A Self-Adaptive Personalized Behavior Change System for Adolescent Preventive Healthcare

Abstract
The majority of morbidity and mortality during adolescence is preventable and related to behaviors such as substance use and vehicle-related injuries. Most adolescents visit a healthcare provider once a year, providing an ideal opportunity to integrate behavioral health screening into clinical care. Although the majority of adolescent health problems are amenable to behavioral intervention, few health information technology interventions have been integrated into adolescent care. Computationally-enabled models of behavior change hold significant promise for adolescent healthcare. The objective of the research is to design, implement, and investigate INSPIRE, a self-adaptive personalized behavior change system for adolescent preventive health. INSPIRE will utilize social cognitive theory of behavior change built around a tight feedback loop in which a narrative-centered behavior change environment will produce improved behaviors in patients, and the resulting patient outcome data will be used by a reinforcing learning optimization system to learn refined computational behavior change models. With a focus on risky behaviors and an emphasis on substance use, adolescents will interact with INSPIRE to develop an experiential understanding of the dynamics and consequences of their substance use decisions. A unique feature of INSPIRE will be its ability to optimize health behavior change at both the individual and population levels. At the individual level, INSPIRE will utilize a patient behavior model to personalize its behavior change narratives for individual adolescents. It will customize interactions based on an adolescent’s goals and affective modes. At the population level, INSPIRE will utilize reinforcing learning to adapt its narrative generation system to systematically increase its ability to improve two types of outcomes: behavioral change and self-efficacy. The project will culminate with an experiment conducted with a fully implemented version of INSPIRE at outpatient clinics within the UC San Francisco Department of Pediatrics.

Research Question
How can we design theoretically grounded, personalized health behavior change systems that can consistently produce significant behavior change and automatically improve their ability to create significant behavior change?

Research Thrusts
Integrating intelligent narrative-centered learning environments, user modeling, and machine learning, the project has three major thrusts:

- **Design, develop, and iteratively refine an intelligent narrative-centered health behavior change environment for preventive adolescent health.**
- **Design, develop, and iteratively refine a machine learning-based patient behavior modeling system and behavior change optimization system.**
- **Investigate the impact of the self-adaptive personalized behavior change system on patient behavior change in a study integrating clinic-based and home-based system deployment.**

Interactive Narrative Environments
Digital games have emerged as a nearly universal source of interactive entertainment for adolescents. A survey by the Pew Research Center found that 97% of school-age teenagers between ages 12-17 play digital games.

Behavior Change & Storyworld Environment
A key challenge posed by behavior change is communicating in an engaging manner the dynamics and consequences of decision making. By leveraging intelligent narrative generation technologies with their rich media and advanced digital storytelling, INSPIRE will introduce adolescents to the issues bearing on risky behaviors through compelling interactive experiences. In contrast to linear narrative media such as text, animation, and film, INSPIRE will create rich, interactive animated narrative-centered behavior change experiences that are dynamically generated.

Adaptive Behavior Change Environment Architecture
In the course of their interactions, adolescents’ behaviors will be modeled with INSPIRE’s integrated patient behavior modeling system. Two families of models will be learned from adolescents’ interactions with INSPIRE. Adolescents’ goals will be tracked with the goal monitoring system, and their emotional states will be tracked with the affect monitoring system. Together, the goal and affect models will comprise the patient behavior model, which will be used by the behavior change environment to tailor all interactions to the needs of individual adolescents.

Technology-Centered Alcohol Prevention Programs
Literature review revealed targeted computer-based adolescent interventions focused on preventing alcohol use as well as other relevant preventive health areas (e.g., substance safety). Many programs incorporated aspects of social cognitive theory including the following components:

- Knowledge of alcohol and its effects/consequences (legal, social, psychological, and physical)
- A story format with limited interactivity
- Vicarious learning/modeling
- Goal setting
- Enhancing skills such as problem solving, resisting peer pressure, avoiding alcohol
- A focus on increasing competence or self-efficacy in avoiding alcohol use

Intelligent Virtual Agents
Intelligent Virtual Agents (IVAs) provide a rich cast of characters that adolescents interact with in the storyworld. The IVAs support adolescents with both cognitive and affective scaffolding.

Focus Groups
A series of three focus groups was conducted to gather initial input about the visual appearance, storylines, and interactive design of related digital environments. Participants were racially and ethnically diverse male and female adolescents (6-17 years of age). Focus groups lasted approximately 1 hour and participants were given a gift card in return for their time.

- Adolescents provided feedback about five related digital games with interactive narratives
- Participants reviewed concept art for the cast of characters
- Participants discussed real-world venues in which adolescents are exposed to alcohol

Current and Future Directions
- Paper prototyping of narrative-centered behavior change environment
- Prototyping user interaction and user controls for the narrative-centered behavior change environment
- Preliminary development of patient behavior models and interactive narrative optimization system
- Conducting small scale pilots of the narrative-centered behavior change environment
- Designing linkages between narrative-centered behavior change environment and UCSF electronic medical record system to support provider feedback to adolescents