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Extending Opinion Dynamics to Model Public Health Problems and Analyze Public Policy Interventions

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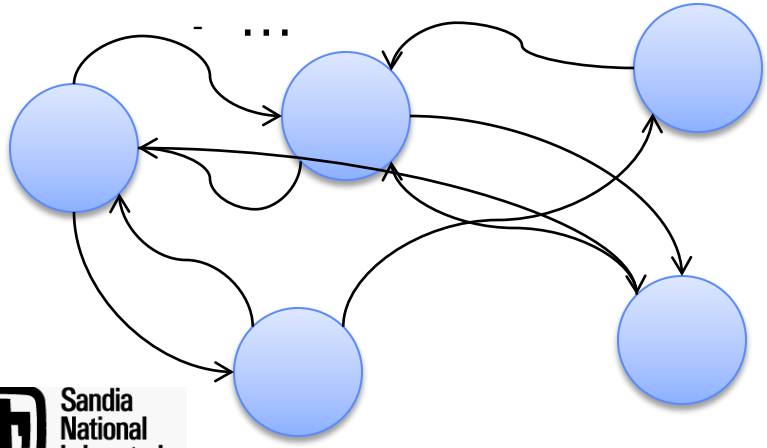
Introduction

- 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?

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
  - …



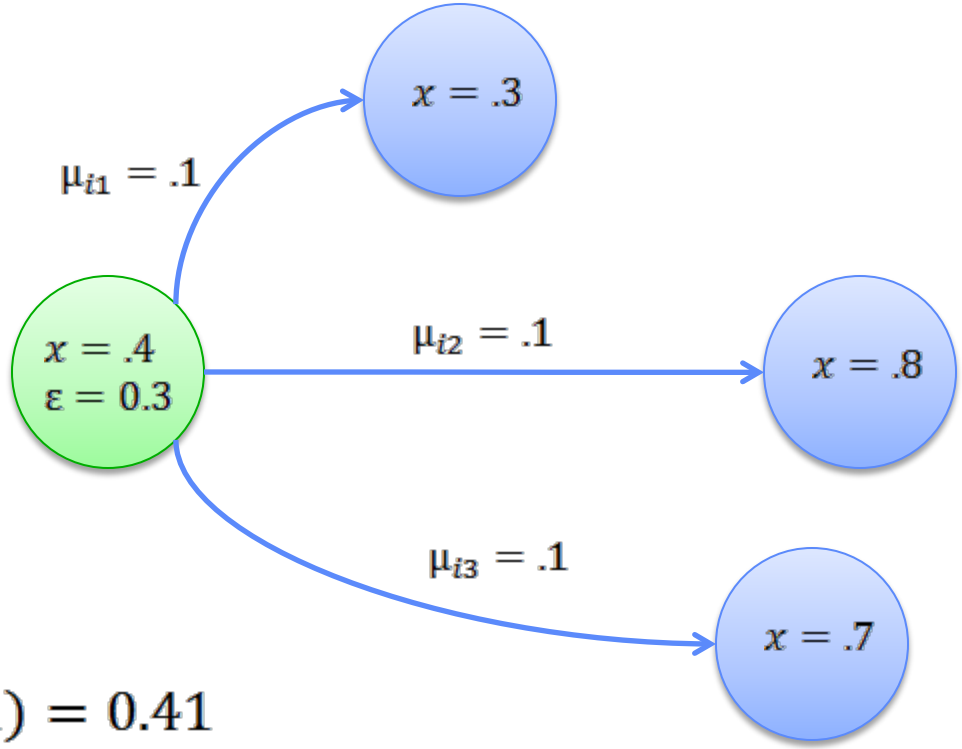
Opinion Dynamics

- 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

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

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

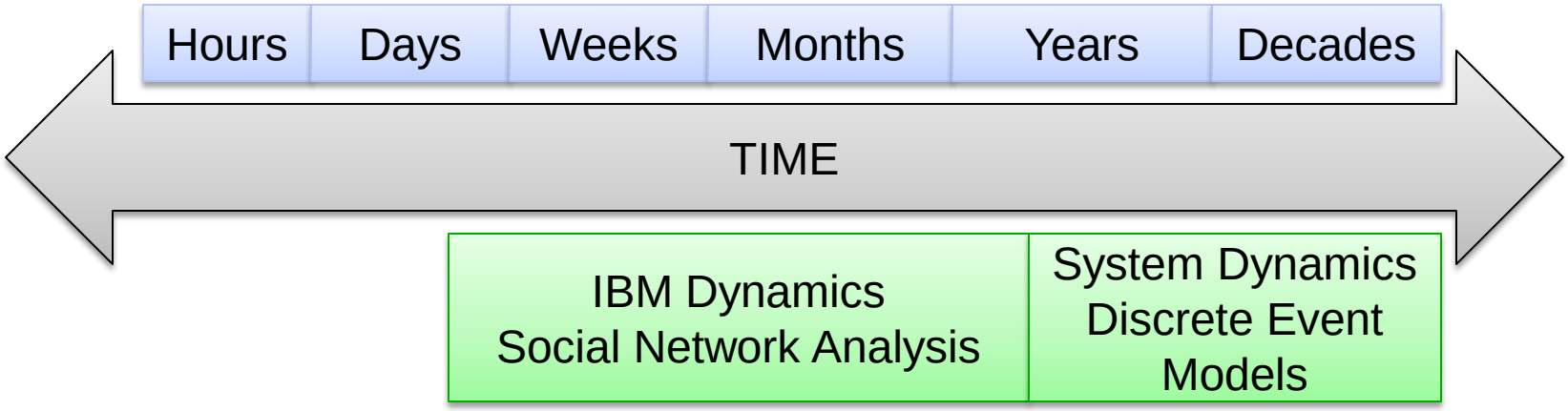


$$x_i(t+1) = 0.41$$

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

What is t?

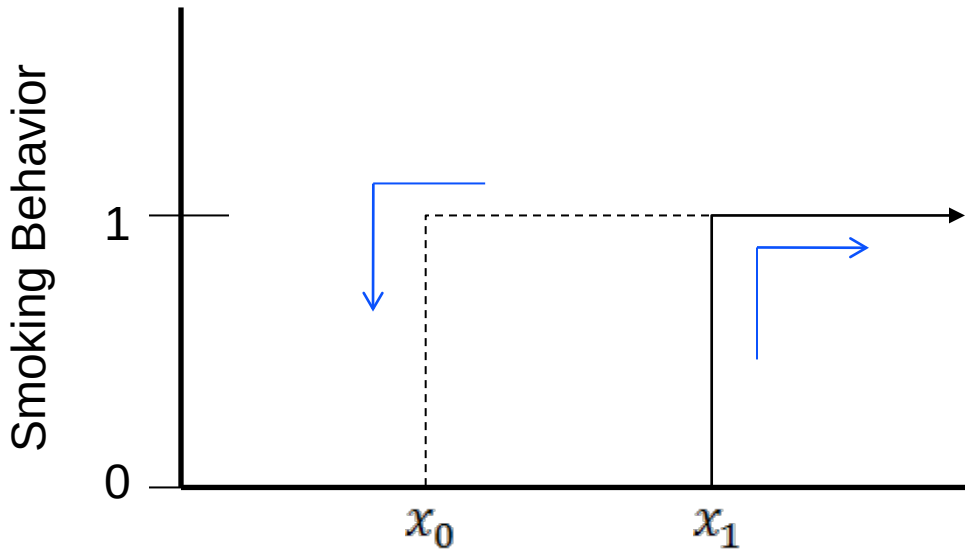
- Depends on the parameters
- Depends on the context of the simulation run
  - Theoretical: tendencies and trends (What happens if…?)
  - Empirical: Depends on data calibration (generally speaking, weeks to a few years)



Adding Behavior

- 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



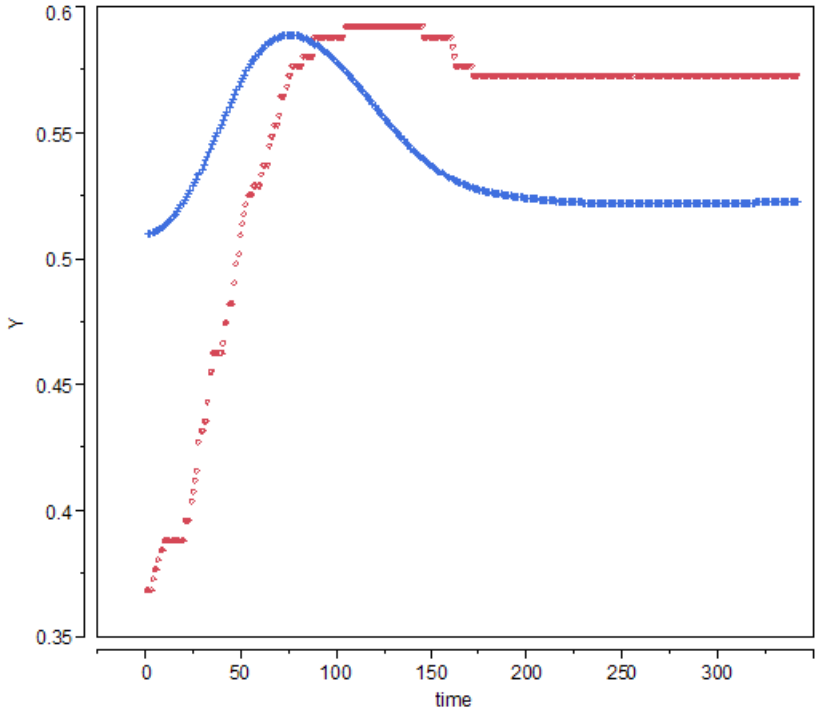
x_1 Initiation Threshold

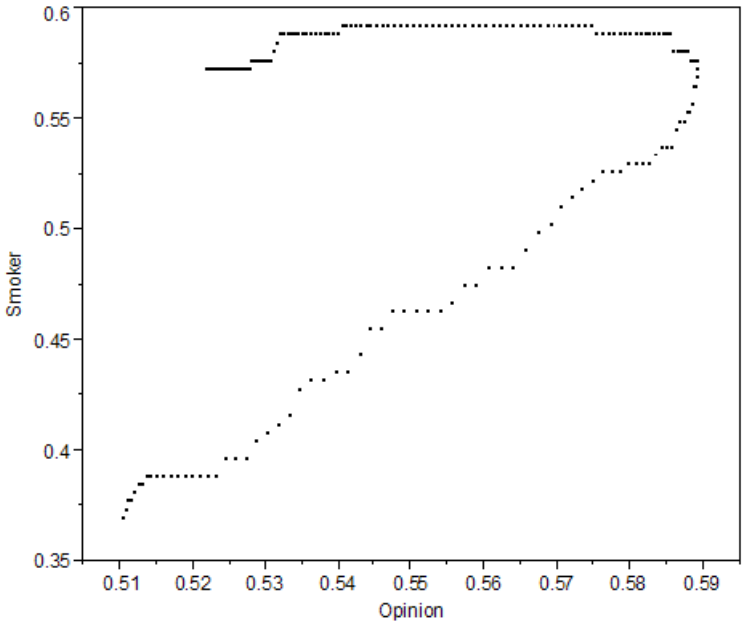
x_0 Cessation Threshold

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

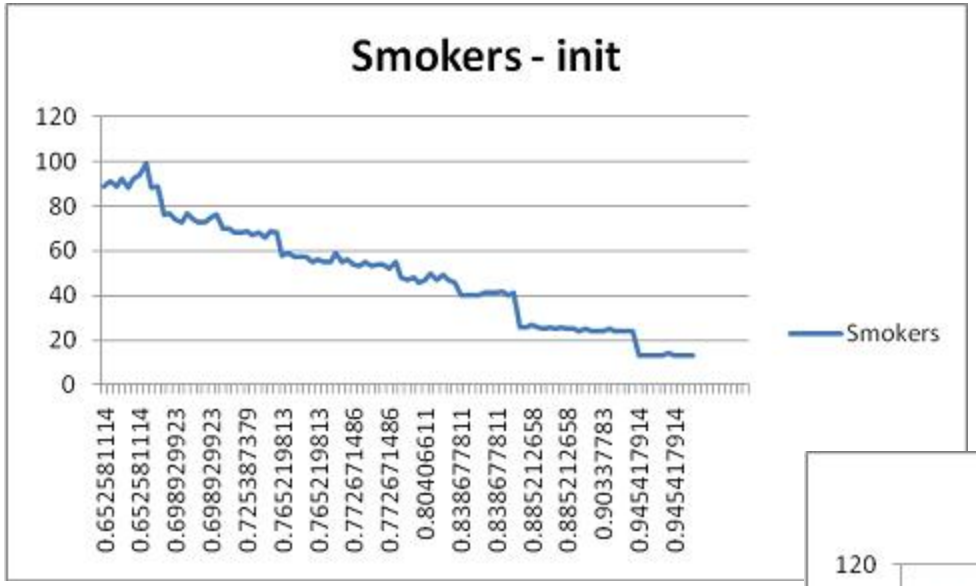
Hysteresis Illustrations

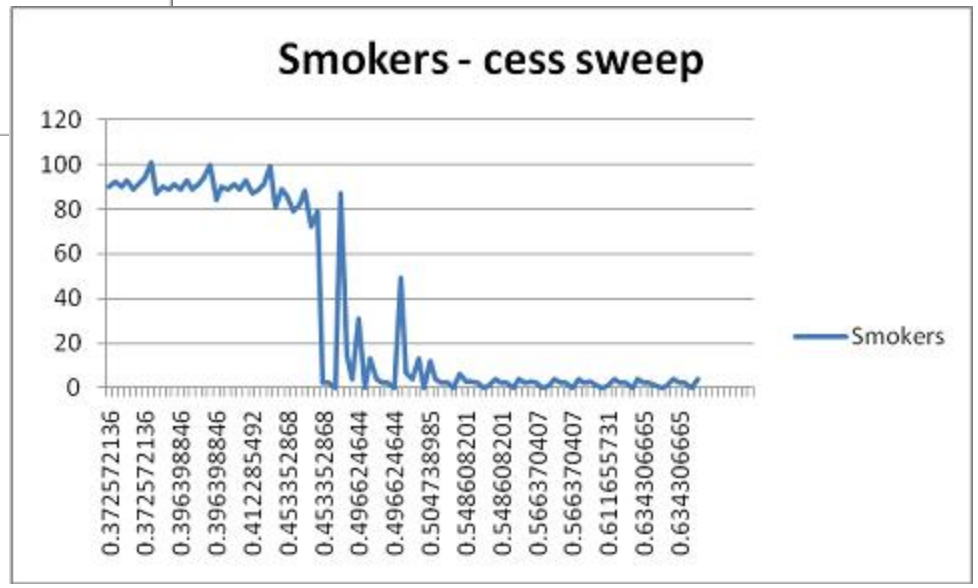




- Industry Ads through t=75 gets smokers addicted
- Educational campaign starting at t=75 pulls down opinion but has limited effect on smoking behaviors

Initiation vs. Cessation





Advertising, Education, and Counter-marketing

- 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

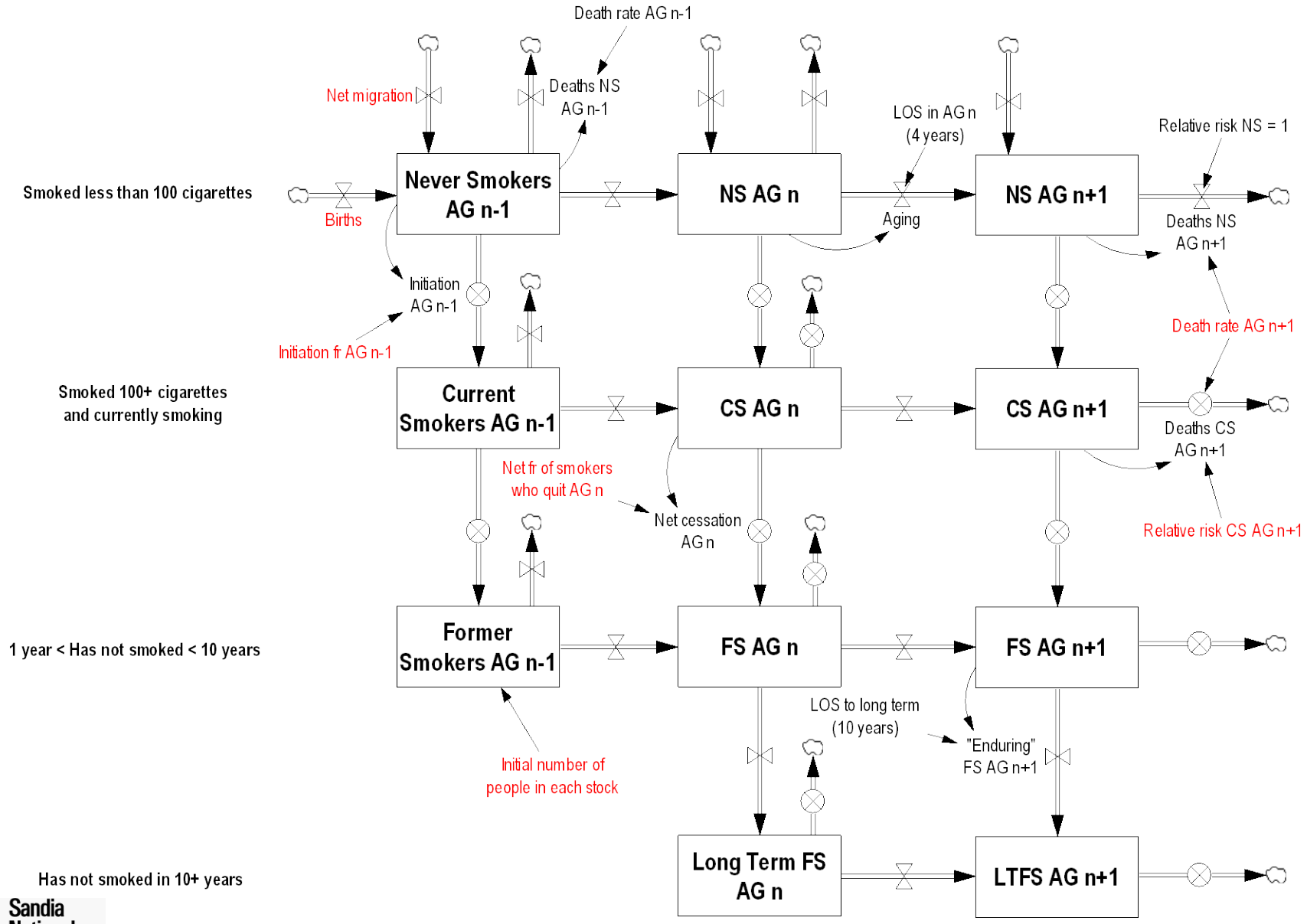
Experimental Results - Effects of Campaigns Affecting Opinion

- 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

Generic 3-age-group representation



Conclusions

- 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