A Multiscale Paradigm Combining Individual-Based Modeling and System Dynamics to Design Policy Options for Obesity

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Outline

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Introduction

- Obesity (clearly) recognized as a problem..
  - a global epidemic (Kumanyika et. al., 2002)
  - a conundrum for public health researchers
- Simulation & complex systems analysis recognized as a solution..
  - IOM (2010) – “Simulation models can be especially useful for considering the potential impact of an array of policies that will be required to tackle the obesity problem.”
  - Huang et al (2009), Hammond (2009) – “The attributes of the obesity epidemic as socio-ecological, multi-factoral, and multi-scale demand analysis that is systems-oriented and uses a multi-level framework with a holistic perspective in order to describe the complex and dynamic nature of the forces at play.”
Motivation and Objective

• “A modeling exercise” → A multimodel paradigm to integrate a local community-scale individual-based model (IBM) with a population scale system dynamics (SD) model to analyze long term results of policy interventions.

• IBM uses virtual agents embedded in a social network to simulate: “Opinion” → ”Behavior” → “Obesity” axis:
  – spread of opinions relating to Nutrition and Physical Activity (N&PA)
  – the effects of these opinions on individual behaviors
  – resulting obesity rates

• IBM ↔ SD: Outputs of IBM used as inputs to SD

Keywords: multiscale modeling, obesity, opinion formation, spread of health behaviors, policy analysis, virtual populations.
Individual Based Model (IBM)

- **Captured Components**
  - Individual: Opinions, behaviors
  - Network: Topologies, media, interventions

- **Dynamics**
  - Psychosocial: Exchanging beliefs, ideas, and opinions, how the opinions and behaviors of others affect the opinions of the individual
  - Psychobehavioral: How those opinions affect the behavior of the individual
  - Psychophysiological: How physiological states affect opinion and behavior, e.g. addiction
IBM- Opinion Dynamics

- Opinion formation as a social process motivated earlier social network analysis, grew into a family of related techniques
- “Opinion” is a variable capturing an individual’s opinion about and attitude towards N&PA related behavior, a real value on the interval [0, 1].
  - Confidence bounds, “tolerance”: Affect people’s susceptibility to arguments that differ from their own
  - an aggregation of many underlying beliefs and opinions relating to lifestyle choices
  - individual will gradually adapt their opinion by using the average value of the opinions of those neighbors
IBM- Behavior dynamics, Policy Interventions

• Behavior of individuals in a social network:
  – employs a function for individuals to derive their behavior
  – Initiation and cessation threshold for each of behaviors, represented as opinion values
  – Initiation threshold sets the bar for the level of favorable disposition necessary to lead health consequence “level of overindulgence”
  – Hysteresis, or lockin effects

• Interventions: Advertising, health-related education, counter-marketing efforts
  – Nodes which promote an opinion value favorable to their own position
Opinion Dynamics in Action

$x_{i}(t + 1) = x_{i}(t) + \frac{1}{n} \sum_{j=1}^{n} \mu_{ij} (x_{j} - x_{i})$

$|x_{i} - x_{j}| \leq \varepsilon_{i}$

$\varepsilon$: Tolerance limit
$\mu$: Plasticity, strength of relationship

$x_{i}^{t+1} = 0.41$
Topology Illustration
Policy Intervention Example

• **Policy Intervention 1:** Elimination of soft-drinks from schools, an elimination-oriented policy in our virtual community- widens the tolerance values in the target population, opens a window of other opportunities to make inroads into otherwise habituated behaviors.

• **Policy Intervention 2:** Counter-marketing campaign: anticipated industry response, counteracts effect of 1st policy by raising opinions regarding affected products. Health Awareness Campaign: increases awareness of health effects of the eliminated product.

• **Policy Intervention 3:** Weight Loss Assistance- an increase in the cessation threshold, increasing ability of people to break out of their habits/addictions.
Preliminary Simulation Results
Effects of Competing Campaigns on Opinion and Behavior

Advertising and educational campaigns competing for the same network.

The educational campaign has the advantage in connecting to influential nodes.
Integration with a Population Scale SD Model

- The IBM characterize tendencies and trends on a community scale.
- Special emphasis is given to N&PA related behavioral habits that may be “carried over,” even if acc. opinion falls below that which would cause its initiation.
- Natural next step is to use output from IBM to analyze longer term dynamics and consequences.
System Dynamics Health Applications- 1970s to the Present

- Disease epidemiology
  - Cardiovascular, diabetes, obesity, HIV/AIDS, cervical cancer, chlamydia, dengue fever, drug-resistant infections
- Substance abuse epidemiology
  - Heroin, cocaine, tobacco
- Health care patient flows
  - Acute care, long-term care
- Health care capacity and delivery
  - Managed care, dental care, mental health care, disaster preparedness, community health programs
- Health system economics
  - Interactions of providers, payers, patients, and investors

Summary and Scope of the main simulation models on obesity

- **SD domain:**

- **Outside of SD domain:**

Homer, Milstein, Hirsh & Colleagues: 2004, 2006, 2009, 2010...

- **2004:** Modeled impact of caloric imbalance on changes in body weight and BMI of adult population in USA. Obesity is a small part of the model explorations as study mainly focuses on diabetics.

- **2006:** Entire US population, aged 0-99 years. Purpose of this study is to understand how the caloric imbalance affects the BMI of various groups in the population. Highly disaggregated, weight transformation explored.

- **2010:** Prevention Impacts Simulation Model (PRISM) explores alternative interventions to prevent risk factors that affect cardiovascular disease (CVD). Has a section on obesity, nutrition, and physical activity (N&PA).
Some Model based insights from Homer & colleagues..

- Interventions among school-aged youth and others to explore how effective new interventions would have to be to alter existing trends.

- Finding: inflection point in the growth of overweight and obesity prevalence probably occurred during the 1990s

- Finding: New interventions among school-age children—even if very effective—would likely have only a relatively small impact on the problem of adult obesity (approx. 20%)
(Why) PRISM..

- …includes the idea of “habit carryover”
- …sophisticated in terms of real-world policies affecting N&PA.
- is less granular than others in terms of age groups (3 youth and 3 adult)
- ….does not go down to the level of net caloric intake
- ..does not calculate calories per se, but goes straight from N&PA unhealthy-behavior prevalences to obesity onset rates.

simplified view of stock-flow structure
Rationale for a Multiscale Incorporation with SD Methodology

- In the architecture proposed by PRISM model, IBM results would be interpreted as:
  - affecting the excess junk food in diets among youth as a result of policy interventions
  - direct effect of decreasing the rate at which youth become obese and correspondingly increase the number of non-obese youth turning 18
  - to the extent that consumption habits are carried into adulthood, for which the consequences are delayed due higher metabolic rates in youth, the interventions would have an effect on rate of non-CVD adults becoming obese by reducing the excess junk food parameter for adults
Rationale for a Multiscale Incorporation with SD Methodology

- To serve as an illustrative example of what a multi-scale modeling process would look like, and serve as a tool to enhance our understanding for the policy intervention
- Gives both the immediate effects of specific combinations of interventions and the long term consequences for the public health profile.
- SD model can identify possible leverage points in system, to be fed into the IBM
- Considering direct effects of interventions on individuals and second order effects on social networks, IBM can identify most effective policy
- The two models are complementary in their approach
(My) Questions..

- Which aspects (if any) of this research proposal is promising to investigate further?
- Comments on appropriateness of scope, scale, resolution?
- Previous exemplary work?
- A better name for the title?
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Backup slides..
Obesity Trends* Among U.S. Adults
(*BMI ≥ 30, or ~ 30 lbs overweight for 5’4” woman)

1991

1995

2000

No Data  <10%  10%-14%  15-19%  20%  Red

Effects of Competing Campaigns on Opinion and Behavior

Opinion

Education

Competition

Smoking Behavior

Education

Competition