



*Complex Adaptive System of Systems
(CASoS) Engineering Initiative
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Extending Opinion Dynamics to Model Public Health Problems and Analyze Public Policy Interventions

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Eighth International Conference on Complex Systems
Quincy, MA
June 26 – July 1, 2011

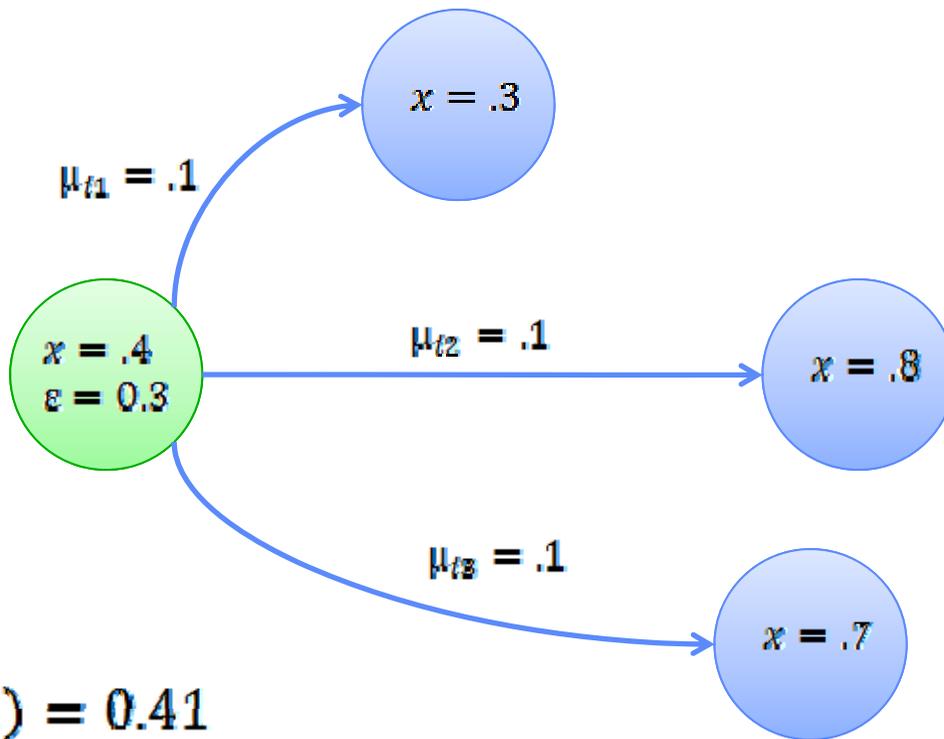
- Chronic diseases associated with individual behaviors are the leading causes of death throughout the industrialized world
- Social network analysis has a long history in epidemiological studies
- Smoking demonstrates clustering behavior in social networks – behavioral contagion
- What are the dynamics that explain chains of initiation and clusters of cessation?

- Family of related techniques for modeling information flow through a group of individuals
 - Derived from Ising spin alignment models
 - Opinions represented by numerical value
- Grounded in structural balance theory
- Individual opinions approach consensus values with neighbors
- Bounded confidence component can prevent consensus, create clusters

Opinion Dynamics in Action

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

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

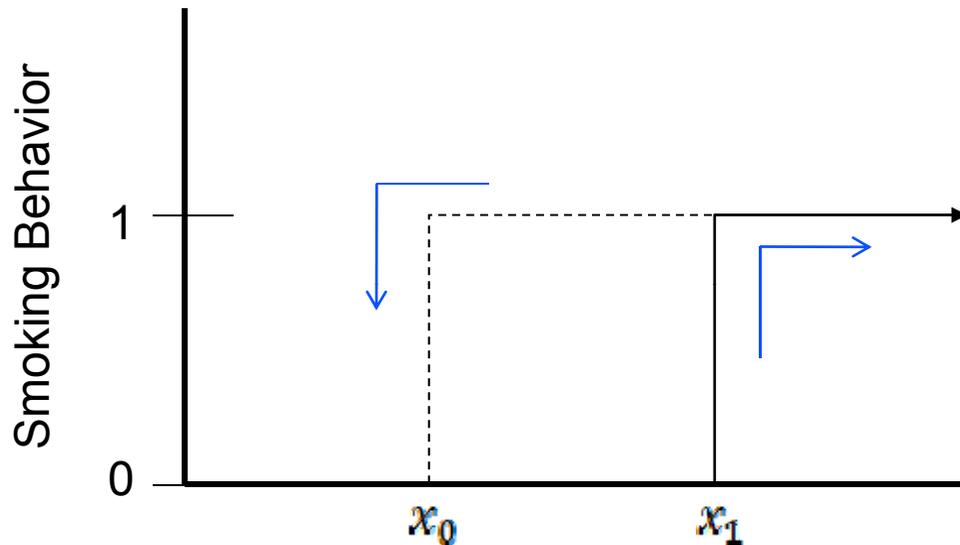


S_i : Set of out-degree neighbors
 ε : Tolerance
 μ : Plasticity



- Behavioral changes triggered by changing opinions
- Initiation threshold for smoking incorporates actual and perceived costs
 - Monetary cost
 - Time/convenience costs
 - Social costs (e.g., enforcement of rules in high schools)
- Cessation threshold determined by level of addiction
 - Age
 - Addictiveness of product
 - Availability of quit support/NRTs

Initiation, Cessation, and Hysteresis



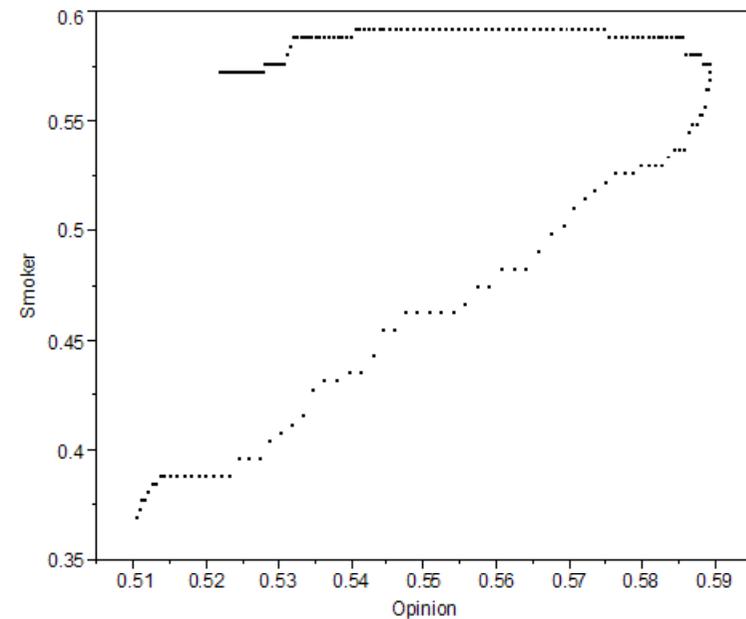
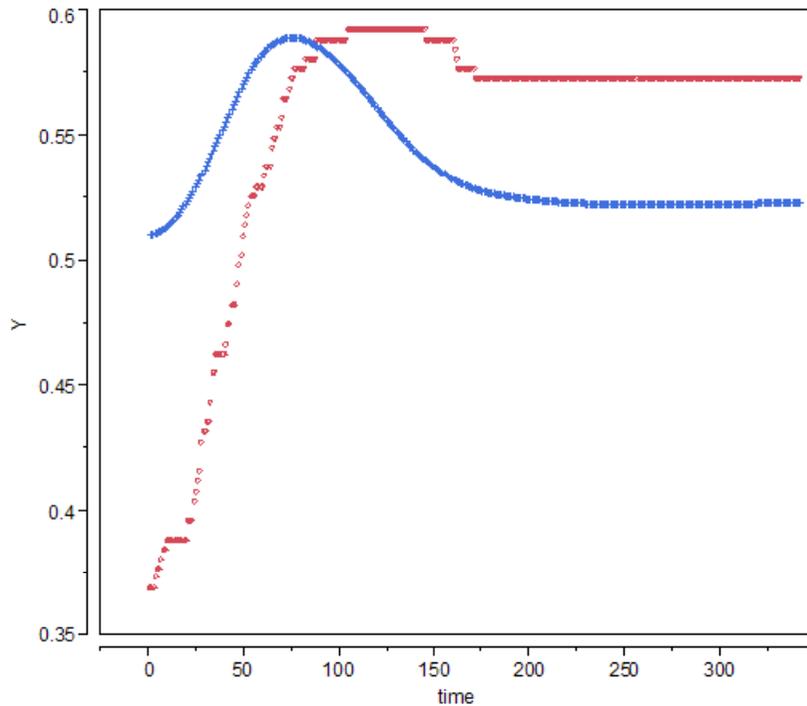
x_1 Initiation Threshold

x_0 Cessation Threshold

Δx Hysteresis Effect

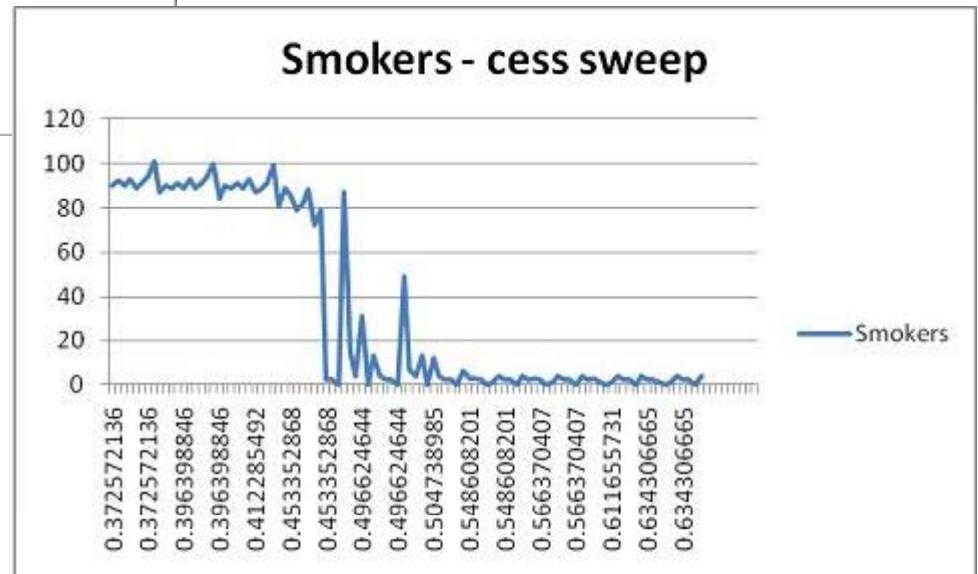
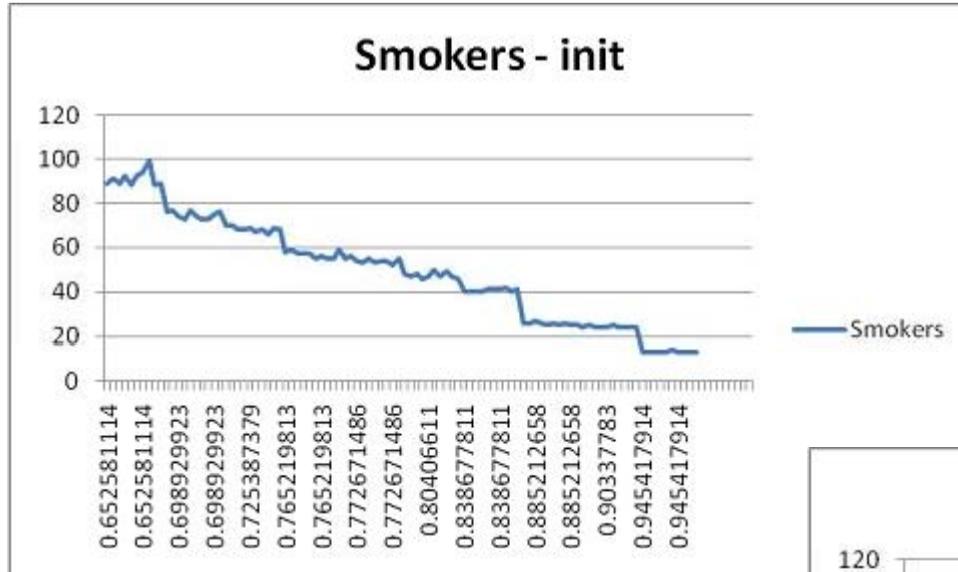
- If the individual's opinion about smoking passes the initiation threshold, the person will become a smoker
- If the individual's opinion falls below the cessation threshold, the person will quit smoking
- The magnitude of the hysteresis effect represents strength of addiction

Hysteresis Illustrations



- Industry Ads through $t=75$ gets smokers addicted
- Educational campaign starting at $t=75$ pulls down opinion but has limited effect on smoking behaviors

Initiation vs. Cessation



- Campaigns to Influence Opinion
 - Directly propagating opinion values using OD algorithm
 - PageRank of target nodes most important for influencing network
- Campaigns to Influence Tolerance
 - Increasing tolerance increases consensus
 - Decreasing tolerance locks down network in current configuration
 - Betweenness most important centrality metric

Experimental Results – Effects of Campaigns Affecting Opinion

- How Advertisements and Educational Campaigns Influence Networks by Changing Opinions
 - Aggressive campaigns can be effective, but can also alienate and polarize; mild campaigns can appeal to a wider range of people, but alone can be ineffective in changing behavior
 - Campaigns can act synergistically to move network incrementally in a particular direction while individually appealing to distinct audiences
 - Conflicts between advertising and educational campaigns will be won on the basis reaching important individuals and clusters

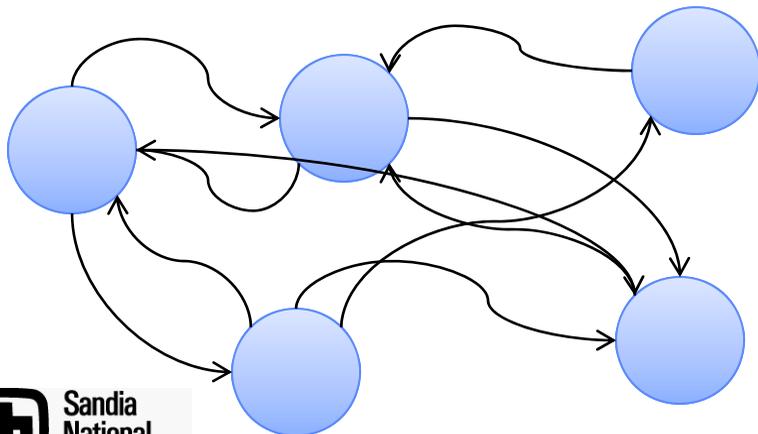
Experimental Results – Effects of Campaigns Affecting Tolerance

- How Advertisements and Educational Campaigns Influence Networks by Changing Tolerance
 - Lowering tolerance values prevents the spread of opinion, inoculates against future advertisements
 - Raising tolerance values increases network-wide vulnerability to advertisements
 - Combining tolerance-related campaigns with education creates a potent mechanism for social change

- Extending opinion dynamics models with psychological and behavioral components allows for the modeling of socially inspired behaviors
- Network effects can amplify or attenuate interventions, and so should be a component of policy evaluation
- Tolerance, behavioral transition points, and network topologies all contribute to create complex dynamics, and should be considered as important model components

What is a Social Network in the Real World?

- Created by individual actions
- Defined by the exchange of information and resources
- No single topology captures all interactions
 - Contact networks
 - Friendship networks
 - Advice networks
 - ...



- Depends on the parameters
- Depends on the context of the simulation run
 - Theoretical: tendencies and trends (What happens if...?)
 - Empirical: Depends on data calibration (generally speaking, weeks to a few years)

