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’

\[ \{k \in S_i: |x_i(t) - x_k(t)| \leq \epsilon_i\} \]

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

- \( S_i \): Set of out-degree neighbors
  - (The people I connect with)
- \( \epsilon \): Tolerance
  - (Do you influence me?)
- \( \mu \): Plasticity
  - (How much do you influence me?)
- \( x \): Opinion
  - (My integrated view of tobacco use)
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)**
- Sophisticated
- Cool
- Group identity
- Adult
- Independent

**Practical Influences (Utility)**
- Weight control
- Stress relief
- Concentration

**Positive**
- SES association
- Addictive
- Smell/taste
- Corporate

**Negative**
- 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.

![Diagram showing 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.

But this mapping does not incorporate the effects of addiction.
Individual smoking behavior is path-dependent (hysteretic)
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Start smoking when opinion of smoking exceeds initiation threshold (solid line)
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)
- Start smoking when opinion of smoking exceeds initiation threshold (solid line)
- Quit smoking when opinion falls below cessation threshold (dashed line)
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
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

Directionality of arrows represents nominations; influence flows in opposite direction
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

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

- 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
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?