PRESENTATION TYPE: Organized Paper Symposia

CATEGORY/THEME: System Science Perspectives

TITLE: Innovative Methodology for Adaptive Interventions Drawing from Engineering and Computer Science

SESSION INTRODUCTION: The goal of this symposium session is to present a series of innovative approaches for developing time-varying adaptive interventions based on ideas from engineering (dynamical systems and control theory) and computer science (reinforcement learning). The symposium supports the conference themes of systems science perspectives and innovative methods and statistics. The symposium brings together researchers from a diverse set of institutions who have actively been pursuing research in this area.

The first paper, "A Dynamical Systems Framework for Modeling Behavior Change Interventions to Prevent Excessive Gestational Weight Gain," combines a mechanistic energy balance model with a behavioral model based on a dynamic extension of the Theory of Planned Behavior. It is shown that an integrated mechanistic-behavioral simulation approach can inform many important decisions related to adaptive interventions, including how often to measure variables and how to optimally sequence intervention components.

The second paper, "Q-Learning: A Data Analysis Method for Constructing Dynamically Adaptive Interventions" presents a method drawn from computer science. The authors illustrate how Q-learning can be applied to formulate dynamically adaptive interventions and discuss the advantages of this method relative to a single regression based approach. Results are presented based on the Adaptive Interventions for Children with ADHD study (Center for Children and Families, SUNY at Buffalo, William E. Pelham as PI).

The third paper, "Robust Optimal Decision Policies for Adaptive, Time-varying Behavioral Interventions using Model Predictive Control" describes an approach from engineering control theory. Because adaptive interventions are often implemented on a population or cohort that will display significant levels of inter-individual variability, it is essential that decision policies for these interventions perform robustly for all members of a population, without demanding excessive effort in their design and implementation. This approach is illustrated on a hypothetical intervention for preventing conduct disorder based on the Fast Track program.

At the conclusion of the presentations, the discussant will make some summary statements and moderate a discussion between the presenters and the symposium attendees. It is expected that the diversity of approaches (dynamical systems, control theory, Q-learning) and applications (obesity, ADHD, conduct disorder) will be appealing to the SPR Annual Meeting participants.

1ST PAPER WITHIN ORGANIZED PAPER SYMPOSIUM

TITLE: Q-Learning: A Data Analysis Method for Constructing Dynamically Adaptive Interventions

PRESENTATION TYPE: Organized Paper Symposia Abstract

CATEGORY/THEME: System Science Perspectives

ABSTRACT BODY:
Introduction: In recent years, research on treatment and intervention development has shifted from the traditional "one size fits all" concept underlying the standard fixed intervention strategies, to developing interventions that are both dynamic (vary over time) and adaptive (utilize heterogeneity and individualization). While in the first approach the composition and dosage of the intervention are not adjusted in response to the needs, or characteristics, of individual subjects; the latter approach is based on the notion that individuals differ in their responses to treatment such that in order for a program to be effective, the intervention should vary over time in response to the needs of the individual. In this sense, researchers are becoming increasingly interested in developing dynamically adaptive interventions, namely interventions that adapt to the dynamics of the system of interest (e.g., individuals, social groups) via decision rules that recommend when and how the intervention should be tailored to fit the specific needs

of subjects.

Although the conceptual advantages of dynamically adapting interventions has long been recognized by behavioral and social scientists, these interventions have been mainly applied in areas such as medicine, public health and clinical psychology. This may be in part because data analysis methods for informing the construction of dynamically adaptive interventions are considered relatively new and complex. Accordingly, we introduce Q-learning - a novel methodology that can be used for the construction of dynamically adaptive interventions from data.

Methods: Q-learning is an analysis method drawn from computer science, with the objective to find a sequence of decision rules that when implemented will optimize the expected value of the outcome. This method uses a series of regressions to evaluate the intervention components at each stage of the intervention when the subsequent adaptive decision is matched to the subjects. Inference based on this method starts from the last decision and moves backwards in time to the initial decision.

Results: We compare the Q-learning approach, with a single regression based approach, and present results based on the Adaptive Interventions for Children with ADHD study (Center for Children and Families, SUNY at Buffalo, William E. Pelham as PI).

Conclusions: We illustrate how Q-learning can be applied to formulate dynamically adaptive interventions and discuss the advantages of this method relative to a single regression based approach.

2ND PAPER WITHIN ORGANIZED PAPER SYMPOSIUM

TITLE: A Dynamical Systems Framework for Modeling Behavior Change Interventions to Prevent Excessive Gestational Weight Gain

PRESENTATION TYPE: Organized Paper Symposia Abstract

CATEGORY/THEME: System Science Perspectives

ABSTRACT BODY:
Introduction: Preventing excessive gestational weight gain (GWG) is an important public health issue. Excessive GWG increases risk factors for pregnancy complications such as gestational diabetes, macrosomia, and birth defects. It can cause long-term weight retention by the mother and offspring following delivery, which in turn increases the risk of obesity for both mother and child. Because obesity represents a preventable cause of premature morbidity and death, developing optimized interventions that result in lasting behavior change represents a very desirable goal.

A dynamical systems framework is applied to modeling a behavioral intervention that encourages increased physical activity and healthy eating behaviors in pregnant women. The novelty of the approach described in this presentation lies in the representation of a behavioral preventive intervention as a dynamical system, the integration of the behavioral and mechanistic model descriptions, and the focus on gestational weight gain as an outcome.

Methods: The modeling framework described in this paper incorporates both physiological and psychological factors. For the physiological component, we rely on the concept of energy balance to obtain a model that describes the net effect of energy intake from food minus energy consumption (which includes physical activity). This is a challenging problem given the dependence on initial conditions of the mother prior to pregnancy, trimester-per-trimester changes due to the different stages of fetal-placental growth during the gestational period, and other characteristics. For the psychological component, a dynamical system model inspired by the Theory of Planned Behavior (TPB) is developed to predict how design variables in an intervention can impact healthy eating and physical activity over time.

Results: Simulation results are shown for the integrated model applied to a set of representative intervention participants. The dynamical systems model is shown to answer questions regarding how much to eat, what kinds of food to eat, how much physical activity to undertake, and the expected outcomes over time from changing intervention dosages, among other questions.

Conclusions: Dynamical systems modeling provides a useful framework for understanding and optimizing behavioral interventions for weight loss (in general) and gestational weight gain (in particular). By being able to test the effect of intervention components on outcomes of interest over time, an intervention scientist can use this information to optimally decide on the ordering and strength of intervention components, and better predict both the inter- and intra-individual variability that will be reflected in these interventions.

3RD PAPER WITHIN ORGANIZED PAPER SYMPOSIUM

TITLE: Robust Optimal Decision Policies for Adaptive, Time-varying Behavioral Interventions using Model Predictive Control

PRESENTATION TYPE: Organized Paper Symposia Abstract

CATEGORY/THEME: System Science Perspectives

ABSTRACT BODY:
Introduction: Adaptive interventions are receiving increasing attention as a means to address the prevention and treatment of chronic, relapsing disorders such as drug abuse. In an adaptive intervention, dosages of intervention components are assigned based on the values of tailoring variables that reflect some measure of outcome or adherence. These interventions are usually implemented on a population or cohort that may display significant levels of heterogeneity in response. Hence, it is essential that decision policies for adaptive interventions perform effectively for all members of a population, without demanding excessive effort in their design and implementation. We refer to this ability as *robustness* of the adaptive intervention.

Methods: The approach taken relies on recent work by Rivera, Pew and Collins (2007) that demonstrates the relationship between forms of adaptive time-varying interventions and feedback control systems from engineering. In this presentation, we describe the use of Model Predictive Control (MPC), a multivariable control system technology used widely in engineering applications, as the basis for robust optimal decision policies for adaptive interventions that can be meaningfully used in prevention and treatment settings. The MPC approach is shown to possess a number of advantages, among them the ability to robustly assign dosages in multi-component interventions, to recognize delays and lagged effects between intervention components and measured intervention outcomes, and to enforce constraints that reflect clinical guidelines, for example, avoiding rapid changes in intervention dosages during the course of the intervention.

Results: The usefulness of the proposed approach is shown through simulation. As a representative case study of a time-varying adaptive behavioral intervention we examine a hypothetical scenario based on an adaptive component of the *Fast Track* program (Conduct Problems Prevention Research Group, 1992) involving assigning frequency of at-home counselor visits to families with at-risk children. Simulation results confirm that the proposed scheme can efficiently assign intervention dosages and reduce outcome variability to participant families that display differing levels of response, while reducing waste of intervention resources.

Conclusions: Model Predictive Control represents an effective means for decision-making in adaptive behavioral interventions. Sensible tuning and prudent dynamic modeling are important considerations in making the best use of this methodology.