The Use of Agent-Based Modeling for Evaluating Community-Level Obesity Interventions

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Outline

• Applying systems science
  – What is systems science?
  – Why is it relevant (to obesity research)?
  – What can systems science do?
  – Agent-Based Modeling

• Application of ABM for obesity/intervention research: ECOSyS Study
What is Systems Science?

• Systems science provides methods to address complex systems. (Agent-based modeling is one such method)

• A complex system is “one whose properties are not fully explained by an understanding of its component parts” (Gallagher and Appeneller, 1999)

• “the whole is more than the sum of its parts because of the interactions between the parts” (Bonabeau E, PNAS, 2002)
Why is systems science relevant to obesity research?
Obesity: A Complex System

- Multiple factors
- Dynamic interactions
- Feedback loops

http://www.shifttn.com/obesity/Full-Map.html
The Complexity of Obesity Research

Some factors that play a role in obesity development

- Food Consumption
- Chronic stress
- Family Environment
- Childcare/Schools
- Food Assistance Programs
- Food System
- Zoning
- Physical Activity
- Food Marketing (and regulations)
- Transportation
- Agricultural Policy
- Health Care Providers
- Retail Food Environment
- Neighborhood Walkability
- Work Places
- Parks & Recreational Facilities
The Socio-ecological Framework

Public Policy

Community and Neighborhood

Organizational

Interpersonal

Individual

Childcare/Schools
Workplaces
Health-care

Family Environment
Friends

Food Behaviors
Physical Activity
Chronic stress

Food system
Agricultural policy
Food assistance programs
Food marketing
Zoning

Walkability
Parks & recreational facilities
Retail food environment
Transportation
Complex Systems have the following properties...

- Large number of heterogeneous elements
- Elements interact
- Produce an emergent effect which differs from the effects of the individual elements
- Effect persists over time and adapts as circumstances change (dynamic behavior)
Implications for research

**Traditional Statistical Modeling**

(not adequate for studying complex systems)

- Correlation-based
- Linearity, Normality, Homogeneity, Independence
- Inherently reductionist
- Interactions between two variables at a time

**Computational Modeling**

- Allows for feedback loops and scale-free distributions
- Interactions among individuals and their environment
Implications for research

Computational modeling ...

.. *does NOT replace* statistical modeling

.. *adds to* existing analytic tools
What Systems Science Can Do

1. Considers the big picture and context of complex problems

2. Examines dynamic interrelationships of variables at multiple levels of analysis (e.g., from cells to society) simultaneously:
   - causal feedback processes
   - impact on the behavior of the system as a whole over time

Source: NIH Office of Behavioral and Social Sciences Research.  
http://obssr.od.nih.gov/scientific_areas/methodology/systems_science/
What Systems Science Can Do

3. Simulates the impact of policy decisions and therefore help decide on the most effective way to address a problem

4. Helps understand why programs and interventions do not have their intended effects

Source: NIH Office of Behavioral and Social Sciences Research.
http://obssr.od.nih.gov/scientific_areas/methodology/systems_science/
Some Systems Science Approaches

- Network Analysis
- Systems Dynamics
- Discrete event simulation
- Dynamic microsimulation modeling
- Agent-Based Modeling
Agent-Based Modeling

- Uses computer simulation
- Investigates complex systems from the ground up
- Within the system, there are “agents” that behave according to their individual properties, environment
- Considers interaction of behaviors \( \rightarrow \) emergent properties of the overall system
- Based on rules and characteristics about agents and their behaviors
## Agent-Based Modeling: Core features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
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<tbody>
<tr>
<td>Heterogeneous</td>
<td>Agents allowed to differ from one another</td>
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<tr>
<td>Spatial</td>
<td>Agents located in a defined space</td>
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<tr>
<td>Bounded rationality</td>
<td>Agents assumed to have imperfect knowledge</td>
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<td>Interactive</td>
<td>Agents interact locally with each other and with the environment</td>
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<tr>
<td>Dynamic</td>
<td>Recursive models, can change non-linearly, with feedback</td>
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An Example

1) “Recreate” the present

2) Make projections

% obese

--- Reality
--- Our new model projections
--- Current model projections

INTERVENTION

Time
Impact of multiple interventions in diverse settings

Virtual population

Computer modeling

Intervention A

Intervention B

No intervention
Evaluating Community Interventions

• Use of the “quasi-experiment”

• Challenges
  – Dynamic situation
  – Unable to “control” what a community does
  – Uses statistical modeling:
    High “precision” but not realistic and poor fit
Statistical models vs. Agent-based models

Statistical models
- High precision and moderate generalizability
- Low realism and fit

Agent-based models
- Moderate generalizability, fit and precision
- High realism

Statistical models not adequate for evaluating community interventions


The Early Childhood Obesity Systems Science Study (ECOSyS)

(Sep 2013-Aug 2018)

Funded by the Eunice Kennedy Shriver National Institute of Child Health and Human Development, NIH

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Los Angeles County: Multiple efforts to address childhood obesity in the same community at multiple levels since the mid-2000s.
Examples of Interventions

Since 2005, considerable effort to address childhood obesity in LA County and California. For example:

- **State/Regional/Local:**
  - HEAC, BHC (The California Endowment)
  - Community Benefits Program (Kaiser Permanente)
  - School wellness programs (California Project LEAN)
  - School food policies (state, local)
  - First 5 LA’s programs to promote breastfeeding and healthy eating among preschool-aged children
  - Community Transformation Grants (CDC)

- **National:**
  - New WIC food package mandate (2009)
Impact on Early Childhood Obesity

Some questions:

What intervention strategies are the most effective?
Are there synergistic effects?
In what context is an intervention strategy most likely to be effective?
Study Aims

1. Identify obesity-related interventions and policies in LA County since 2003
2. Develop and validate community-level “intervention dose index”
3. Estimate obesity trends in preschool-aged WIC participants
4. Evaluate relationships between preschool-aged obesity trends and community-level intervention dose
   • Use multilevel modeling, causal inference methods
5. Apply agent-based modeling to explore dynamic interactions, feedback mechanisms, and efficacy of intervention strategies
Data Sources (2002-2013)

Child Obesity Rates
- Data Mining Project (PHFE WIC)

LA County Community Interventions & Policies
- LACDPH data
- Key informant interviews
- Index of community intervention dose
  - Workgroup 1: Constructs & Domains
  - Workgroup 2: Review variables Data Collection

LA County Neighborhoods
- U.S. Census
- Food store environment (Dun & Bradstreet)
- Local planning department
- Local police department
Development of Community Intervention Dose

Identify LA County Community Interventions & Policies (2003-2013)

Two workgroups

• WG1: Identify relevant domains & constructs
  – Physical resources, social resources, capacity development, programs and policies, context

• WG2: Operationalize constructs & develop data collection instruments/protocols
Analysis

- Use multi-level modeling and causal inference methods to evaluate relationships between various intervention strategies and early childhood obesity risk.

- Build ABMs to explore dynamic interactions and feedback mechanisms, and predict early childhood obesity rates under various scenarios involving different intervention strategies.
ABM:
An Example
Some References


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“Today’s knowledge about something is not necessarily the same tomorrow. Knowledge is changed to the extent that reality also moves and changes. Then theory also does the same. It’s not something stabilized, immobilized.”

Horton & Freire, 1990

Thank you!