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Opinion Dynamics Modeling in Tobacco Control Policy

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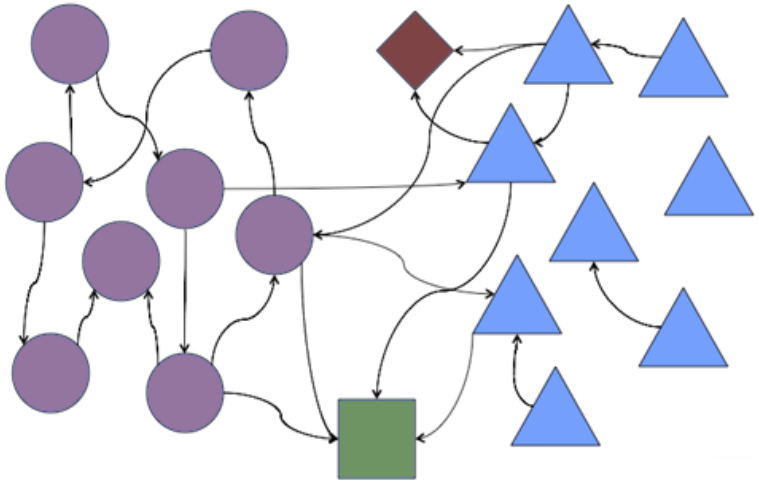
Opinion Dynamics Modeling Presentation

- Opinion Dynamics overview
- Tobacco specific features
  - Addiction
  - Media and public-health educational influences
  - Risk and multiple products
- Uncertainty and Validation
- Future Directions

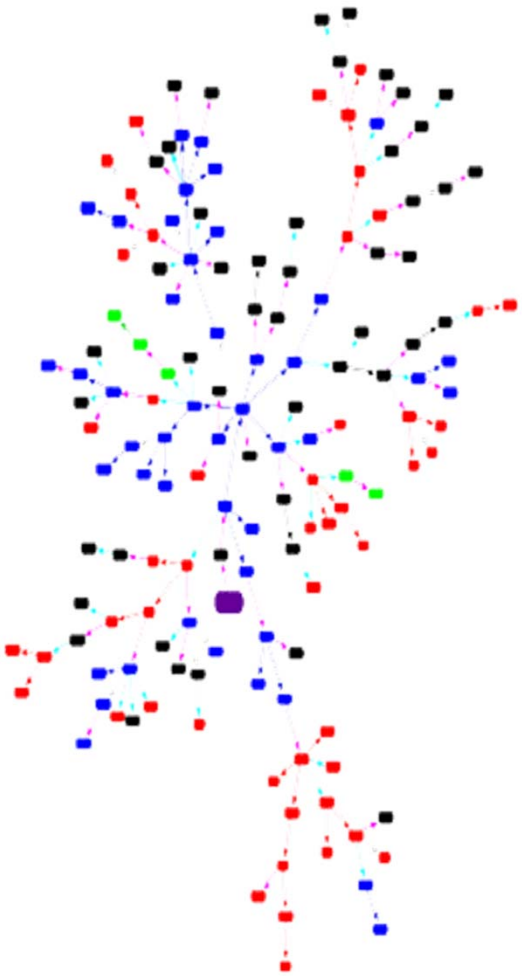
Why Use Opinion Dynamics Modeling?

- Simple and it works
- Applied and validated in many domains
  - Originated from Statistical Physics
  - Applied to voter behavior in UK and Italy
  - Spread of green agricultural processes in Europe
- Sandia Opinion Dynamics experience
  - 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:* Positive or negative perception
  - *Tolerance:* Openness to consider other ideas
- At each time step, agents adjust opinion based on opinions of neighbors and their own tolerance
- Opinion clusters form dynamically based on initial opinions, tolerance and network structure



Opinion Dynamics focused on 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 of the differences from neighbors' opinions*

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

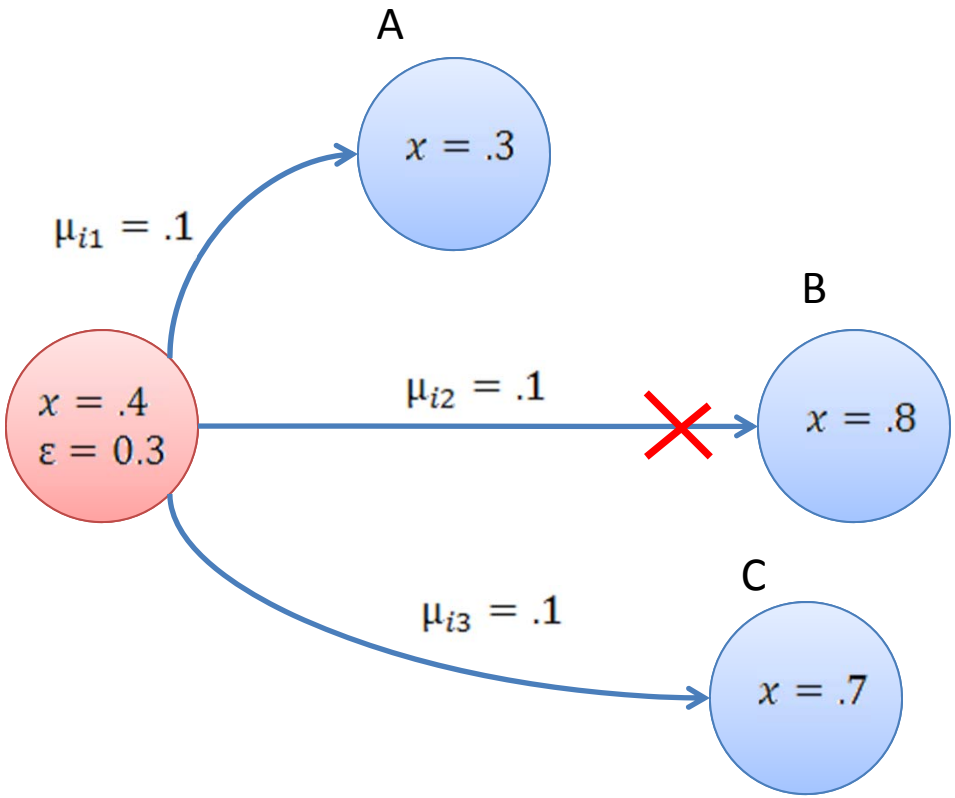
Effect of tolerance*: Ignore neighbors whose opinion is outside individual's tolerance.*

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

Opinion Dynamics Model: Effect of Tolerance

- A and C are within tolerance bound of red node
- B is outside of tolerance bound of red node and is excluded
- New value is original value plus scaled mean of neighbors' opinion

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



ε: Tolerance
μ: Plasticity
x: Opinion

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

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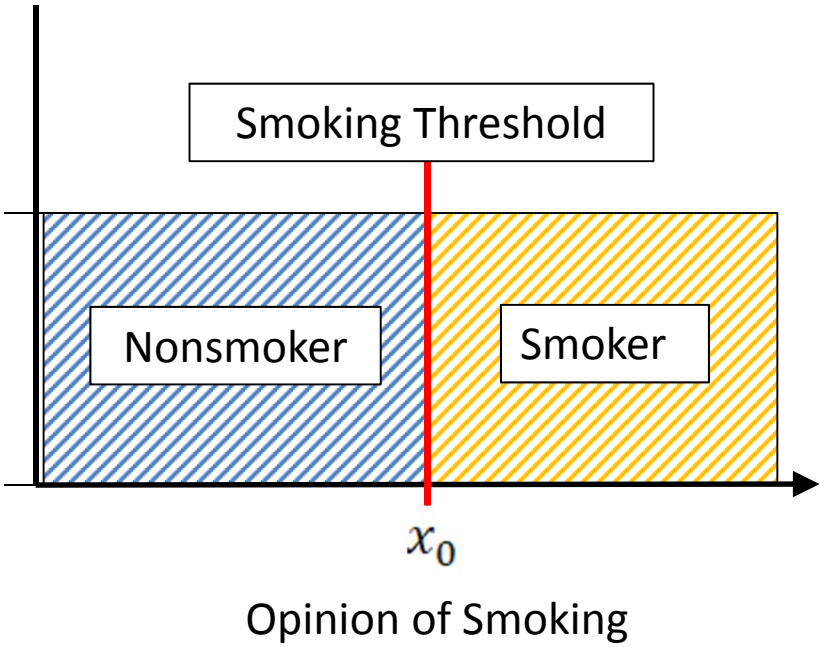
Mapping of Opinion to Behavior

- *Nonsmoker if opinion below threshold*
- *Smoker if opinion above threshold*



Mapping of Opinion to Behavior

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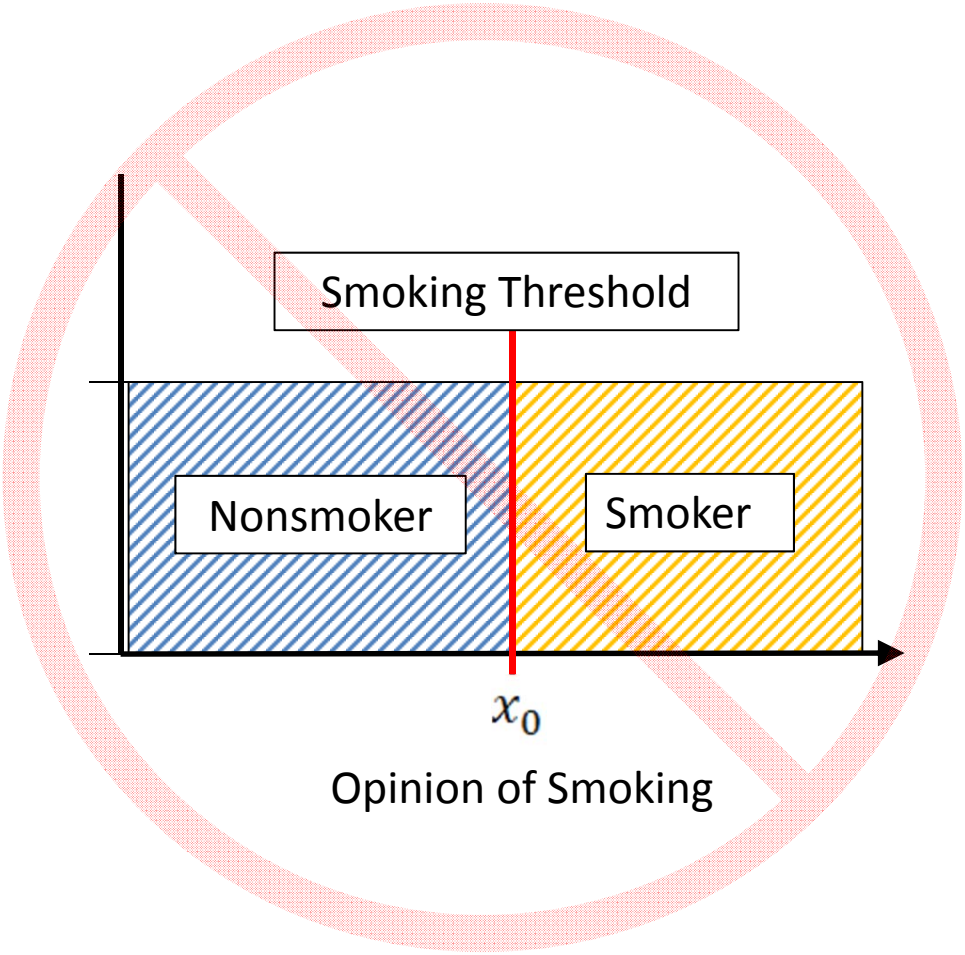
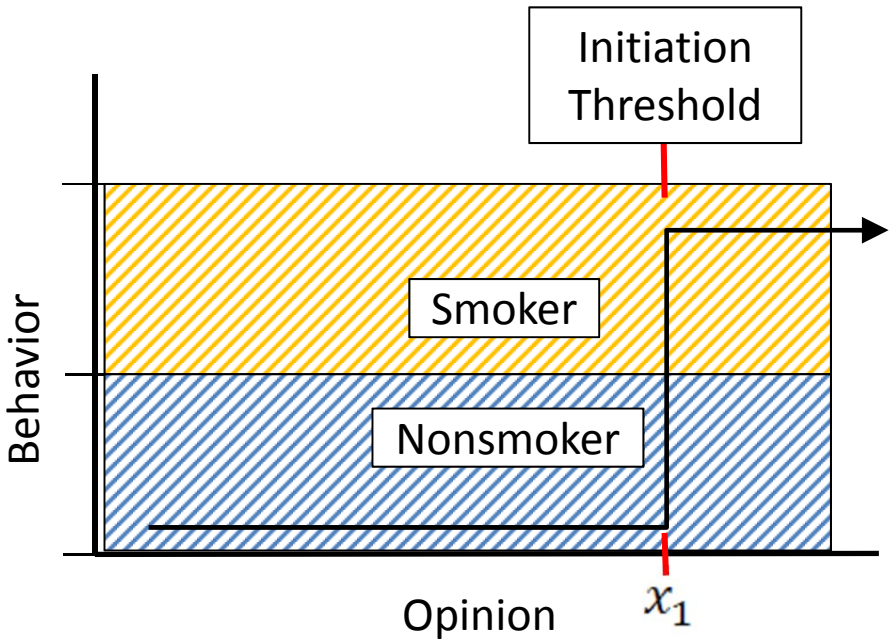


But this mapping does not capture effects of addiction

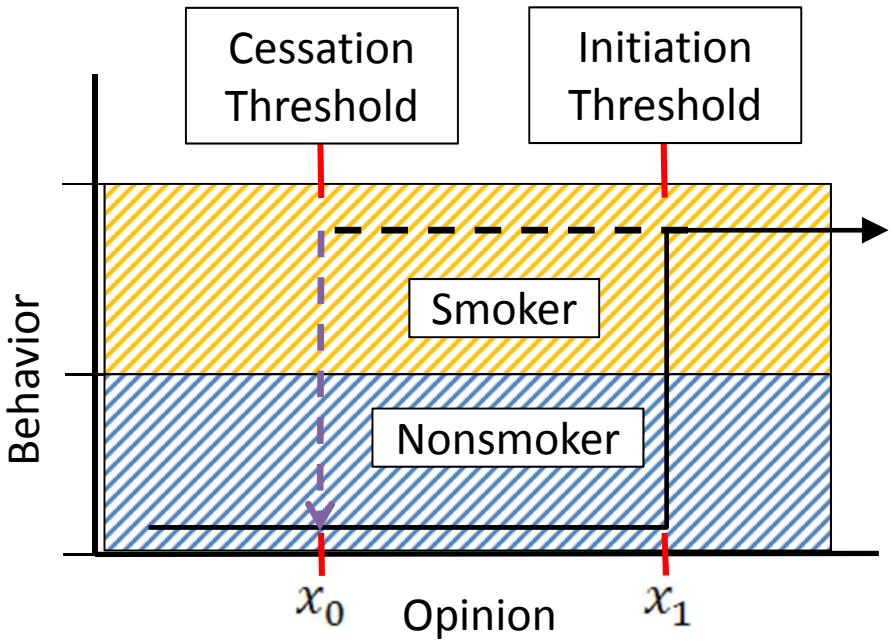
Opinion to Behavior Mapping with Addiction

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



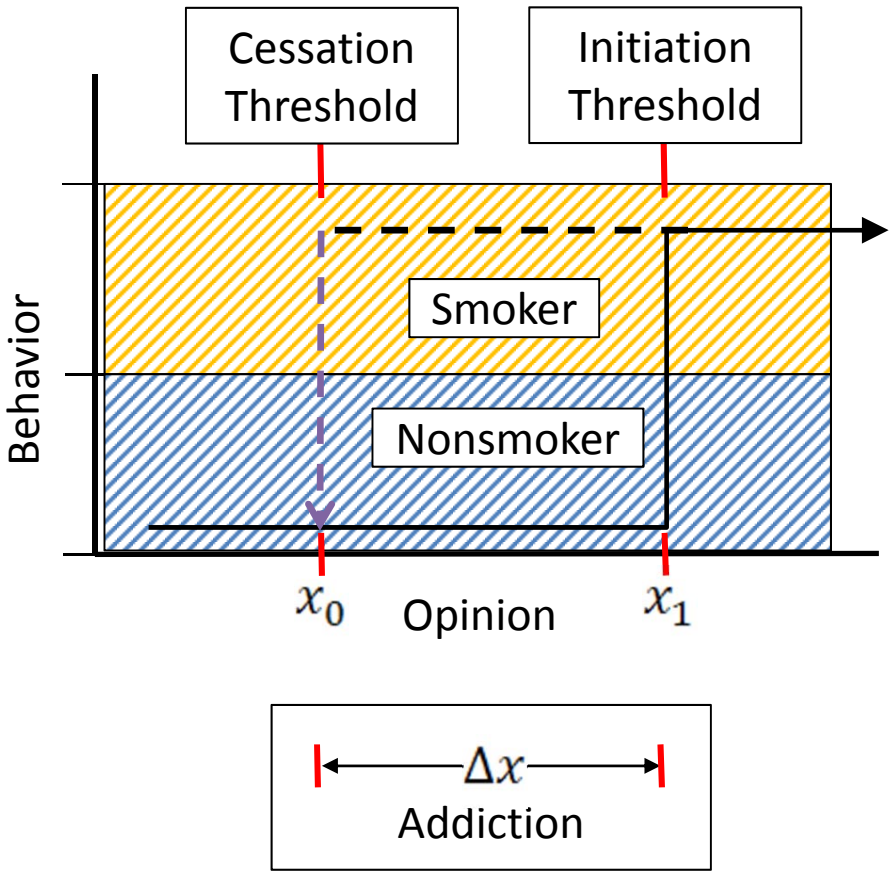
Opinion to Behavior Mapping with Addiction

- Individual smoking behavior is path-dependent (hysteretic)
- Start smoking when opinion exceeds initiation threshold (solid line)
- Quit smoking when opinion falls below cessation threshold (dashed line)



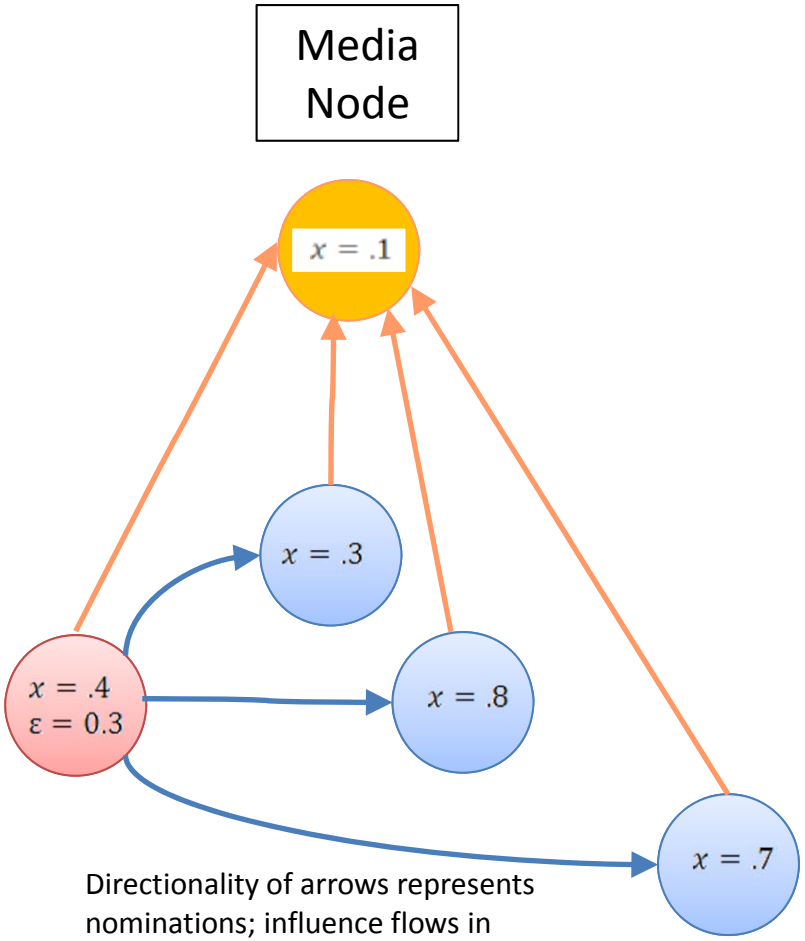
Opinion to Behavior Mapping with Addiction

- Individual smoking behavior is path-dependent (hysteretic)
- Start smoking when opinion 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 Media and Education

- Media nodes broadcast messages to individuals or specific groups
- Pro-tobacco media nodes push high-opinion or high-tolerance messages
- Public-health media nodes push low-opinion messages
- Multiple media nodes can act concurrently on population



Directionality of arrows represents nominations; influence flows in opposite direction

Applying the model

Example question:

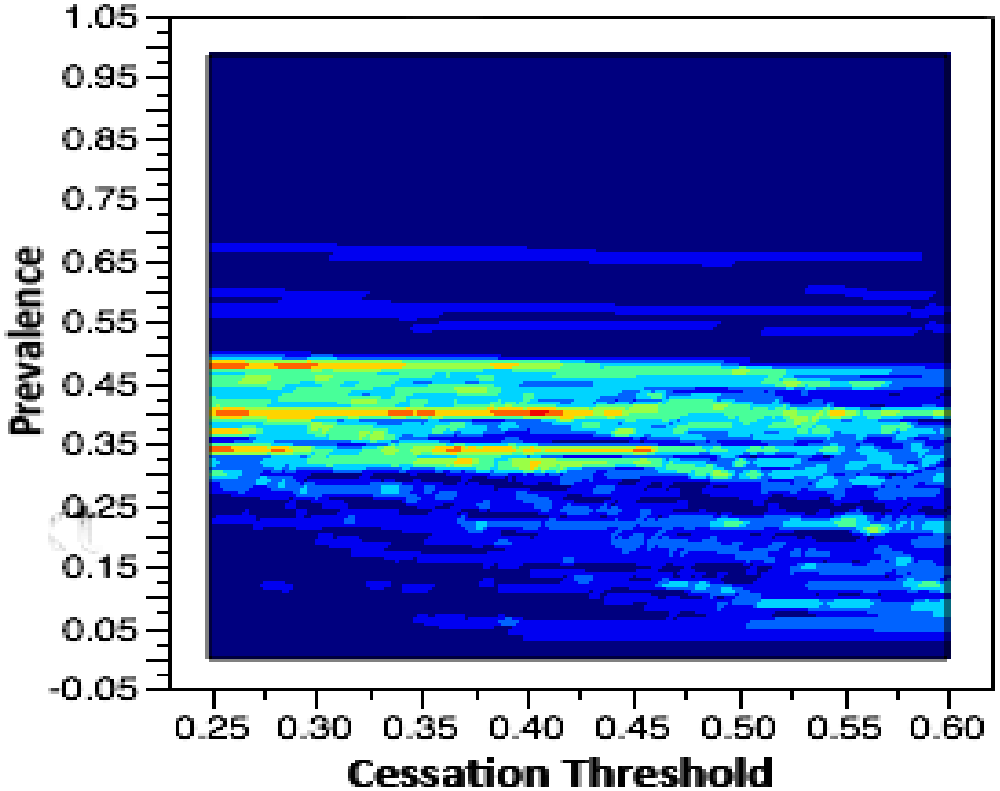
Does increased quit-line support affect smoking prevalence?

Basic Steps:

- Translate question into model-speak (Quit Supports = Cessation Threshold)
- Parameterize model with inputs which approximate study scenario
- Run model many times with different parameters and random components for exhaustive Sensitivity Analysis and Uncertainty Quantification.
- Generate ranges possible outcomes with explicit reliability bounds
- Visualizing model results often gives a better feel for complex relationships than simple numerical probability estimates

Example Result: Increase Cessation Threshold

No media influence



Without media influence :

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

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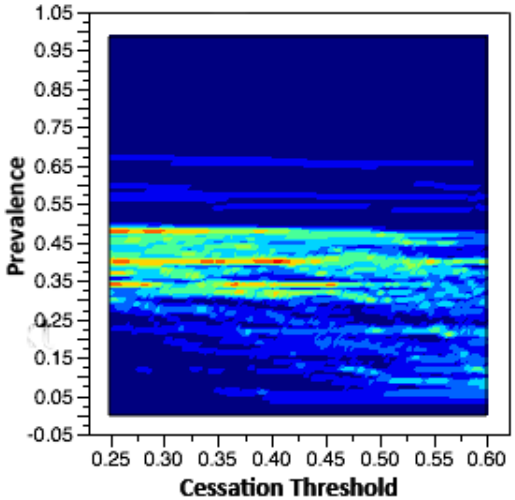
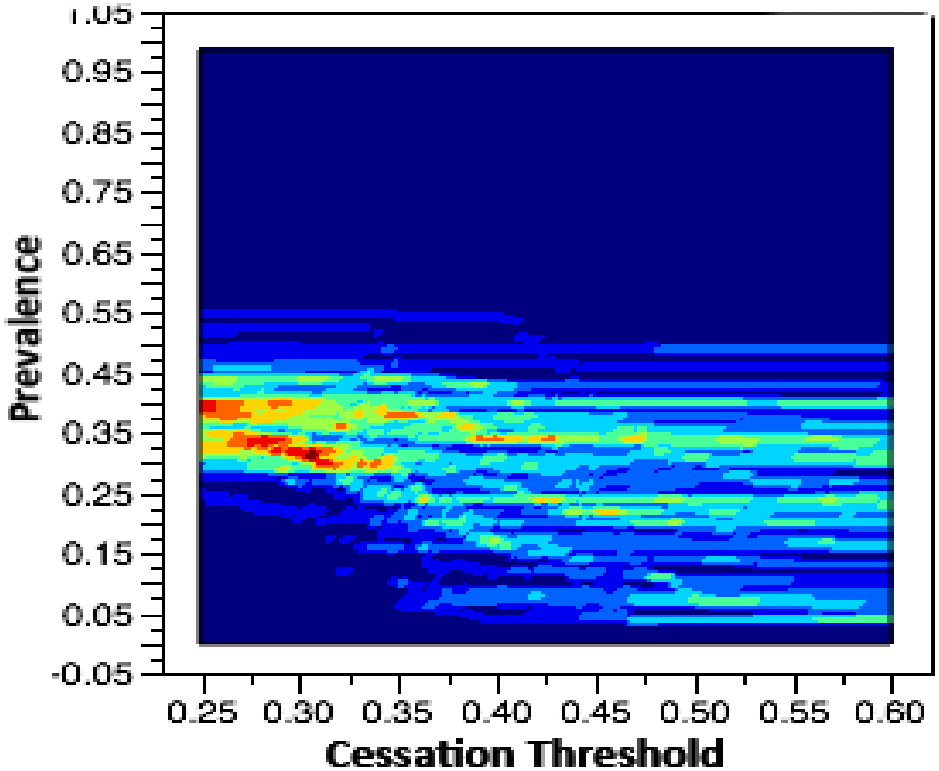
Add Public Health Education

No media



Public Health messaging



With concurrent Public Health education campaign:

Decrease in prevalence with small changes in cessation threshold

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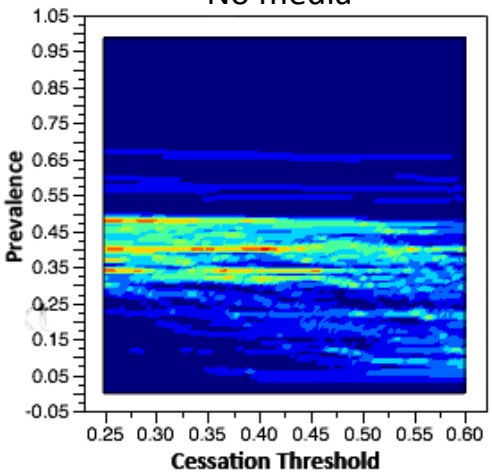
Add Pro-smoking Messaging

No media



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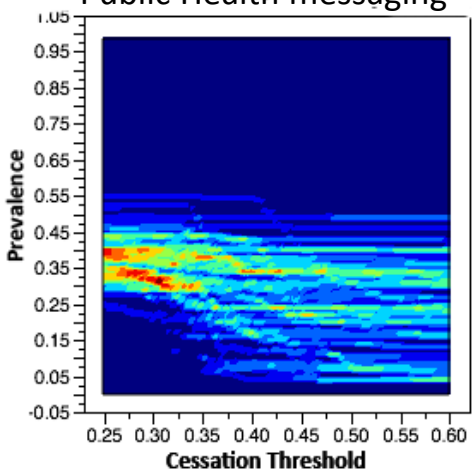
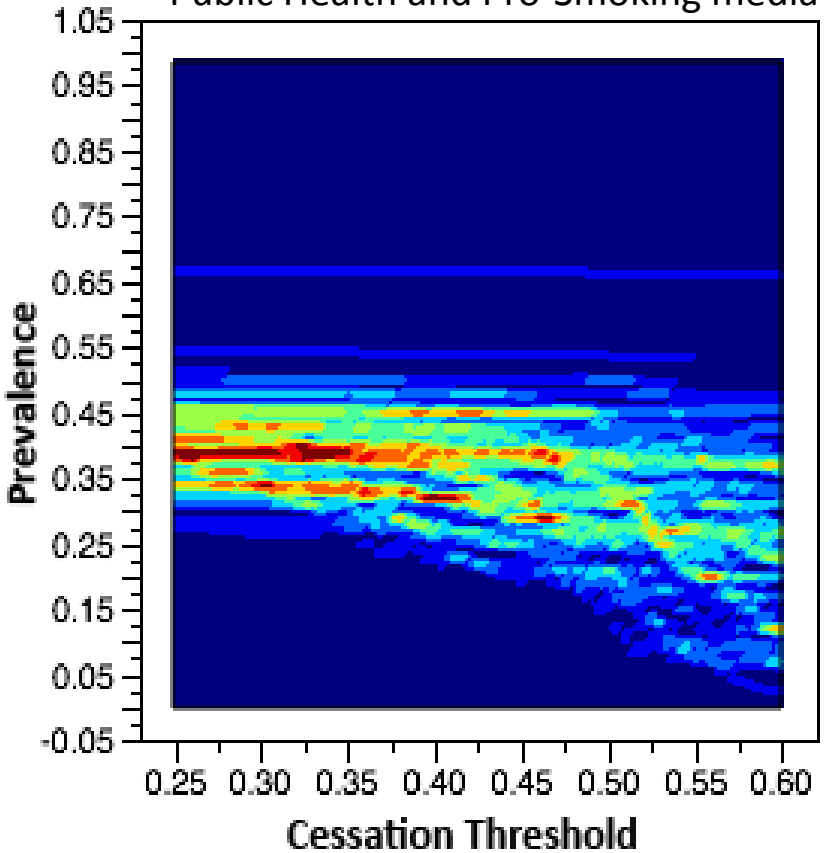


Public Health and Pro-Smoking media



Adding pro-smoking messaging:

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

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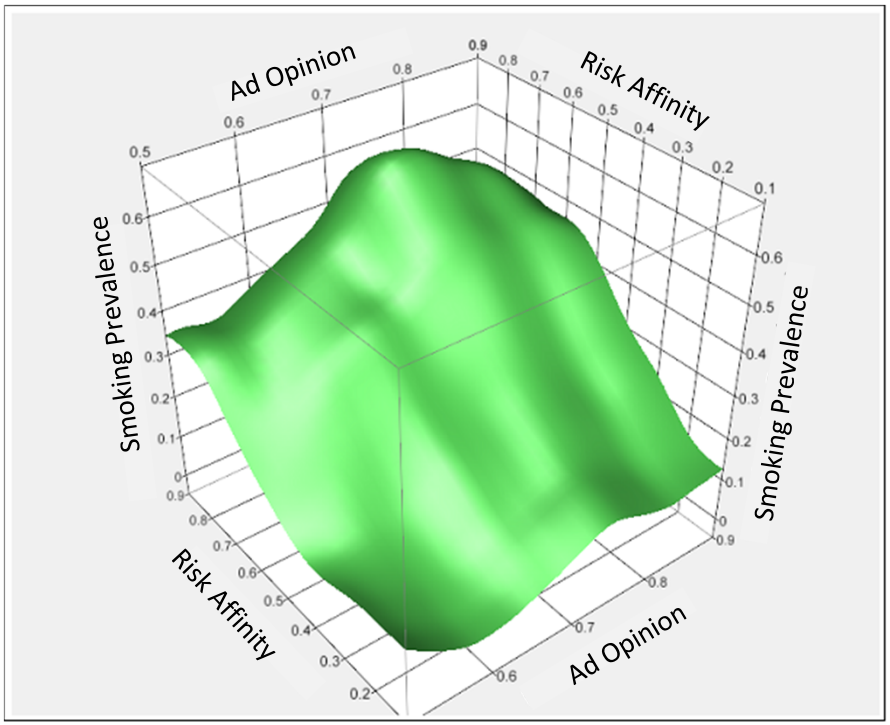
Modeling Risk

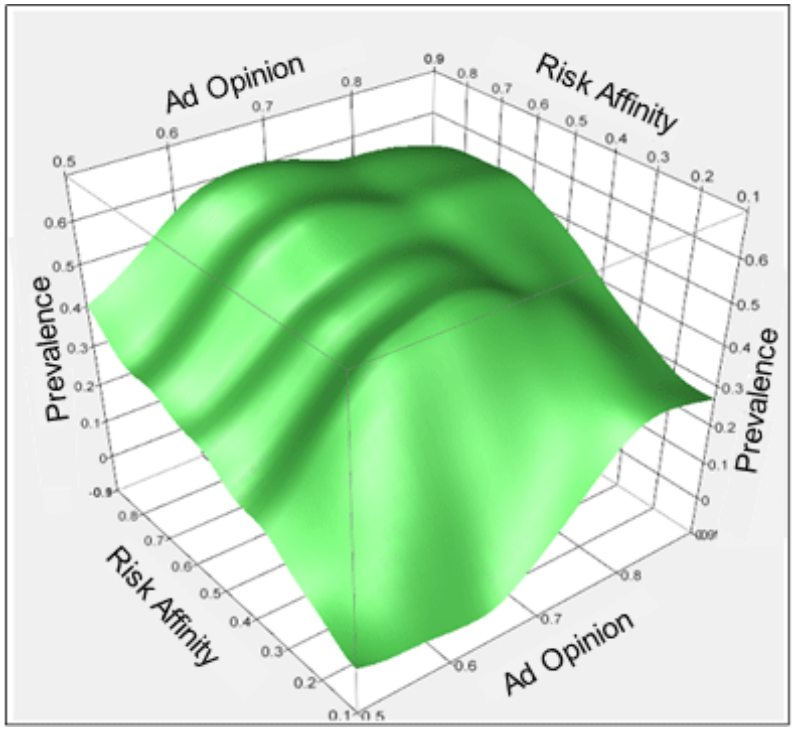
- Risk modeled by adding two new elements
  - Risk affinity: Property of individuals
  - Risk perception: Property of a class of products

- Risk-tolerant individuals ignore potential harm and use products with high perceived risk
- Risk averse individuals will use only products with low perceived risk
- Risk modeling enables analysis of multiple products

Risk Result: Multi-Product Prevalence



Cigarettes



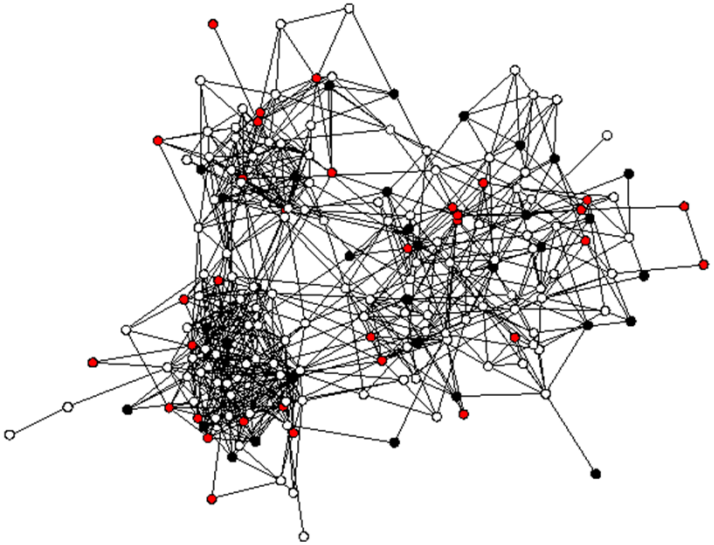
Novel Tobacco Product

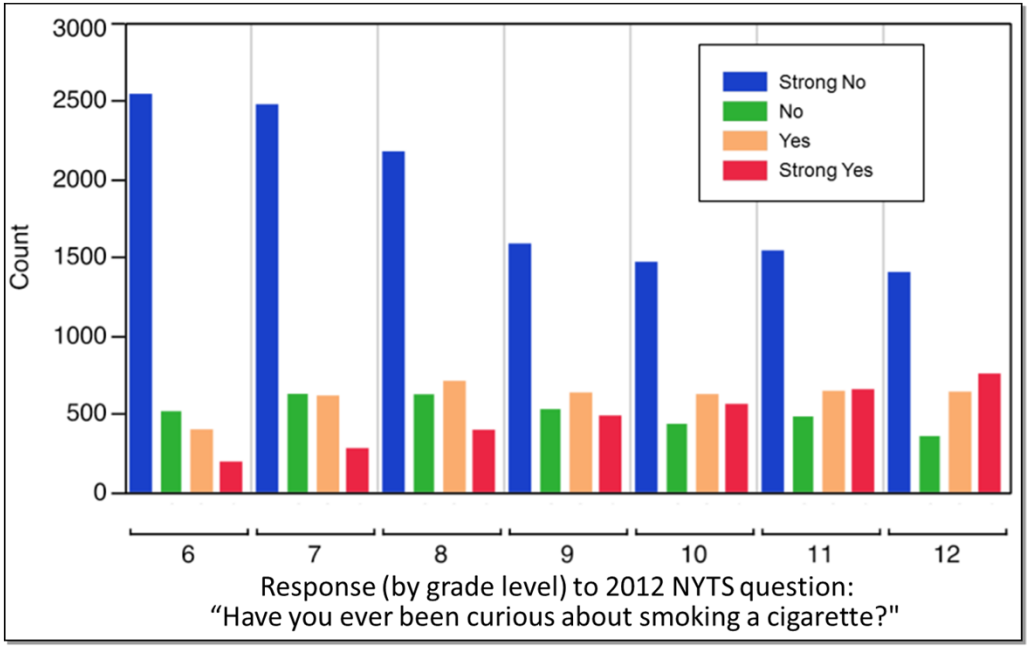
- Risk-averse individuals are less likely to use cigarettes due to the high perceived risk
- Low perceived risk tobacco products may cause risk-averse individuals to initiate
- Substantial numbers of non-tobacco users may become tobacco users

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





Uncertainty Analysis

- Sensitivity Analysis: *Effects of parametric uncertainty*
  - Identify impact of individual inputs
  - Identify where better data could reduce uncertainty
  - Traditional stats: Rank and stepwise regression
  - Sobol Variance Decomposition
  - ANOVA overlain on Gaussian process surrogate surfaces
  - Ensemble meta-models (e.g. PCE, TGP, Random Forest, CART classification trees) to map decision fronts and confidence bounds
- Second-order sensitivity: *Both parametric and stochastic uncertainty*
- Social Network Analysis
  - Traditional SNA
  - Bayesian methods, ERGMs

Lessons Learned Using Network Models

- Strive for smaller models
- Incorporate uncertainty analysis early in process
  - Sweeping parameter ranges and visualization for intuition
  - Evaluate large ensembles of results instead of single examples
- Use multivariate uncertainty methods
  - Single parameter analysis ignores interactions
  - Time domain multivariate uncertainty methods combine accuracy and interpretability
- Network models need a different type of data
  - Traditional surveys ignore connectivity among respondents
  - Need better surveys and borrowing from web analytics

Conclusions and Future Directions

- Individual-based models used to explore network-based influences on initiation and cessation rates useful for dynamic population models
- Opinion Dynamics framework enables exploration of possible future market conditions or actions
- Quantify effects of media and online factors on specific demographic segments.
- Future directions:
  - Extend multiple product modeling capabilities
  - Integrate additional data sources
  - Increase model resolution and scope

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Thank You