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A Multi-scale Paradigm to Design Policy Options for Obesity Prevention

Exploring the Integration of Individual-Based Modeling and System Dynamics

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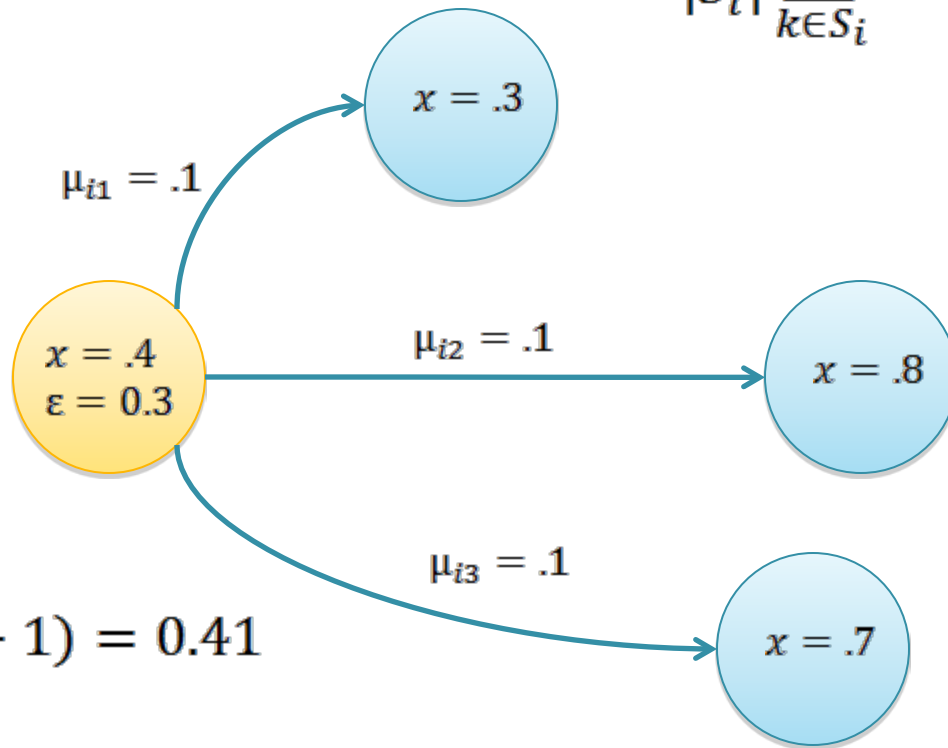
- A multi-model paradigm to integrate a local community-scale individual-based model (**IBM**) with a population scale system dynamics (**SD**) model to analyze long term results of policy interventions
- IBM uses social network opinion dynamics model to simulate:
 - Spread of opinions relating to Nutrition and Physical Activity (**N&PA**)
 - The effects of these opinions on individual behaviors
 - Policy interventions with network level effects
 - IBM ↔ SD: Outputs of IBM used as inputs to SD, SD identifies leverage points for investigation by IBM
- SD model uses stock and flow paradigm to analyze impacts of behaviors on public health metrics at population scale across decades

- **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

- 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 obesogenic behaviors on the interval $[0, 1]$
 - Confidence bounds, “tolerance”: Affect people's susceptibility to opinions that differ from their own
 - An aggregation of many underlying beliefs and opinions relating to lifestyle choices
 - Individuals will gradually adapt their opinion by using the average value of the opinions of neighbors

$$\{k \in S_i: |x_i(t) - x_k(t)| \leq \varepsilon_i\}$$

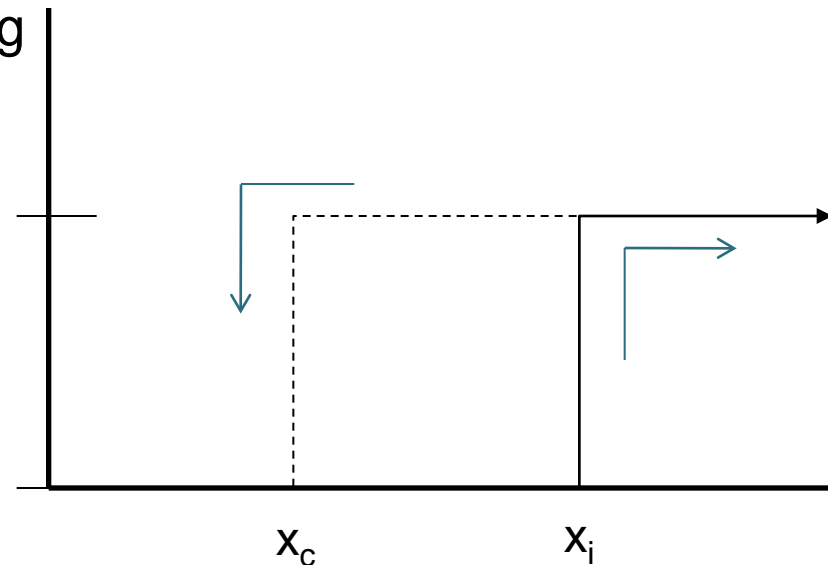
$$x_i(t + 1) = x_i(t) + \frac{1}{|S_i|} \sum_{k \in S_i} \mu_{ik} [x_k(t) - x_i(t)]$$



S_i : Set of out-degree neighbors
 ε : Tolerance
 μ : Plasticity

- Opinion-Behavioral mapping

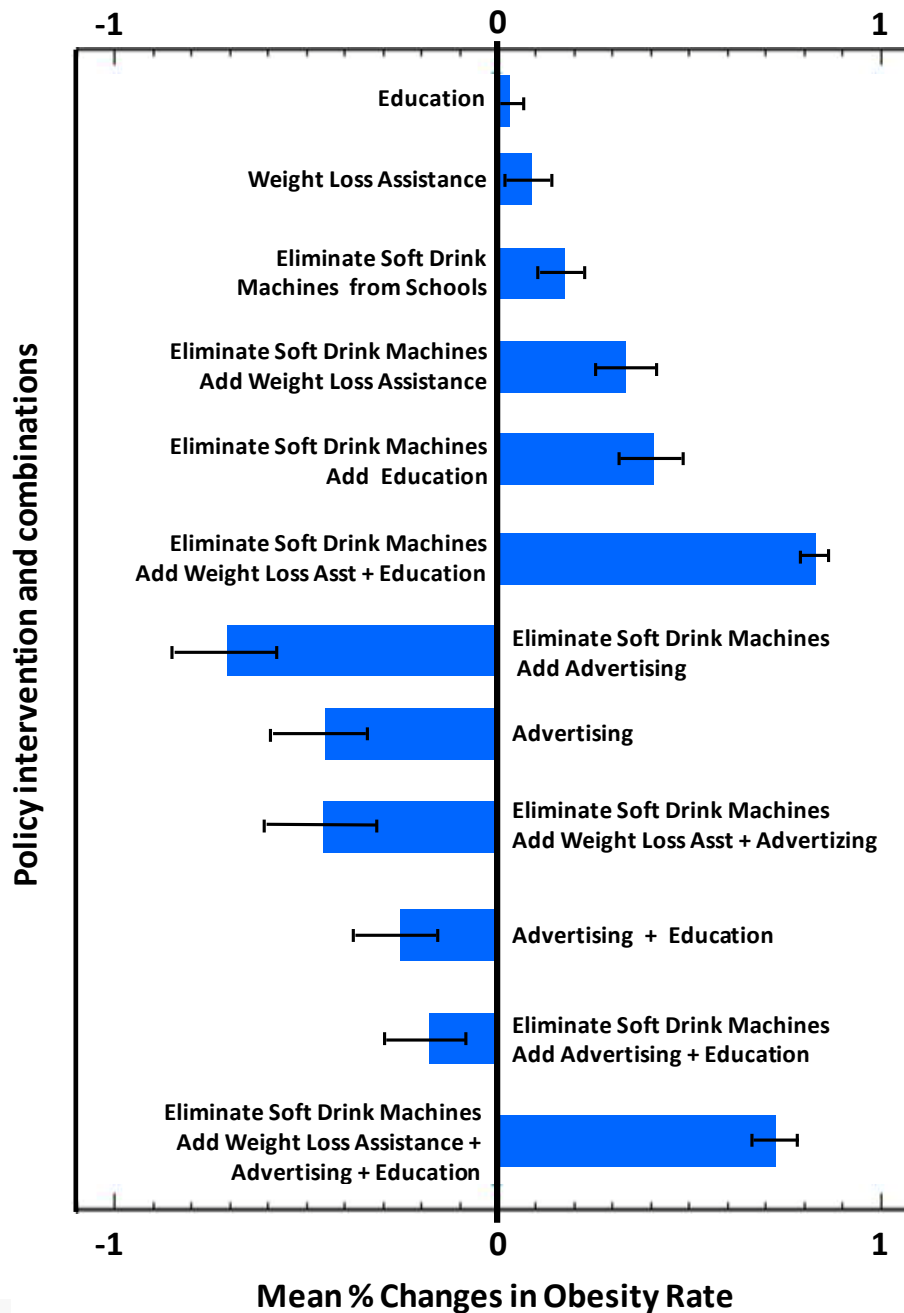
- Initiation threshold x_i
- Cessation threshold x_c



- Interventions

- Structured weight loss assistance programs
- Educational and counter-marketing campaigns
- Elimination of product availability – **intervention as perturbation**

Preliminary Simulation Results



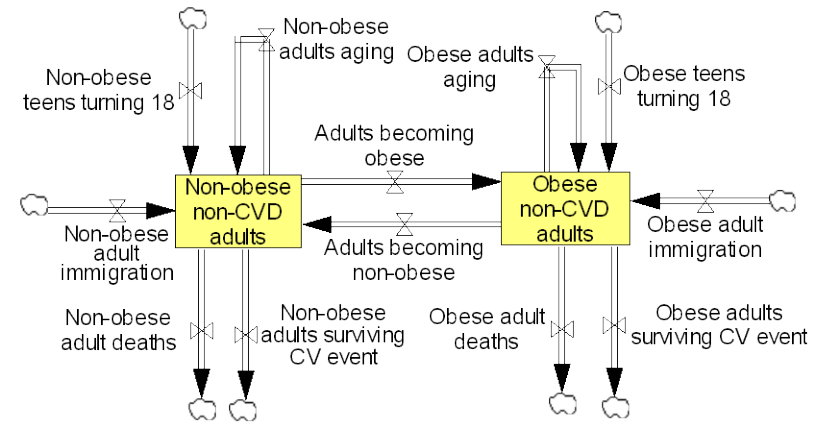
Mean % Reduction in
Obesogenic
Behaviors by
Intervention

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 opinion falls below that which would cause its initiation
- Health behavior tracking studies point to this type of N&PA habit carryover, or “hysteresis “ effect (on the order of 30%)
- Natural next step is to use output from IBM to analyze longer term dynamics and consequences of policies
- IBM model presented here can speak in terms of the relative risk for obesity based on N&PA related health behaviors

Summary and Scope of Main (SD) Studies on Body Weight & Obesity

- Abdel-Hamid (2002, 2003, 2009)
- Homer (2003)
- Flatt (2004, 2011)
- Nuhoğlu and Barlas (2009, 2010)
- Karanfil, Osgood and Finegood (2009)
- Homer, Milstein, Hirsh, Dietz, et.al... (2004a,b, 2006, 2010)
- Dangerfield and Abidin (2010)
- Rahmandad and Sabounchi (2010, 2011)
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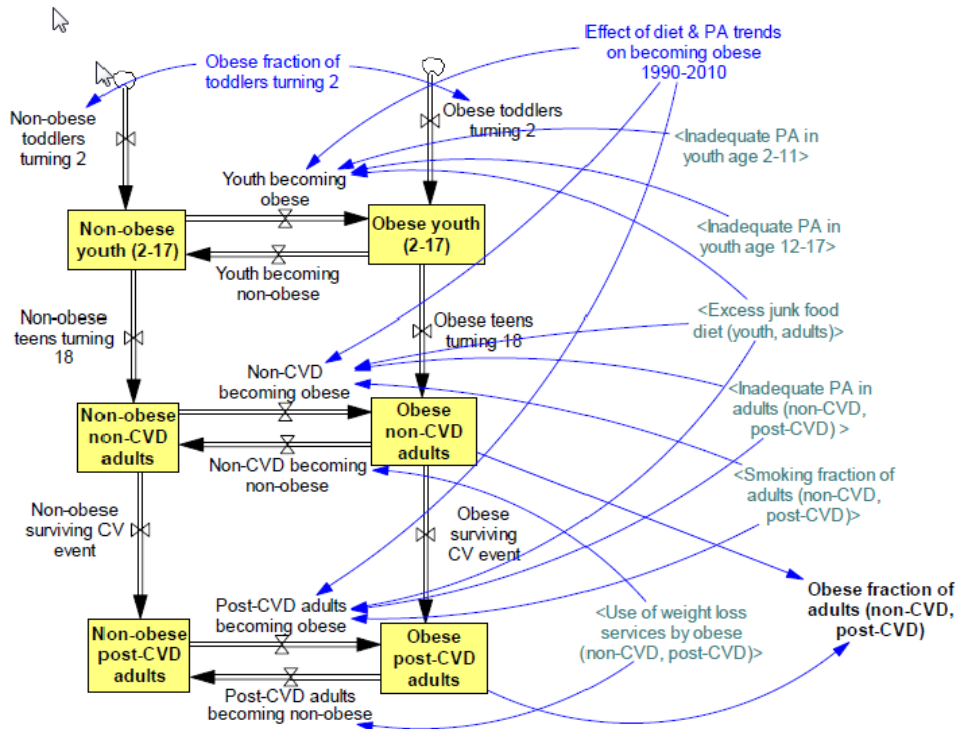
Homer J, Milstein B, Dietz W, et al. Obesity population dynamics: exploring historical growth and plausible futures in the U.S. *Proc. 24th Int'l System Dynamics Conference*; Nijmegen, The Netherlands; July 2006.

SD models focusing on obesity at a population level:

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

- **2004:**
 - Modeled impact of caloric imbalance on changes in BW and BMI of adult population in US.
 - Obesity a small part of model explorations, study mainly focuses on diabetics.
- **2006:**
 - Entire US population, aged 0-99 years. Purpose of this study to understand how the caloric imbalance affects BMI of various groups.
 - Highly disaggregated, weight transformation explored using ageing chain.
- **2010:**
 - Prevention Impacts Simulation Model (PRISM) explores alternative interventions to prevent risk factors affecting CVD.
 - Has a section on obesity, nutrition, and physical activity (N&PA).

(Why) build on Prevention Impacts Simulation Model (PRISM)?



Simplified view of stock-flow structure

- ...embraces the idea of “habit carryover”
- ...less granular in terms of age groups (3 youth and 3 adult), and BMI categories
- ...sophisticated in terms of real-world policies affecting N&PA.
- ...does not go down to the level of net caloric intake
- ...but goes straight from N&PA unhealthy-behavior prevalence's to obesity onset rates.

- In the architecture proposed by PRISM model, IBM results would be interpreted (for example) 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, the interventions would have an effect on rate of non-CVD adults becoming obese by reducing the “excess junk food” parameter for adults

- Aim to build on an SD model :
 - To determine long term policy effects analyzed using the IBM opinion dynamics network model.
 - 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
 - To identify possible leverage points in the system, which can be fed into the IBM for further investigation, e.g. best timing for intervention.

- Extended information exchange btw IBM & suggested SD model
 - Multi-scale analysis, combinations of policy interventions enable us to evaluate:
 - Immediate effects of specific combinations of interventions
 - Long term consequences for the public health profile
 - The two models (paradigms) are complementary in their approach:
 - Considering large-scale, population level effects, the SD model can identify important leverage points for intervention
 - Considering direct effects of interventions on individuals and second order effects on social networks, IBM can help to identify more effective policy

- Jack Homer
- Aldo Zagonel
- John D. Sterman
- PJ Lamberson
- 22nd MIT-UAlbany-WPI System Dynamics Ph.D. Colloquium participants



Thank you!

Questions, Comments..

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BACKUP SLIDES

- Introduction
- Individual based model (IBM)
 - Opinion dynamics with behavioral mapping
 - Policy interventions
- Integration with a Population Scale System Dynamics (SD) Model
 - Existing SD Models on Obesity
 - PRISM (Prevention Impacts Simulation Model)
- Multi-level, multi-scale
 - Different theoretical frameworks and analytical tools
 - Different aspects of same problem

“Resistance- Hysteresis- Lock-in” effects in Obesity

- Once obesity establishes itself, both habituated behaviors and physiological processes resist weight loss (Leibel, 2008):
- Resistance including cultural norms and behaviors:
 - Simple computational experiment, Hammond (2008) demonstrates changing norms of body weight could propagate obesity
 - Cultural norms shift such as parents or caregivers do not recognize child obesity as readily therefore “normalizing” obesity
 - Increased screen time cause children to get less sleep (Owens et al.) causing hormonal changes that make them more likely to get less physically active, eat more, and watch more TV (Taveras et al, 2006, 2008)
 - Resistance or “lock-in” at physiological level (Parker 2010, Monteiro and Victora, 2005, Singhal et al, 2003)
 - Childhood obesity studies:
 - Obesity is more persistent than other common chronic conditions (VanCleave and Gortmaker, 2010). By age of 5 years, aspects of obesity appear resistant to change (Gardner, Hosking and Metcalf, 2009)

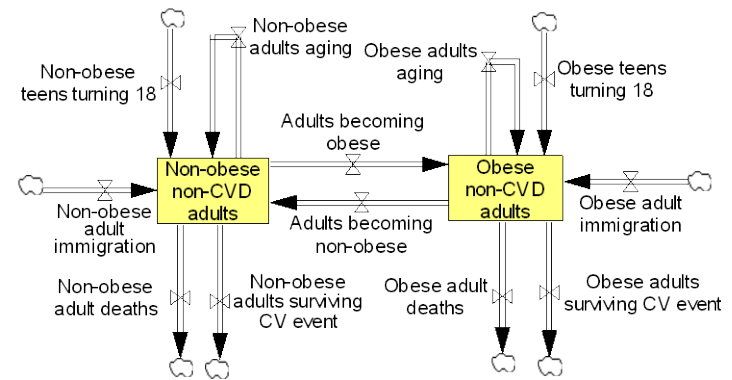
IBM- Behavior dynamics, Policy Interventions

- 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 lock-in effects
- Interventions: Advertising, health-related education, counter-marketing efforts
 - Nodes which promote an opinion value favorable to their own position

- Diet and health-related behaviors behave similarly to tobacco-related behaviors, with some differences, e.g:
- Tobacco related behavior is smoking only, which is discrete, whereas:
 - Obesity related behavior(s) are more complex, including both food intake behavior, and physical activity expenditure. (e.g. one can quit smoking, but cannot quit eating)
- Secondary (non)smokers' rights was helpful in the success of the campaigns against tobacco, and to protect the health of the population, whereas:
 - In case of obesity, even if food intake behavior is shown to affect people around you, it cannot be treated same way...

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 (apprx. 20%)



- Disease prevention programs face tough challenges and questions
 - Pressure for *results* on disease burden, not just behavioral change
 - Diabetes Prevention Program indicates primary prevention is possible, but may be difficult and costly
 - What is achievable on a population level?
 - How should funds be allocated?
- Standard epidemiological models rarely address such policy questions
 - SD is appropriate for quantitative analysis of “chronic” problems