Systems Science: Past, Present, and Future

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Complex Systems, Health Disparities and Population Health: Building Bridges

Bethesda, MD
February 25, 2014
Historical Perspective
OBSSR in the NIH Context

NIH budget: ~ $30.9B

27 Institutes & Centers (ICs):
- National Institute on Aging (NIA)
- National Institute on Deafness and Other Communication Disorders (NIDCD)
- National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS)
- National Institute of Child Health and Human Development (NICHD)
- National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)
- National Cancer Institute (NCI)
- National Heart, Lung, and Blood Institute (NHLBI)
- National Institute on Drug Abuse (NIDA)
- National Institute on Aging (NIA)
- National Institute on Alcohol Abuse and Alcoholism (NIAAA)
- National Institute of Environmental Health Sciences (NIEHS)
- National Institute of Mental Health (NIMH)
- National Institute of Neurological Disorders and Stroke (NINDS)
- National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)
- National Library of Medicine (NLM)
- National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)
- National Institute of Mental Health (NIMH)
- National Institute on Drug Abuse (NIDA)
- National Institute on Aging (NIA)
- National Institute of Dental and Craniofacial Research (NIDCR)
- National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS)
- National Institute of Neurological Disorders and Stroke (NINDS)
- National Institute of Mental Health (NIMH)
- National Institute of Neurological Disorders and Stroke (NINDS)
- National Institute of Mental Health (NIMH)
- National Institute of Aging (NIA)
- National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS)
- National Institute of Neurological Disorders and Stroke (NINDS)
- National Institute of Mental Health (NIMH)

Office of the Director

Division of Program Coordination, Planning, & Strategic Initiatives

Office of Behavioral and Social Science Research

NIH budget: ~ $25.7 M

http://www.nih.gov/about/organization.htm
What does OBSSR do?

Develops **funding initiatives** for research

Provides opportunities for **training and career development** for behavioral and social scientists

Organizes **conferences, workshops, and lectures**
Current Directions for OBSSR

The next generation of methods and measures
- mHealth
- Systems Science
- Big Data
- Measure Harmonization

Enhancing health and lengthening life in populations
- Population Science
- Dissemination and Implementation Science
- Adherence
- Multiple Chronic Conditions
- Shared Medical Decision Making

Training the next generation of research investigators
- PhD Curricula
- Medical School Reform
- Short Courses
“Systems science” refers to a family of methodologies enable the study of complex problems represent the complexities of a problem in a tractable form by simplifying it while retaining the salient characteristics address the “big picture” of a complex problem as well as the components that make up the system complement traditional linear, reductionist methods

Modeling and simulation characterize much if not most of the systems science methodologies
Health problems are complex, especially in context

We need to employ complex methods to match
are becoming aware
BSSR investigators not aware of these methods
are seeking training
BSSR investigators not trained in these methods

We want to aid investigators in using systems science methods to address important public health problems
Historical Perspective: SS in context

*Cancer Intervention and Surveillance Modeling Network* (CISNET) NCI – Rocky Feuer

*Models of Infectious Disease Agents Study* (MIDAS) NIGMS – Irene Eckstrand

*Interagency Modeling and Analysis Group* – (IMAG) NIBIB, Grace Peng

*Initiative on the Study and Implementation of Systems* (ISIS) NCI - Scott Leischow

*Prevention Impacts Simulation Model* (PRISM) CDC - Bobby Milstein, Diane Orenstein

March 2006, special issue of American Journal of Public Health

University of Michigan Complex Systems conference 2007
The spread of obesity across the social network

Tobacco, Happiness, Cooperative behavior…
PRESENT

2007-2013
OBSSR – investments in Systems Science

Increase awareness of the methods
– 2007 Symposia on Systems Science and Health – a primer

Establish communication tool to create cohesion

Create opportunities for learning and cross-fertilization
– Institute on Systems Science and Health – weeklong training and cross-disciplinary cohesion
– Conferences – SBP08-SBP14

Develop Funding Opportunities
– PAR-08-224 Using Systems Science to Understand and Improve Population Health (R21)
– PAR-10-10-145/146 Social Network Analysis and Health (R01, R21)
– PAR-11-314/315 Systems Science and Health in the Behavioral and Social Science (R01, R21)

See Mabry and Kaplan, Health Education and Behavior, 2013
National Collaborative on Childhood Obesity Research (NCCOR)

NCCOR – est 2008

Four funders, working together to coordinate and leverage investments in obesity research

Members: NIH, CDC, USDA, Robert Wood Johnson Foundation

Envision est 2009 – (forerunner was COMNet 2007-2009)

Part of NCCOR, led by OBSSR and NICHD

11 teams developing statistical and computational models related to obesity policy, including:

- Agent Based Models
- Social Network Analysis
- Microsimulation
- System Dynamics Models

www.nccor.org/envision
Set out to determine whether 1) social influence, 2) homophily (selection of friends who are similar) was responsible for the observation that similar-weight people are clustered within social networks.

A Stochastic Actor Based Model was used.

Some selection of friends of similar weight was found. Selection of friends based on screen time was not found. Selection of friends based on physical activity was mixed.

Friends influence on physical activity, screen time and eating was also found.

Agent-based Modeling:

A Model of Food Reward Learning with Dynamic Reward Exposure

Ross A. Hammond¹, Joseph T. Ornstein¹, Lesley Fellows², Laurette Dube³, Robert Levitan⁴, Alain Dagher²

¹ Center on Social Dynamics and Policy, The Brookings Institution, Washington DC, USA
² Montreal Neurological Institute and Hospital, McGill University, Montreal, Canada
³ Desautels Faculty of Management, McGill University, Montreal, Canada
⁴ Department of Psychiatry, University of Toronto, Toronto, Canada

Grant #1R01HD08023; PO: Layla Esposito, NICHD

Exploring interactions between modules

Hammond et al., long term goals

$P = \left( \frac{10.0 m}{1 \text{ kg}} + \frac{6.25 k}{1 \text{ cm}} - \frac{5.0 a}{1 \text{ year}} + s \right) \text{ kcal/day}$
Population level intervention – unintended consequences

Source: Adapted from Rose. (p74)
Note: Arrows depict the shifting of the curve after a population-level approach. Circles indicate where the variation in risk is most flagrant.

FIGURE 2—Illustration of a potential increase in the variation of risk following a population-approach intervention.

Population level interventions

It appears from empirical observations that individuals from vulnerable populations are the least able to positively respond to population-approach interventions. This “inverse care law” states that those with the most resources at hand to adapt to new situations will be the first to derive maximum benefits from population-approach interventions.

Variability in Responses to Diet and Food

A top priority for future nutrition research is the need to better understand variability in metabolic responses to diet and food. All individuals have varying responses to diet and food components and their impact on overall health. Findings in variability will lead to advances in personalized nutrition and will better inform public health and food policy, such as Dietary Reference Intakes for nutrients and recommendations for bioactives. Research in the following areas is necessary to determine the origins and components of variability, and to explain similar responses to diet and food components by subpopulations, such as ethnic and racial minorities:

Omics
Microbiome
Imprinting
Biological networks
Tissue specificity and temporality

http://asn-cdn-remembers.s3.amazonaws.com/0f6ef3d6837726b125f5c47db1939872.pdf
How might systems science methods help?

Bayesian Quantile Regression and mediation analysis (Berhane et al) could help identify whether vulnerable populations are helped or hurt by population level obesity interventions.

Dynamic Chain Markov Models (Ip et al) could examine vulnerability as constructs (e.g., SES, education, poverty, housing) that lie under the obesity superstate.

SD (Rahmandad et al; Homer et al) could be used to examine the effect of obesity policy on vulnerable subpopulations.

ABM (Hammond et al) could generate new theories on how risk accumulates by imbuing agents with realistic vulnerabilities (e.g., where they live, education, employment, discrimination).
Using System Dynamics Modeling to Inform Community Level Policy Decisions:

An Example Using PRISM
The PRevention Impacts Simulation Model (PRISM)

PRISM is led by CDC with support from NHLBI and OBSSR
What is the optimum allocation of resources to simultaneously:

- improve population health?
- eliminate or reduce health disparity?
- reduce costs of preventable CVD?

While recognizing the constraints and opportunities in particular places & settings?

And, over what time frame?
Strategic question guiding the development of PRISM

PRISM is a comprehensive, evidence-based system dynamics simulator

Built to understand how policies can be combined to reduce cardiovascular disease and other chronic disease-related mortality and costs

Integrates best evidence available into a testable framework for prospective planning and evaluation

34 possible interventions affect environmental factors and prevention-oriented policies

PRISM Online tool will be available to PH officials

[CDC Logo]
PRISM Application in Community Initiatives

Communities Putting Prevention to Work (CPPW)
- Utility for prospective evaluation of primary prevention interventions in all ~50 communities
- One of several evaluation initiatives
- TA for motivated communities

Community Transformation Grants (CTG)
- Technical assistance for interested and ready communities
- Using PRISM in any way to support strategic planning, action, and/or evaluation.


Annual ISSH Training – archives available

ISSH Co-Directors: Drs. Patricia Mabry and Bobby Milstein

http://obssr.od.nih.gov/training_and_education/issh/index.html
Short Courses on Innovative Methodologies in the Behavioral and Social Sciences (R25)

RFA-OD-13-009

This funding announcements encourages research projects that propose to:

- to develop, implement, evaluate and disseminate short courses in innovative methods for behavioral and social sciences research (BSSR).

Methodological domains include but are not limited to:

- experimental design
- data collection
- measurement
- data analysis
- data visualization.

- Single receipt date: November 14, 2013
- Letter of intent: October 14, 2013
- Be sure to view “related announcements” and FAQs

Encourage basic and applied research projects that propose to:

- utilize systems science methodologies
- relevant to human behavioral and social sciences and health.

This FOA covers a broader scope of topics to be addressed with systems science methodologies

- including methodological development,
- Must have a human behavioral and/or social science focus, and feature systems science methodologies.

- Expires Sept 2014; last receipt date June 2014. We do plan to reissue.
- **NIDA NOT PARTICIPATING**
- NCI – R01 only


Predictive Multiscale Models for Biomedical, Biological, Behavioral, Environmental and Clinical Research (Interagency U01)

PAR-11-203

This funding announcements encourages research projects that propose to:
- develop multiscale models to accelerate biological, biomedical, behavioral, environmental and clinical research.
- Remaining application receipt dates: 09/27/13, 01/31/14
- Expires: February 2014 – will be reissued
- Cooperative Agreement; work with NIH partners


Modeling Social Behavior (R01)
NIGMS PA-13-374
Why Behavioral And Environmental Interventions Are Needed To Improve Health At Lower Cost

Health Affairs, 2011

Paper of the year
Guest Editors:
Patricia Mabry and Bobby Milstein
Future of Systems Science

Big Data
mHealth
D&I – tobacco, obesity, workforce
Training
VVUQ
You!
What is Big Data?

Big Data usually includes data sets with **sizes** beyond the ability of commonly used software tools to capture, curate, manage, and process the data within a tolerable elapsed time.

Complex Data - High on 3 (or 4) dimensions (Laney):

- **Volume** (amount of data)
- **Velocity** (speed of data in and out)
- **Variety** (range of data types and sources)
- **Veracity** (new; data integrity)

Biomedical Big Data primarily emanate from three sources:

1) a few groups that produce very large amounts of data, usually as part of projects specifically funded to produce important resources for the research community;
2) individual investigators who produce large datasets for their own projects, which might be broadly useful to the research community; and
3) an even greater number of investigators who each produce small datasets whose value can be amplified by aggregating or integrating them with other data.
What is Big Data?

4) Ubiquitous data; e.g., social media, search histories, and cell phone data.
What is Big Data?

Big Data types may include:
- imaging
- phenotypic
- molecular (including –omics)
- clinical
- behavioral
- environmental

and many other types of biological and biomedical data.
How it all fits together...
NIH addresses ‘Big Data’

Associate Director for Data Science (ADDS)

Dr. Phil Bourne

Scientific Data Council (SDC)

Big Data to Knowledge (BD2K) Initiative
Big Data to Knowledge (BD2K)

- Major trans-NIH initiative addressing an NIH imperative and key roadblock
- Overarching goal:

By the end of this decade, enable a quantum leap in the ability of the biomedical research enterprise to maximize the value of the growing volume and complexity of biomedical data
BD2K: Four Programmatic Areas

1. Facilitating Broad Use of Biomedical Big Data

2. Developing and Disseminating Analysis Methods and Software for Biomedical Big Data

3. Enhancing Training for Biomedical Big Data

4. Establishing Centers of Excellence for Biomedical Big Data
Big Data = Big money!

Big Data to Knowledge - $27M in FY14

www.bd2k.nih.gov


Centers of Excellence for Big Data Computing in the Biomedical Sciences (U54) - $24M per year

OBSSR is participating
Other Big Data

NIST Data Science Symposium March 4-5, 2014

NSF 12-99
Core Techniques and Technologies for Advancing Big Data Science & Engineering (BIGDATA)

The phrase "big data" in this solicitation refers to large, diverse, complex, longitudinal, and/or distributed data sets generated from instruments, sensors, Internet transactions, email, video, click streams, and/or all other digital sources available today and in the future.
How Big Data Can Be Used

**YouTube:** Participatory Sensing

**YouTube:** Big Data Small N

Deborah Estrin TedMed
What is mHealth?

mHealth refers to mobile technologies as they are applied to understand and improve health.

At NIH we emphasize the need for research in this area
Billions of mobile devices + Billions of sensors = Billions using social networks

Unprecedented opportunities for population-level sensing

mHealth

And…
understanding and intervening at the individual level
Improving Dietary Assessment Methods Using the Cell Phone and Digital Imaging
PI: Carol Boushey, Purdue University

Uses a mobile phone as a food record
Image processing to identify food in real time
Supplement with search list
Calculates volume to estimate portion size
Calculates nutrient and food intake
Problem: Adherence to chronic disease medications is poor. In resource-poor settings, getting people medication is only part of the solution.

Solution: Wireless medication canisters that signal medication timing, transmit adherence data and allow resources to target the non-compliant
Detect Bouts of Activity

Research Question: Are small, low quality neighborhood parks better than large regional parks for continuous minutes of MVPA?

How long do participants engage in periods of intense physical activity?

Where are participants getting sustained activity?

(from Kevin Patrick, UCSD)
Microsoft Research Prototype… now the Vicon Revue

- Contains a camera, accelerometer, light color/intensity, temperature, infrared motion detector, compass
- Takes about 5,500 photos per day
- Pending: incorporation of GPS and Bluetooth
Participant’s evening commute with measured CO levels and traffic conditions
How mHealth Can Be Used

Models of individual behavior – prediction and regrounding models in real-time

Other search terms: Intensive longitudinal data, ecological momentary assessment

Challenges: data privacy and security, data integration
Join the mHealth listserv to find out about upcoming training. Contact Wendy Nilsen, OBSSR.
Dissemination and implementation research

- examine a variety of policy scenarios (e.g., PRISM)
- Goal setting – what would it take? (e.g., Levy et al)
- Identify and prioritize research needs

AJPH Theme Issue
Working Title:

The Application of Systems Science Methodologies to Address Policy-Relevant Obesity Research Questions

Guest Editors: Patty Mabry and Regina Bures

July 2014

Sponsored by Envision, a network of research teams modeling obesity

http://www.nccor.org/envision
RFA-GM-14-011 *Modeling the Scientific Workforce* (R01)

- NIGMS is the lead
- OBSSR participating
- Reissue
- Applications under review
- OBSSR aims to understand the BSSR workforce and how various NIH policy changes would affect it.
Future of systems science

Identifying data for primary data collection

Need for more longitudinal data on social networks

Verification and validation issues

Need to develop some guidance for good practices for model building, model reporting, transparency.

This will aid authors, grant applicants, publication reviewers and grant reviewers.

Will facilitate communication and understanding of behavior modeling and simulation studies.

Health Disparities areas ripe for SS:

- Intergenerational transmission of disadvantage (see Osgood diabetes)
- Geographical aspects of health disparities
- Gene x Environment interactions
- Decision tools for vulnerable communities

Conclusion
What can you do for systems science?

- Read the resources
- Take training
- Serve on review committee – submit your CV
- Apply for funding – application pressure and learning experience
- Feds – include systems science language in FOAs
- Take the time to find a collaborator
- Join the listserv to stay informed
- Be an evangelist
NIH BSSR-Systems Science Listserv

contact Patty Mabry to join: mabryp@od.nih.gov

2007 Symposium Series on Systems Science and Health

a primer for beginners; comes with listserv
Must read for systems science

A readable, short paperback with key systems thinking issues explained.


A bargain at $12.58 (new)

"Must read" for systems science


Explains why our intuition leads us to act in ways that create unintended consequences.

Social Computing, Behavioral-Cultural Modeling, and Prediction (SBP)

Brings together computer scientists and engineers with topic area experts, including but not limited to health

Travel scholarships for students available

April 2-4, 2014 in Washington, DC

See conference website: http://sbp-conference.org/
BD2K contact for OBSSR

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The future of systems science depends on you! Insert your face here!
Contact Information

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Systems Science: Past
Systems Science: Present
A range of methods including (but not limited to):

- Agent-based modeling,
- Microsimulation,
- System Dynamics Modeling,
- Network Analysis – including social network analysis
- Discrete Event Simulation,
- Markov Modeling,
- Many operations research and engineering methods,

and a variety of other modeling and simulation approaches.
Systems Science Methods are Motivated by Complexity in Behavioral & Social Science Data

- Temporal Properties (on multiple scales)
- Spatial Properties
- Network Structures
- Hierarchical, Nested Structures
- Feedback Loops
- Individual Level Variation (Observed and Unobserved)
- Group Level Variation (Observed and Unobserved)
- Mediating & Moderating Variables
- Non-Linear & Non-Parametric Properties
Systems Science approaches appreciate the complexity, context, dynamic nature, and emergent phenomena associated with the problem under study.

SS methodologies include:

- Computational/mathematical modeling
- Agent-based modeling
- Dynamic modeling (including System Dynamics)
- Network Analysis

Related Terms:

- Complexity science
- Complex adaptive systems
- Non-linear dynamics
Figure 1. Health as a continuum between biological and social factors across the lifespan. (Adapted from Glass & McAtee, 2006).
General Characteristics of SS Methodologies

SS methods are designed to capture:

- dynamic behavior of the system (change over time)
- bidirectional relationships (aka feedback loops; A affects B and simultaneously B affects A)
- non-linear relationships (threshold behavior, worse-before better)
- time-delayed effects

SS methods can help detect:

- unintended consequences
- emergent properties – individual behavior leads to aggregate outcome
- Gaps in existing knowledge; sensitivity analysis can tell us how important they are

Enable virtual experimentation – *in silico* laboratories

Can generate hypotheses for empirical testing
OBSSR mHealth Activities

OBSSR leads the trans-NIH mPower working group (27 ICOs). Activities include:

– Development of Funding Opportunity Announcements (FOAs)
– Released *Smart and Connected Health* joint FOA with NSF in June 2013
– Co-leading a scientific conference Wireless Health 2014

**OBSSR led three mHealth training institutes in 2013:**

– 1 Intensive Training at UCLA
– 2 Brief Trainings in conjunction with the mHealth Summit the Society for Behavioral Medicine

**OBSSR co-funded a 2013 NIH-NSF-EU conference on technology and health behavior.**

**OBSSR hosts the mHealth webinar series**

– Two webinars in 2013
The next generation of methods and measures
Interventions Affecting: Weight Loss Services

- Excess junk food diet
- Fruit/vegetable poor diet
- Sodium consumption
- Physical inactivity

- Obesity
- Smoking
- Secondhand smoke
- Air pollution exposure (PM 2.5)

- Chronic Disorders
  - Hypertension
  - High cholesterol
  - Diabetes

- Uncontrolled chronic disorders

- Use of quality preventive care

- Distress

- Cardiovascular events

- Trans fat consumption

Other deaths and costs attributable to risk factors, and costs of risk factor management

CVD deaths, disability, and costs

Total consequence costs

This slide has animation graphics which do not show up on the .pdf version
Care provides
quick and sustained reduction in CV events,
but little cost savings.

Air provides
rapid and growing reduction in CV events,
and major cost savings.

Lifestyle provides
Growing CV event reductions over time, but little immediately
Substantially increasing cost savings over time
How to bring it all together

Collaborate
with mHealth researchers collecting Big Data
with Systems Scientists/Data Scientist to help analyze it

Learn more
about Big Data, mHealth, and Systems Science
Past: Historical perspective

- About OBSSR
- Roots at NIH – CISNET, MIDAS, IMAG, ISIS
- Publications – AJPH March 2006, HEB 2013
- FOAs – policy-resistant problems, SNA, broad FOAs
Present: 2007-2013 Activities
  – Examples: Envision, PRISM

Future:
  – Big Data
  – mHealth
  – D&I : Informing policy – tobacco, obesity, workforce
  – Training
  – Validation, verification, uncertainty quantification
Simulating and Evaluating Local Interventions to Improve Cardiovascular Health

Jack Homer, PhD; Bobby Milstein, PhD, MPH; Kristina Wile, MS; Justin Trogdon, PhD; Philip Huang, MD, MPH; Darwin Labarthe, MD, MPH, PhD; Diane Orenstein, PhD


Introduction

Conditions in particular neighborhoods or cities can profoundly enhance or impede people’s prospects for a healthy life (1). This dependence on local context is especially evident in cardiovascular health, for which behavioral, social, and environmental factors combine to affect the likelihood of developing disease or dying prematurely (2). Heart disease and stroke are largely preventable, but they remain...