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Opinion Dynamics Modeling in Tobacco Control Policy

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Opinion Dynamics Modeling Presentation

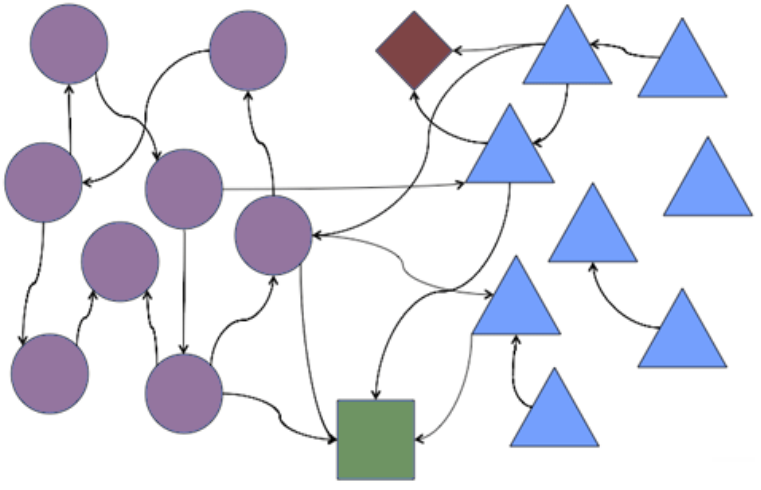
- Multiple-model approach for tobacco control
- Opinion Dynamics and Social Networks
- Addiction
- Media and public-health educational influences
- Modeling risk and multiple products
- Validation progress
- Future Directions

Multiple Models for Tobacco Control Policy

- Tobacco impacts can be modeled on an individual or population basis
- Individual-based models can:
  - Investigate tobacco-use influence factors
  - Estimate effects of market changes on initiation and cessation rates
- Population-based models
  - Calculate aggregate health/economic consequences of tobacco use
  - Show long-term effects of changes in relative risk, and initiation or cessation rates
- Applying both modeling motifs permits:
  - More informative analysis of policy options or market changes
  - Better identification of effective loci for intervention
  - More detailed analysis of uncertainties in system responses

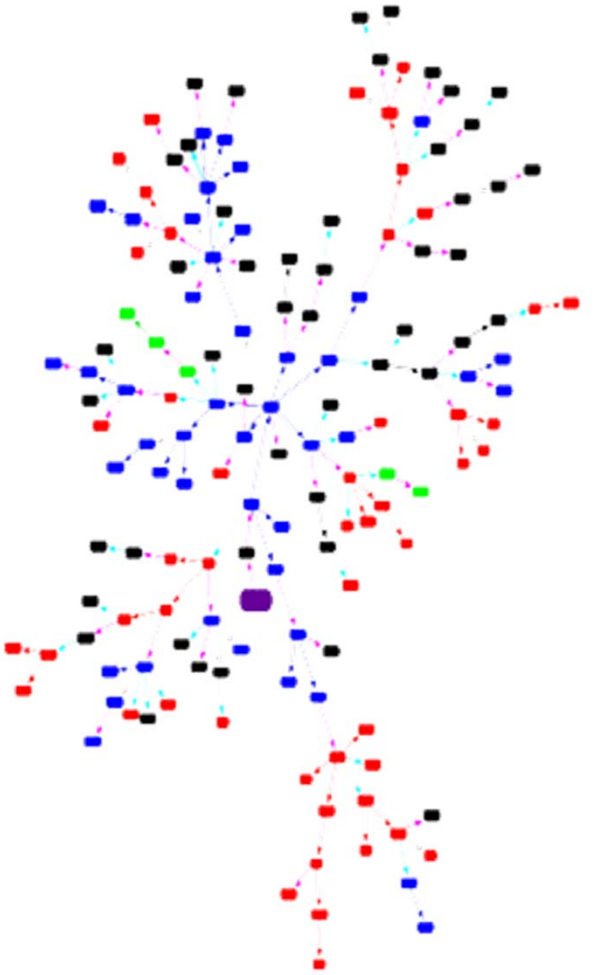
Why Opinion Dynamics Modeling?

- Ability to model information spread demonstrated and validated in many domains
  - Spread of green agriculture practices in Europe
  - Voter behavior in UK and Italy
  - Political extremism
- Sandia experience includes:
  - Extremist group dynamics
  - Obesity-promoting behaviors
  - Afghani tribal politics
  - Gender-based social networks in developing countries
  - Community formation in social networks



Opinion Dynamics Concepts

- Population of software agents representing individuals
- Each individual assigned two values to start:
  - Opinion: Current strength of belief in issue under study
  - Tolerance: Degree of openness to consider other ideas
- At each time step, agents adjust their opinion based on opinions of neighboring agents and their own tolerance
- Output is a distribution of agent opinions



Model Formulation for Tobacco

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

Update Rule: *Adjust individual's opinion by mean scaled opinion differences of opinion and neighbors'*

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

Effect of tolerance*: Ignore neighbors whose opinion is outside individual's tolerance.*

S_i: Set of out-degree neighbors
(The people I connect with)

ε: Tolerance
(Do you influence me?)

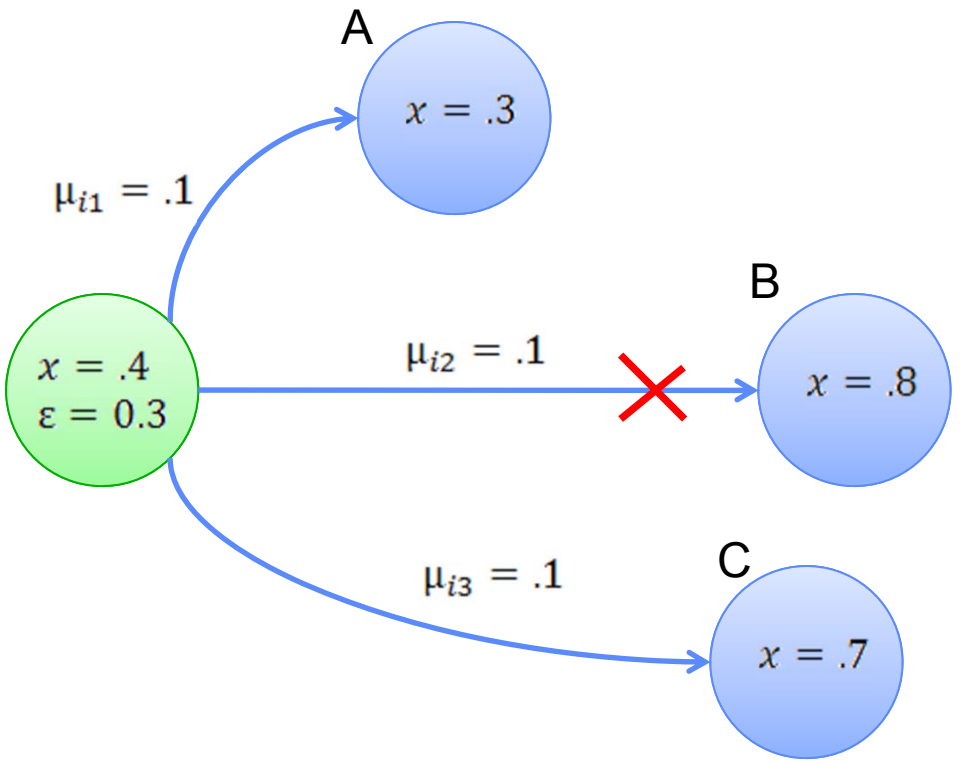
μ: Plasticity
(How much do you influence me?)

x: Opinion
(My integrated view of tobacco use)

Opinion Dynamics Model: Effect of Tolerance

- A and C contribute to new opinion value
- B's opinion excluded since it is outside of tolerance
- New value is original value plus mean residual scaled by edge weight

$$x_i(t) = 0.40$$
$$x_i(t+1) = 0.41$$



ε: Tolerance
μ: Plasticity
x: Opinion
(integrated view of tobacco use)

What makes up Opinion about Tobacco?

Social Influences (Affect)

Positive

- Sophisticated
- Cool
- Group identity
- Adult
- Independent

Negative

- SES association
- Addictive
- Smell/taste
- Corporate

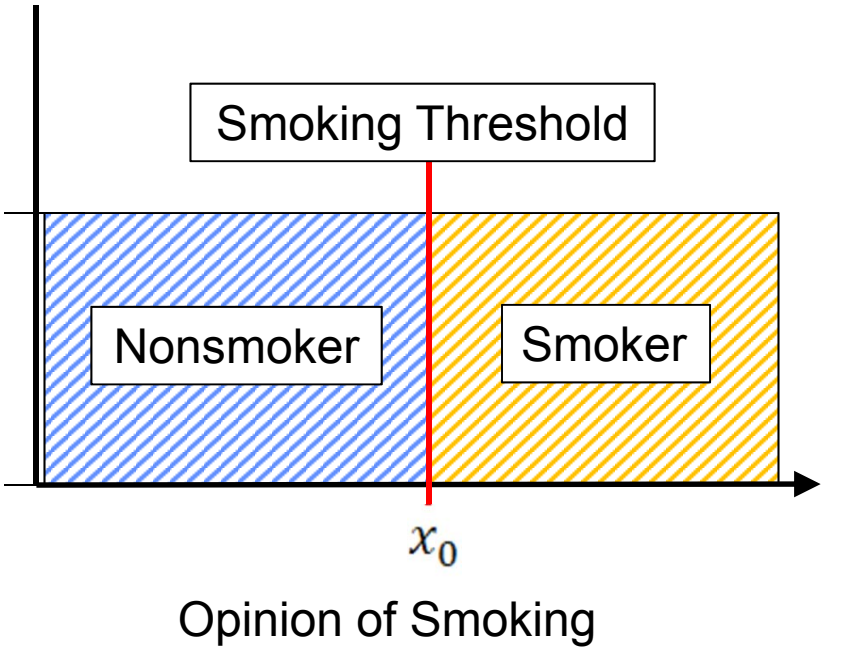
Practical Influences (Utility)

- Weight control
- Stress relief
- Concentration

- Disease
- Going outside
- Dangers of SHS

Simple Mapping of Opinion to Behavior

- If the individual's opinion about smoking is greater than threshold, the person is a smoker
- If the individual's opinion is below the cessation threshold, the person does not smoke



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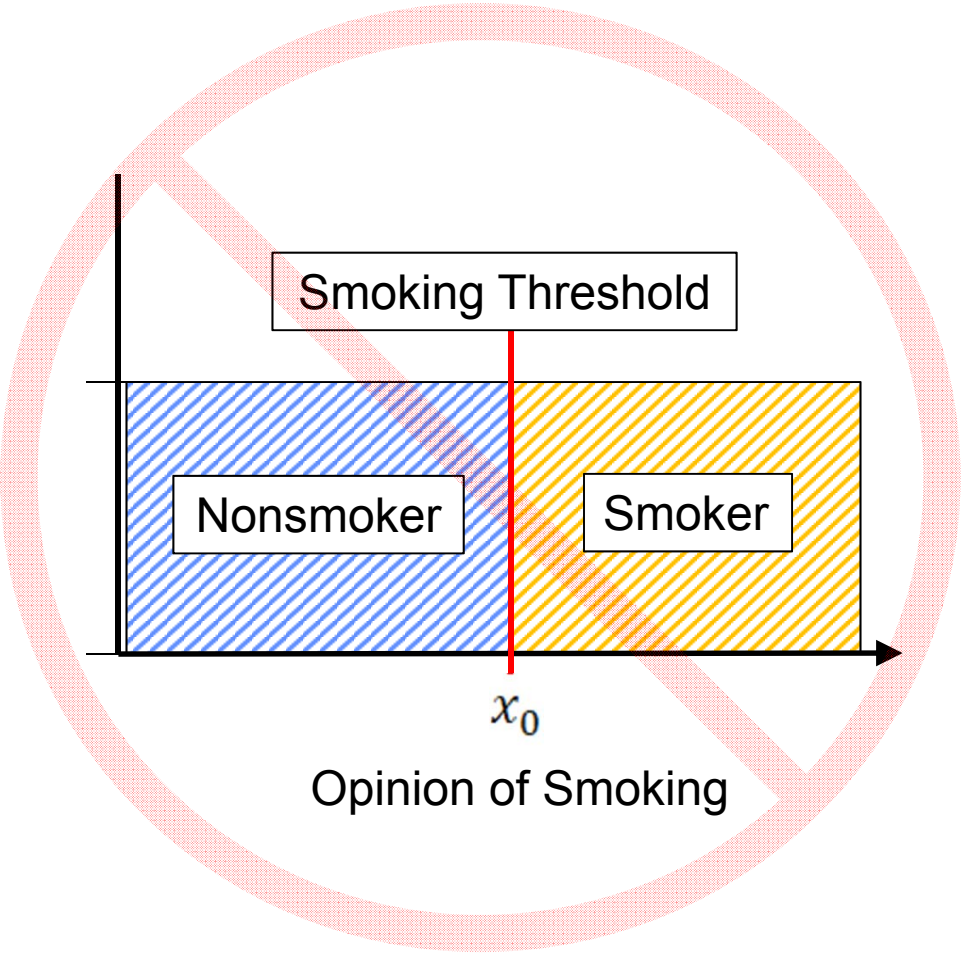
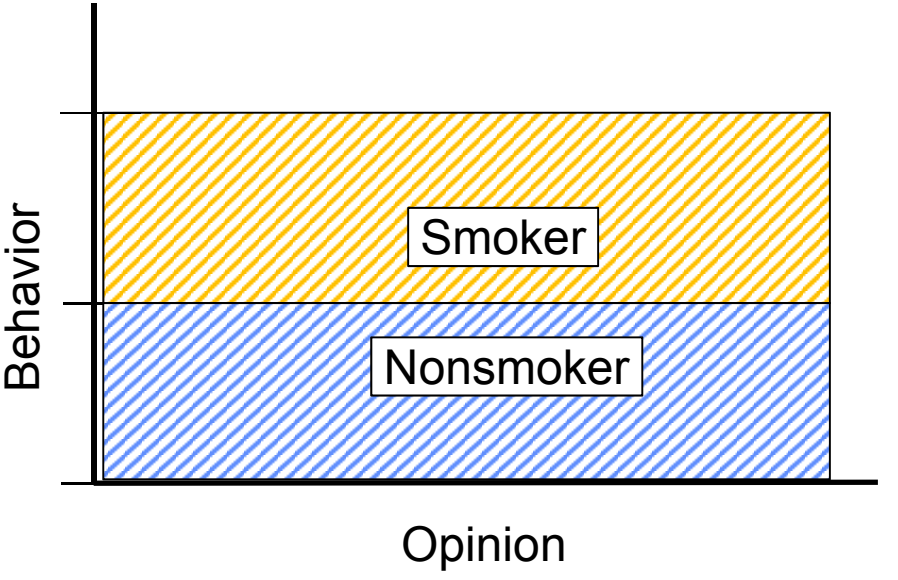


But this mapping does not incorporate the effects of addiction

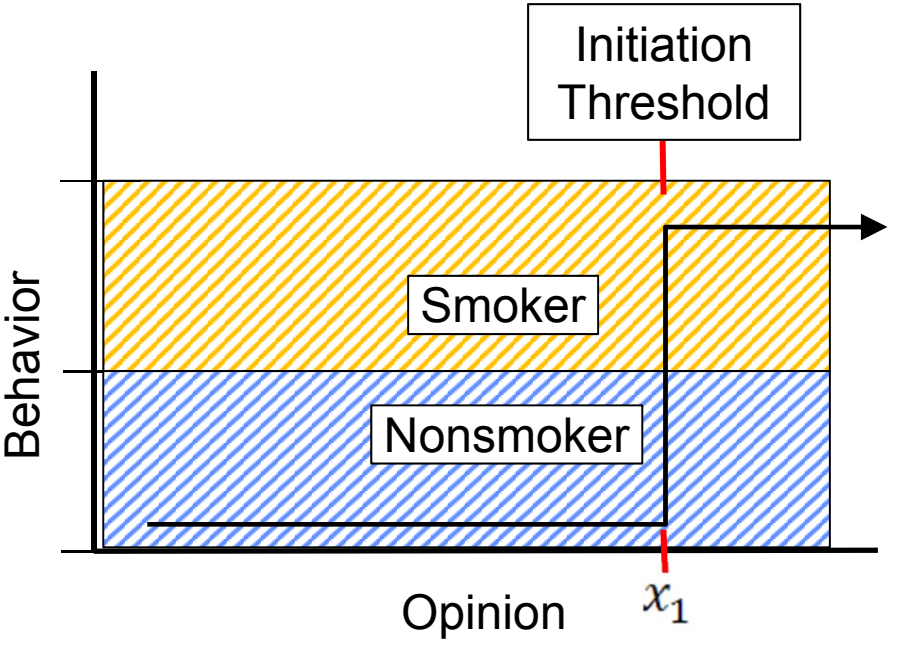
Modeling Smoking Opinion/Behavior including Addiction with Hysteresis

- Individual smoking behavior is path-dependent (hysteretic)



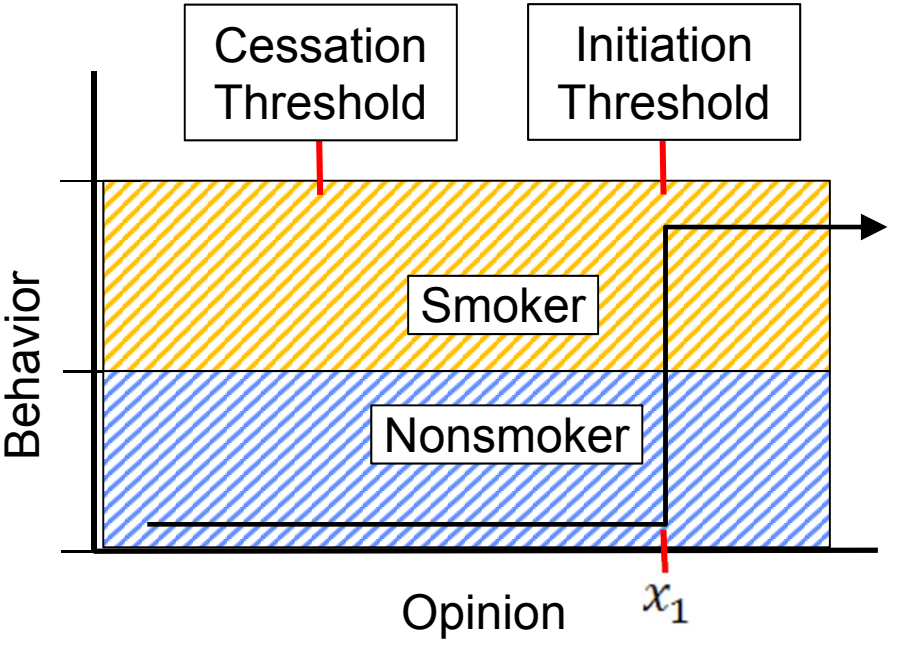
Modeling Smoking Opinion/Behavior including Addiction with Hysteresis

- Individual smoking behavior is path-dependent (hysteretic)
- Start smoking when opinion of smoking exceeds initiation threshold (solid line)



Modeling Smoking Opinion/Behavior including Addiction with Hysteresis

- Individual smoking behavior is path-dependent (hysteretic)
- Start smoking when opinion of smoking exceeds initiation threshold (solid line)
- Opinion must fall below cessation threshold to overcome addiction



Modeling Smoking Opinion/Behavior including Addiction with Hysteresis

- Individual smoking behavior is path-dependent (hysteretic)
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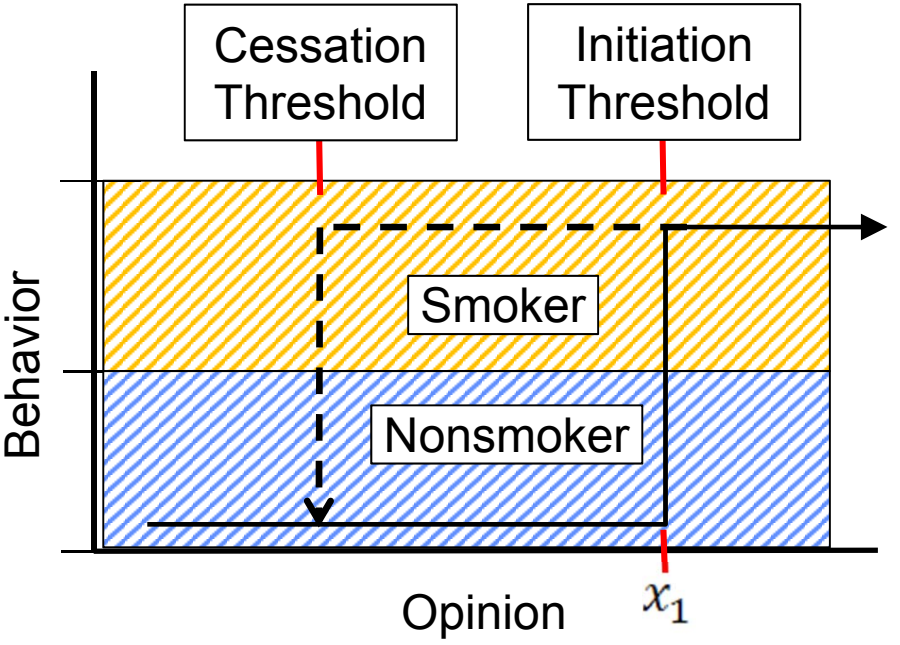
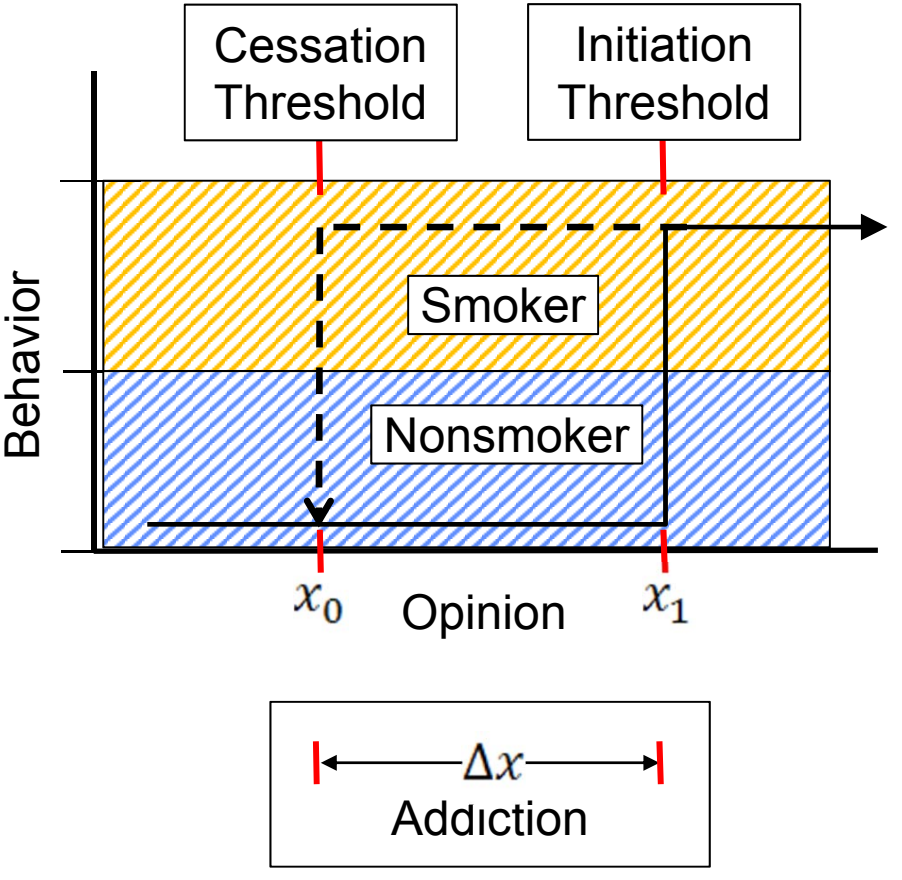


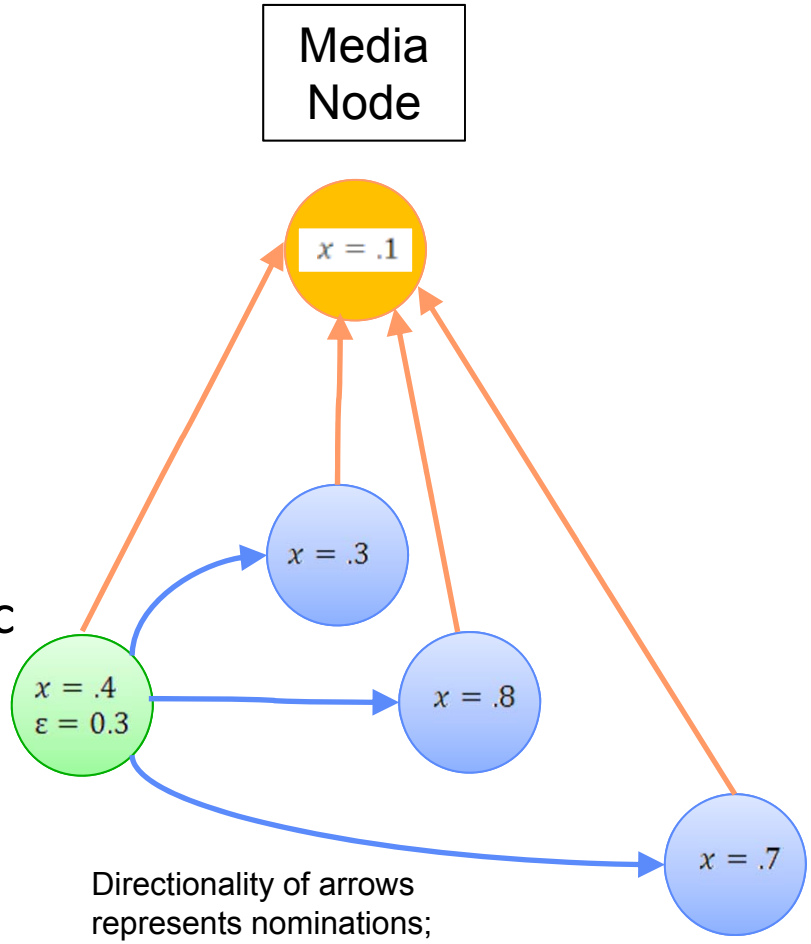
Modeling Smoking Opinion/Behavior including Addiction with Hysteresis

- Individual smoking behavior is path-dependent (hysteretic)
- Start smoking when opinion of smoking exceeds initiation threshold (solid line)
- Quit smoking when opinion falls below cessation threshold (dashed line)
- Magnitude of the hysteresis effect represents strength of addiction

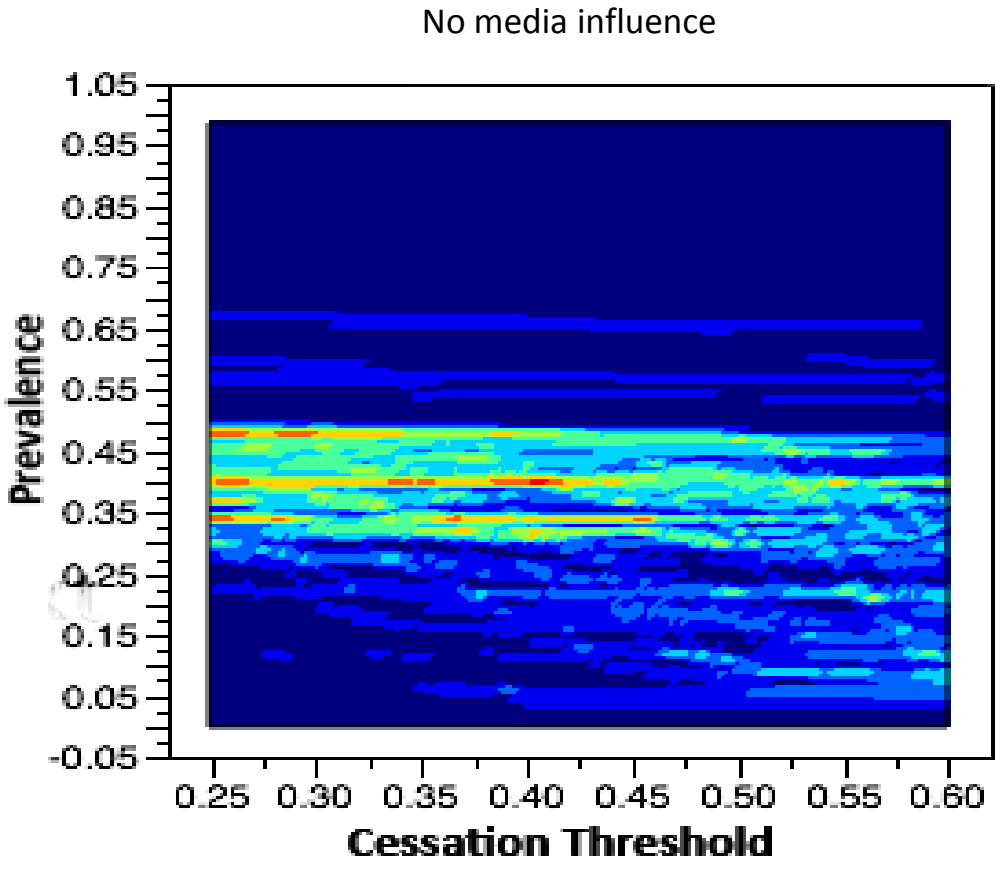


Modeling of Media and Education Effects

- Information sources modeled as social network nodes broadcasting messages to individuals
- Pro-tobacco information sources push high-opinion or high-tolerance messages
- Public-health information sources push low-opinion messages
- Messages can be targeted at specific classes of individuals
- Multiple-message campaigns represented in competition or collaboration



Example Result: Varying Cessation Threshold

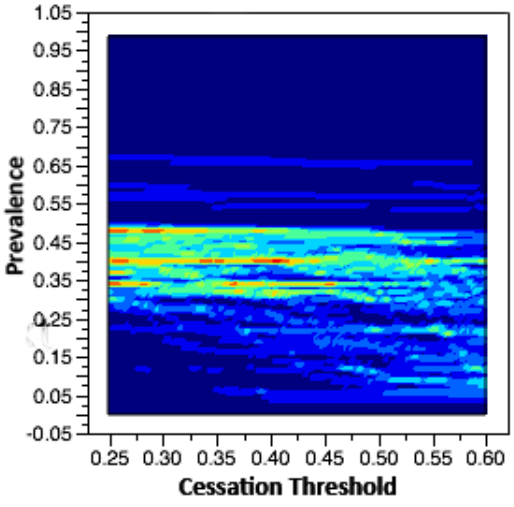


Without media influence (pro or con): large changes in cessation threshold may yield only minor changes in prevalence

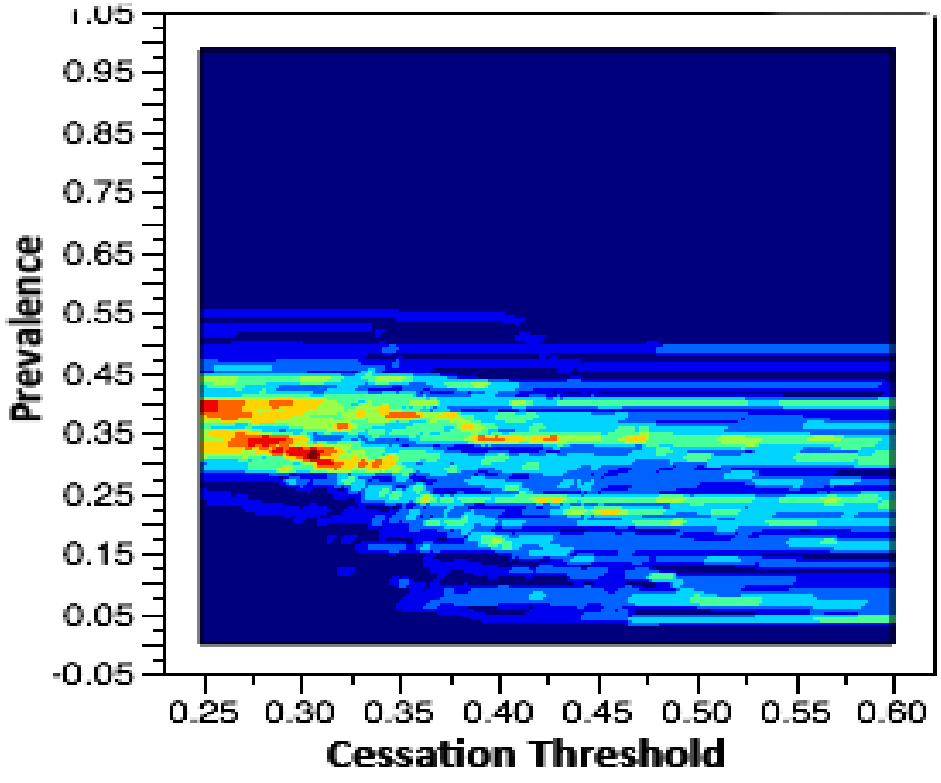
3-D histograms of model outputs:
Each graphic illustrates 10,000 simulations of 250-node networks

Example Result: Adding Education

No media



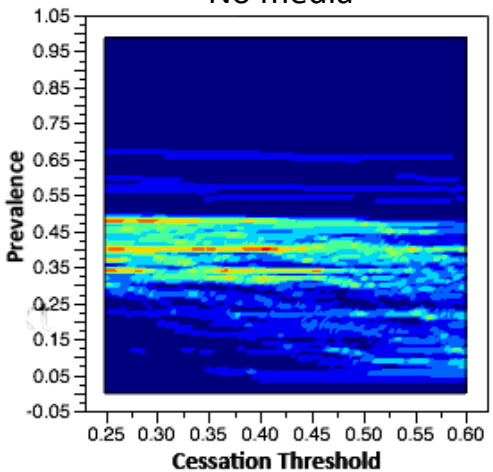
Public Health messaging



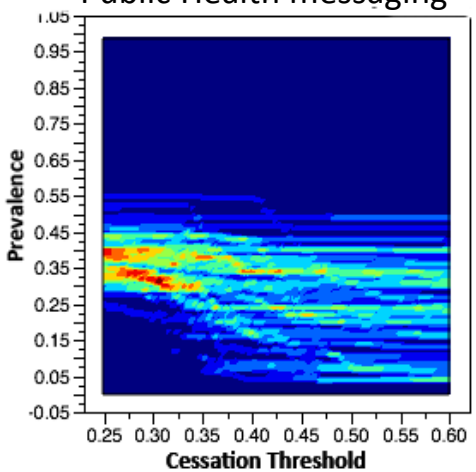
With Public Health education campaign:
Decrease in prevalence with small changes in cessation threshold

Example Result: Adding Pro-smoking Messaging

No media



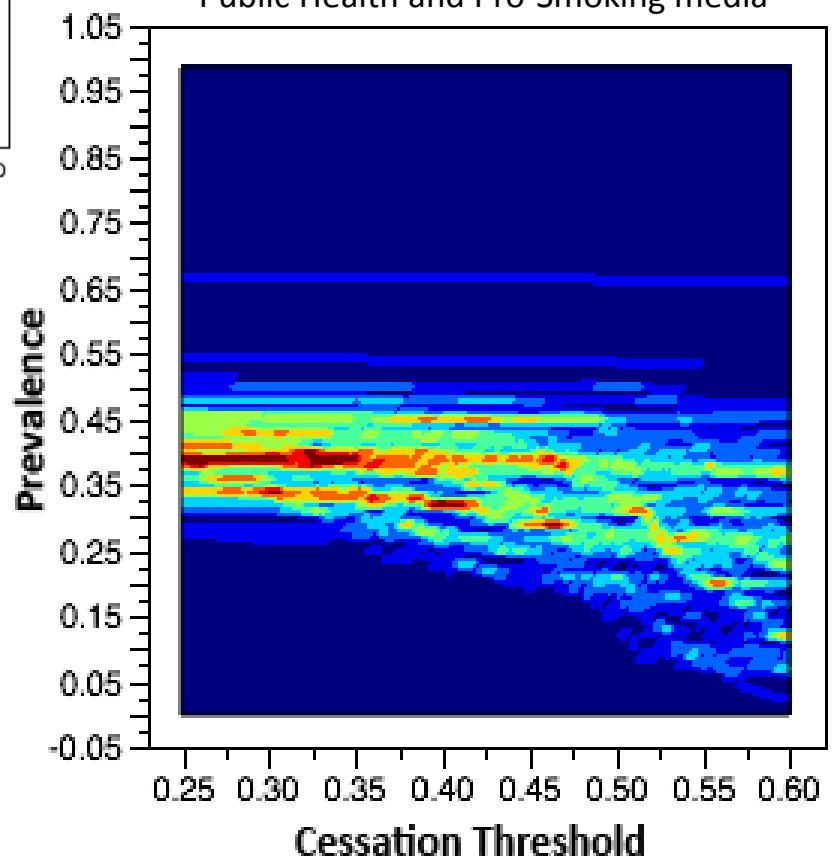
Public Health messaging



Adding pro-smoking messaging (e.g., through advertising and promotion) to existing Public Health education campaign:

requires larger change in cessation threshold to achieve similar decreases in prevalence

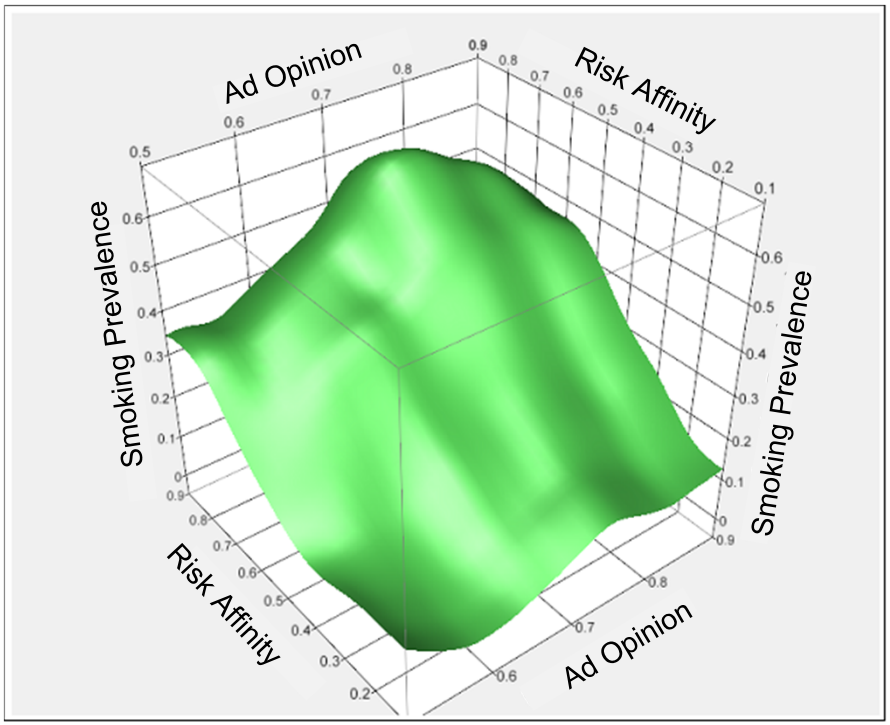
Public Health and Pro-Smoking media



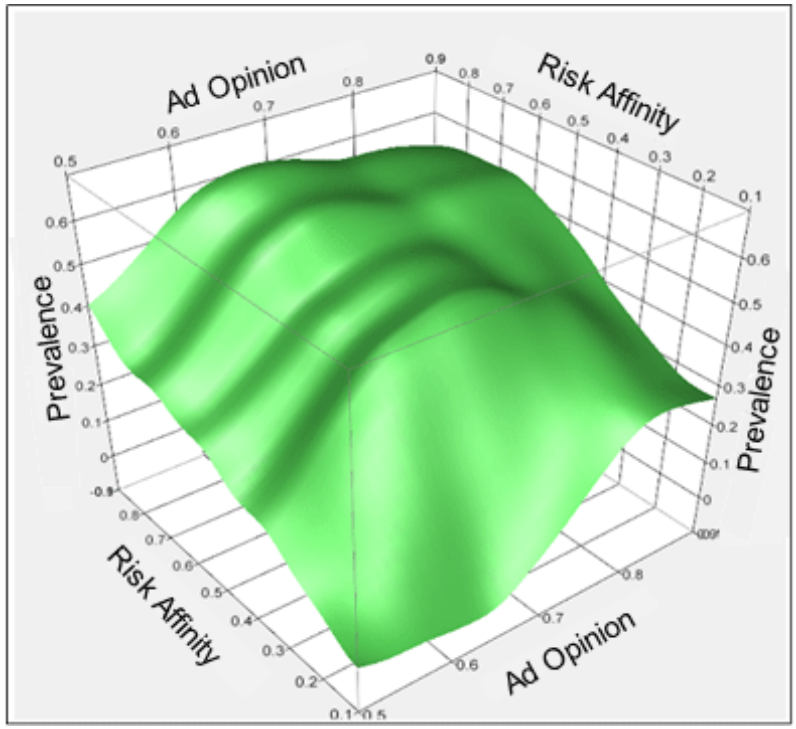
Modeling Risk

- Risk is key component in modeling behavior change in multiple-product regimes
  - Risk affinity: Property of individuals
  - Risk perception: Property of a class of products
  - High-risk-affinity individuals are not deterred by potential harm and will use products with high perceived risk
  - Low-risk-affinity individuals will use only products with low perceived risk
- When risk is considered comparative values can be found for use of multiple products

Example Result: Risk Affinity, Opinion, and Prevalence



Cigarettes



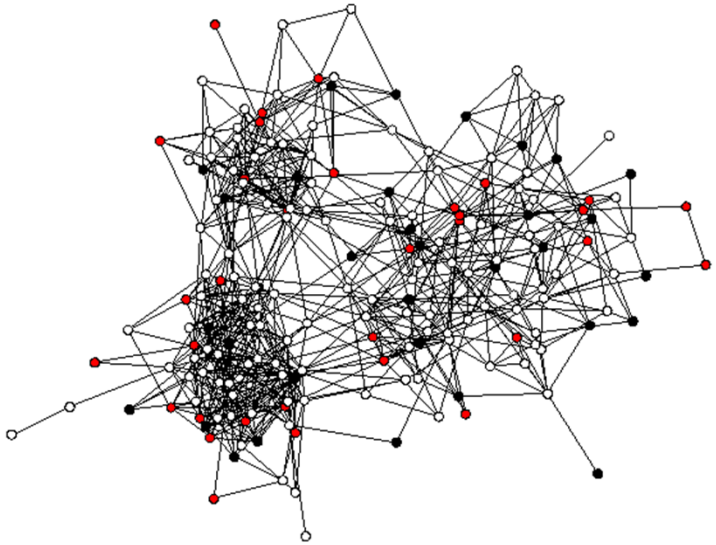
Electronic Cigarettes

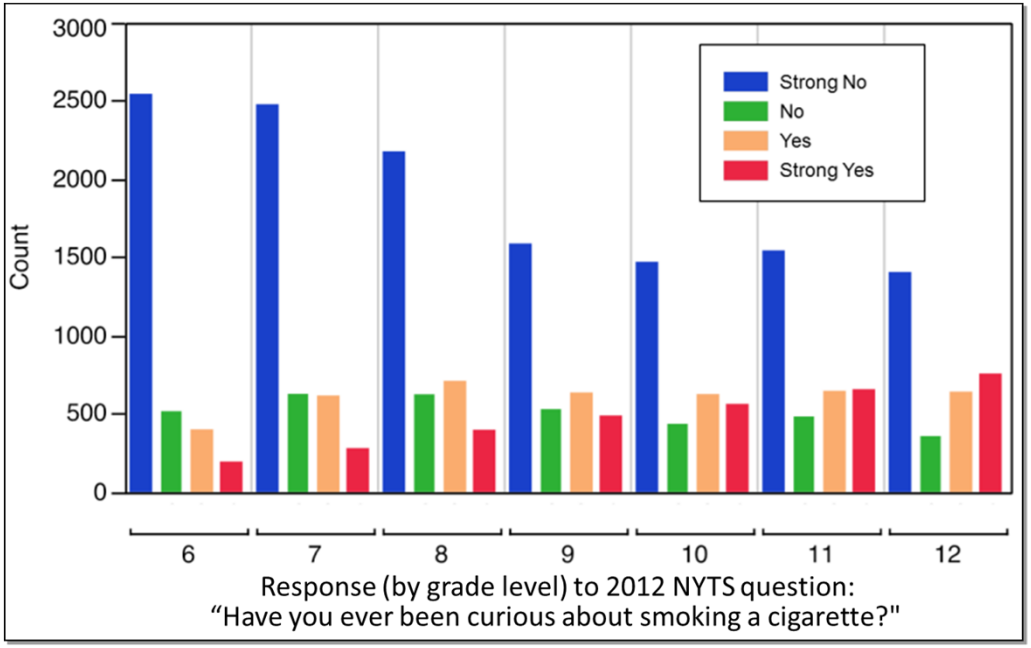
- Individuals with lower risk affinity are vulnerable to e-cigarettes
- Those who would not otherwise use tobacco products may become users
- Individuals with a greater range of risk affinities are more likely to use e-cigarettes

Model Validation

- Model verified by comparison of results to synthetic test cases
- Model parameters calibrated by extensive sensitivity analysis, uncertainty quantification and parameter estimation methods
- Ongoing validation through comparison to real-world datasets
  - Add Health survey for behavior and network topology
  - NYTS for dynamic changes in adolescent opinions

Example Add Health adolescent tobacco-use network





Statistical Methods are used throughout Modeling and Analysis Process

Examples of methods and techniques employed:

- **Sensitivity Analysis**: Variety of methods to explore parameter uncertainty: Sobol variance decomposition, Morris method, GP surrogate surfaces, ACOSSO meta-models, PCE, CART classification tree, stepwise regression, stochastic kriging
- **Statistical Network Analysis**: exponential random graph models used to examine smoking assortativity in adolescent school networks
- **Distribution Analysis**: Log-normal distributions were fit to smoking related survey answers to validate model representation

Conclusions and Future Directions

- Individual-based models provide meaningful information on initiation and cessation rates useful for dynamic population models
- Framework enables exploration of possible future market conditions or actions
- Effects of media on specific demographic segments more easily illustrated
- Future directions:
  - Incorporate additional real-world data
  - Increase model resolution and scope

Questions?