferences, personality, and social relationships and helps them understand users' activities, routines, and lifestyles. This could redefine the relationship between computers and the interacting human, changing the computer's role from that of passive observer to a socially active participant that can influence people's attitudes and behaviors in their everyday, natural environments.

The goal of this special issue is to contribute to the advancement of ubiquitous information societies, where computers and humans are part of the same ecosystem. A crucial property of entities living in the same ecosystem is that they mutually influence and affect each other's behavior and internal states (such as attitudes) in a variety of ways—including implicitly and indirectly. This special issue, organized as a follow-up to the Second International Workshop on Human Behavior Understanding,[2] investigates several domains where behavior change starts with a real-time understanding of human behavior.

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Human Behavior Understanding

The pipeline for human behavior analysis can be roughly described as having three stages: sensing, analysis, and application. In the sensing stage, real or virtual behavior is observed with sensors. The analysis stage applies models from psychology, cognitive science, sociology, and even physics if available. Otherwise, it employs statistical approaches, machine learning, and pattern recognition techniques. In the final application stage, the results are fed into an application, which might continue to apply sensing and analysis techniques to adapt to its users.

For this special issue, we received more than 60 submissions, which collectively described the scope and challenges of each of these stages. These submissions described sensing systems using cameras, microphones, mobile and wearable sensors, or software scripts that sense virtual behavior. In the analysis stage, they used social signal-processing and machine-learning approaches, in particular. There were also contributions on mental models and on attention and cognitive load, all of which are extremely relevant to behavior change.

However, the true richness of the domain became evident in the chosen applications of these submissions. We received contributions on gaming, coaching, cyberbullying, e-learning, profiling and personalization, smart homes, ambient assisted living, health support systems and wellness, life logging, urban interactions, energy management, participatory sensing, robotics, applications for autistic individuals, and affective computing. We selected six articles that jointly covered a broad area, but many aspects of the problem were necessarily left out.

In This Issue

One of the major application areas of behavior change is healthcare, including systems that help patients and the elderly, coaching systems, and personal healthcare assistants. Healthcare interventions are well-studied in the literature, and several models have been developed to account for different factors relevant for such applications. In "An Intelligent Coaching System for Therapy Adherence," Michel Klein, Nataliya Mogles, and Arlette van Wissen provide a survey and attempt to unify these models by proposing a computational model that differentiates between internal and external determinants of behavior. Identifying close to 20 factors, the authors propose a mobile application with a personalized persuasion mechanism that uses these factors for model-based reasoning.

In a second study on sustaining healthy behavior, "Designing for Engaging Experiences in Mobile Social-Health Support Systems," Eric P.S. Baumer, Vera Khovanskaya, Phil Adams, John P. Pollak, Stephen Voida, and Geri Gay report on two in-depth studies of a mobile application for documenting and sharing health decisions. Their observations show that user experience is particularly important, and social connections make the application more engaging. Consequently, they suggest emphasizing social experiences in an application with several degrees of social sharing on existing social structures. Their approach also demonstrates that open-ended systems are difficult to design and require iterative user testing, because many factors are difficult to control in such applications.

Gaming is a particularly important domain for this special issue, because games can serve as experimental platforms with easily controlled parameters and with very rich behavior palettes. Subsequently, they lend themselves to natural behavior and affect analysis. In "Socially Aware Interactive Playgrounds," Alejandro Moreno, Robby van Delden, Ronald Poppe, and Dennis Reidsma survey social signal-processing approaches in the context of interactive playgrounds. Behavior change can be achieved by manipulating game mechanics to create applications that address child exclusions, restore engagement, adapt to children with disabilities, and help resolve conflicts. Research in this area points toward more interactive and socially aware environments for play, where certain behaviors can be stimulated or discouraged.

Digital games are widespread and thus have enormous potential to influence users. One consequence of the gaming sector's rapid growth—with millions of users, in some cases—was the development of serious gaming, in which existing gaming assets are used in novel forms to create games that have purposes other than entertainment. In "Serious Gaming for Behavior Change: The State of Play," Björn Schuller, Ian Dunwell, Felix Weninger, and Lucas Paletta inspect how serious games can be used for behavior change. In reviewing two European projects, ASC-Inclusion and Maseltov, the authors provide in-depth examples of two games that aim to improve the social interactions of their players. The first example is a virtual world that teaches affective and social skills through minigames, and the second example is a mixed-reality game for urban interactions. The authors not only identify the potential of real-time behavior analysis for in-game feedback and customization but also point out its challenges. More often than not, a behavior change setting has multiple stakeholders in addition to the main subject (in this case, the gamer)—including caregivers, parents, or therapists. One obvious challenge is identifying how to keep these stakeholders in the loop.

A behavior change application often piggybacks on other mechanisms that prompt the user to continue using the application. This can be the "fun" aspect in gaming applications, the "social" aspect in social-media supported applications, or any other mechanism of persuasion. Whether the persuasive message is given directly or subliminally, factors such as attention and cognitive load are important to user perception. In "Blinking: Toward Wearable Computing that Understands Your Current Task," Siyuan Chen and Julien Epps discuss cognitive and perceptual load estimation from blink patterns. For always-on wearable interfaces, in particular, real-time cognitive load analysis would be very useful in correctly timing behavior change interventions.

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Smart phones with multiple sensors can sense not only behavior, but also the time and place, which can help with the timing of interventions. In "Smartphones for Large-Scale Behavior Change Interventions," Neal Lathia, Veljko Pejovic, Kiran K. Rachuri, Cecilia Mascolo, Mirco Musolesi, and Peter J. Rentfrow describe the UBhave project, in which a framework is developed for mobile phones to learn behavior patterns, moods, activities, and social relations to deliver timely messages—referred to as "behavior change interventions." The authors describe two applications—EmotionSense and SensibleSense—and highlight key open challenges to behavior changing applications on mobile phones. In particular, continuous sensing of behavior isn't energy efficient and thus depletes phone batteries. Even with interrupted sensing, the mobile phone can generate large amounts of data, which can be difficult to process in a timely manner. Furthermore, behavior patterns can be highly idiosyncratic, so even if the context is adequately sensed, that doesn't mean the application can customize the content to match it. According to the authors, creating open source platforms can help concentrate various efforts in this area so researchers can better tackle some of these challenges.

Behavior Change Technology

It's difficult to underestimate the potential for computer systems that induce behavioral change. Such systems can promote individual and social values by helping users reach their behavior goals through interaction and immersion. The enormous potential is partly due to the ubiquity and informality of such systems; they can be everywhere and can function through subtle and inconspicuous influences. It's also due to the richness of the application domain, because these technologies stand to transform numerous sectors—including healthcare, entertainment, organizational and individual psychology, business management, education, commercial advertising, and politics. The effect on society won't be limited to new and revolutionary technologies; these applications will also change the relationship between systems and their users in fundamentally different ways.

Many technical challenges remain, including the difficulty of assessing the long-term effects of interventions. Additionally, these systems require careful preservation of privacy and the maintenance of appropriate levels of control by users. Once the ethical and legislative framework is in place, researchers from different fields will have access to first-hand, empirical data on how computer-induced change works in realistic contexts, as well as to models and paradigms for initiating new projects for behavioral change.

To approach autonomous human-like behavior, machines must also be able to affect human behaviors and attitudes. Indeed, this possibility is intrinsic to the overall vision of machines acting as autonomous agents in constantly changing environments, which lies at the heart of research areas such as artificial intelligence, cognitive systems, embedded systems, ambient intelligence, and pervasive and ubiquitous computing. Such capabilities are also an essential ingredient for applications that aim to turn those technological and scientific advances into valuable services for users. P

REFERENCES

1. B.J. Fogg, "Persuasive Technologies," *Comm. ACM*, vol. 42, no. 5, 1999, p. 26–29.
2. A.A. Salah and B. Lepri, eds., *Proc. Human Behavior Understanding: Second Int'l Workshop* (HBU 11), vol. 7065, Springer, 2011.