SnapDragon: A Social-Network Behavioral Dynamics Model of Tobacco Product Use

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What is SnapDragon?

- Model of tobacco use within hypothetical social networks
  - Information about tobacco product use is exchanged among persons in a population
  - Changes in attitudes toward tobacco products affect individuals’ initiation and cessation decisions
- Potential to incorporate media influences
  - Public Health messages
  - Industry advertisements
- Potential to incorporate risk / potential to provide insight
  - Product risk perception
  - Individual risk affinity
- Provides insight on effects of market and regulatory changes
  - What-if workbench to examine possible outcomes
  - e.g. Multiple product uptake and cessation rates under different conditions
Social Networks

- Network of people and social interactions.
- Represented mathematically as a graph
  - Nodes: People
    - Demographic info
    - Behaviors
  - Edges: Social connections
    - Type (friendship, romantic, influence)
    - Strength (good friend vs. acquaintance)
- Well-developed statistical methods to analyze graphs (networks).

Add Health adolescent tobacco-use network for a high-school class
Social networks: one way to understand tobacco use

“The evidence is sufficient to conclude that there is a causal relationship between peer group social influences and the initiation and maintenance of smoking behaviors during adolescence.”

- Preventing Tobacco Use Among Youth and Young Adults, A Report of the Surgeon General, 2012
Unger and Chen (1999) found that friends and family members who smoked influence age of initiation.

Alexander et al. (2001) looked at network influences on adolescent smoking,
- Smoking by best friends or > 50% of friends was predictive of adolescent smoking.
- Schools with high prevalence of smoking tended to be associated with more popular students being smokers.

Valente et al. (2005) showed that the probability of being a smoker in middle school is correlated with network position.

Christakis and Fowler (2008) looked at network correlations for smoking cessation, finding spousal, family, friend, and coworker influences on cessation.
SnapDragon: Causal Modeling Approach

- **Builds on social-network tobacco research:**
  - Leverage documented network effects on tobacco use
  - Supplant statistical look-back analysis with prospective modeling for changing conditions.

- **Computational simulation of tobacco initiation and cessation**
  - Flow of information between people and from media
  - Addiction
  - Risk-based decision making

- **Advantages of causal modeling**
  - Extend analyses to networks and demographics where data do not exist
  - Experimentally vary parameters, conditions and assumptions (for SnapDragon, this is on a hypothetical social network)
Conceptual Model: Network Influences Individual Opinions

- Family/Friends
- Products
- Information

Individual Opinion

WARNING: Tobacco smoke can harm your children.
Opinion Drives Behavior Transitions

Family/Friends → Individual Opinion → Individual Tobacco-Use Behavior

Products

Information

WARNING: Tobacco smoke can harm your children.
Many Factors Contribute to Behavior Change

Family/Friends

Individual Opinion

Products

Barriers to Access

Costs

Addiction

Risk Affinity

Information

Individual Tobacco-Use Behavior
Computational Model: Start with Opinion Spread

- Use software agents to represent a population of individuals

- Each individual assigned two values to start:
  - Opinion: Integrated view of tobacco
  - 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
Opinion Spreads in Network

\[ x_i(t + 1) = x_i(t) + \frac{1}{|N_i|} \sum_{N_i} \mu_{ik} [x_k(t) - x_i(t)] \]

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

\[ N_i \in S_i : |x_k(t) - x_i(t)| \leq \varepsilon_i \]

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

\[ S_i: \text{Set of out-degree neighbors} \]
\[ N_i: \text{Out-degree neighbors within tolerance} \]
\[ \varepsilon: \text{Tolerance} \]
\[ \mu: \text{Plasticity} \]
\[ x: \text{Opinion} \]
Opinions of Like-Minded Peers Matter in this Simulation of a Social Network

- Albert and Carol hold opinions within Pat’s tolerance bound.
- Beth is outside of Pat’s tolerance bound; her opinion is ignored.
- Pat’s peer-influenced opinion value is made up of his original value plus the scaled mean of Albert’s and Carol’s opinions.

\[ x_i(t) = 0.40 \]
\[ x_i(t + 1) = 0.41 \]

\[ \varepsilon: \text{Tolerance} \]
\[ \mu: \text{Plasticity} \]
\[ x: \text{Opinion} \]

(integrated view of tobacco use)

Scenarios are created using hypothetical social networks and inputs to demonstrate the functionality of the model. No policy purpose or outcome should be inferred.
Opinion: Integrated View of Tobacco

Social Influences (Affect)

- Sophisticated
- Cool
- Group identity
- Adult
- Independence

Practical Influences (Perceived Utility)

- Stress relief
- Concentration
- Avoiding the effects of withdrawal
- Weight control

Positive

Negative

- Déclassé
- Smell/taste
- Corporate

- Disease
- Addiction
- Dangers of Environmental Tobacco Smoke
Simple Opinion to Behavior Mapping

- **Tobacco Non-User if opinion below threshold**
- **Tobacco User if opinion above threshold**

![Diagram showing opinion to behavior mapping for tobacco product use. The diagram illustrates the mapping of opinion about tobacco products to behavior (use or non-use) with a threshold.](image-url)
- Tobacco Non-User if opinion below threshold
- Tobacco User if opinion above threshold

But this mapping does not capture effects of addiction
Opinion to Behavior Mapping with Addiction

- Individual tobacco-use behavior is path-dependent (hysteretic)
- Start using tobacco when opinion exceeds initiation threshold (solid line)
- Quit using tobacco when opinion falls below cessation threshold (dashed line)
Opinion to Behavior Mapping with Addiction

- Individual tobacco-use behavior is path-dependent (hysteretic)
- Start using tobacco when opinion exceeds initiation threshold (solid line)
- Quit using tobacco when opinion falls below cessation threshold (dashed line)
- Magnitude of the hysteresis effect represents strength of addiction
Modeling Media and Education

Information sources modeled as social network nodes broadcasting messages to individuals

- Pro-tobacco information sources represented as high-opinion messages, values closer to 1.0
- Public-health information sources represented as low-opinion messages, values closer to 0.0

Scenarios are created using hypothetical social networks and inputs to demonstrate the functionality of the model. No policy purpose or outcome should be inferred.
Effect of Media Message Content on Network Opinion

- Public Health messaging (0.0 to 0.5) drops average network opinion
- Industry Advertising (0.5 to 1.0) increases average network opinion

Scenarios are created using hypothetical social networks and inputs to demonstrate the functionality of the model. No policy purpose or outcome should be inferred.
Asking Questions with SnapDragon

Example question:

*How can boosting cessation support affect smoking prevalence?*

Basic Steps:

- Map 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
- Visualize model results to give better understanding of interactions and unanticipated consequences than simple numerical probability estimates

*Scenarios are created using hypothetical social networks and inputs to demonstrate the functionality of the model. No policy purpose or outcome should be inferred.*
In a hypothetical network in which there is no knowledge of the harms of tobacco products, changes in the cessation threshold may yield only minor changes in smoking prevalence (people are not trying to quit)

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

Scenarios are created using hypothetical social networks and inputs to demonstrate the functionality of the model. No policy purpose or outcome should be inferred.
In a hypothetical network, in which there is messaging about the harms of tobacco, and people are trying to quit, if the cessation threshold is increased due to cessation support, there is a greater impact on prevalence.

Scenarios are created using hypothetical social networks and inputs to demonstrate the functionality of the model. No policy purpose or outcome should be inferred.
In a hypothetical network with both public health and pro-smoking messaging, a larger increase in the cessation threshold is required to achieve smoking-prevalence values similar to the those seen in the absence of pro-smoking messages (some people are trying to quit, other are not).

Scenarios are created using hypothetical social networks and inputs to demonstrate the functionality of the model. No policy purpose or outcome should be inferred.
Parameterize Model to Test Tobacco Control Measures

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Model Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide cessation support</td>
<td>Raise the cessation threshold</td>
</tr>
<tr>
<td>Decrease access through age limits, and enforce regulations</td>
<td>Raise the initiation threshold for specified age group or population</td>
</tr>
<tr>
<td>Decrease access through indoor air laws, or taxes</td>
<td>Raise the initiation and cessation thresholds for a specified age group or population</td>
</tr>
<tr>
<td>Increase health consciousness</td>
<td>Add education node(s)</td>
</tr>
</tbody>
</table>
Modeling Risk to Address Multiple Products

- Risk is a key component in modeling behavior change in multiple-product regimes
  - Risk affinity: Property of individuals
  - Risk perception: Property of a class of products

- Assumptions:
  - Risk-tolerant individuals neglect potential harm and will use products with high perceived risk
  - Risk averse individuals will use only products with low perceived risk

- Incorporating risk can provide comparative values for use of multiple products
Preliminary Results: Effect of Perceived Risk on Modeled Prevalence

- Lower perceived risk increases modeled prevalence for the same ranges of risk affinity and broadcast opinion (greater volume under the surface)
- The effectiveness of broadcast opinion is altered by the combined effects of perceived risks and risk affinity
Iteratively verify model additions as model is developed
  – Incrementally adding features by layering complexity only as needed
  – Exhaustive use of testing and sensitivity analysis to confirm model responses

Ongoing Testing and Validation of Assumptions
  – Formal testing of assumptions
  – Documentation of validation results

Plan for Validation with Real-World Data
  – Piece-wise validation of components with data from studies and surveys
  – Requires data set covering opinion, behavior and network dynamics for comprehensive verification
SnapDragon Validation Data Needs

- Require integrated data sets for comprehensive validation
  - Add Health* provides behavior and possible network topology
  - NYTS** shows changes in adolescent opinions but lacks connectivity

* Add Health: National Adolescent Health Survey
** NYTS: National Youth Tobacco Survey
Promising New Data

- Valente et al. 2014* collected three-year longitudinal data on 1,200 students in five LA High Schools
- Final year surveys included questions on tobacco opinion from SnapDragon team
- Preliminary data providing critical information on network topologies, assortativity patterns and opinion-to-behavior mapping

*From Variations in network boundary and type: A study of adolescent peer influences, Thomas W. Valente et al., [in press: Social Networks, an international journal of structural analysis]. Support for this research was provided by NIH/NCI grant #CA157577-02S1 (Valente, PI)
SnapDragon Summary

- Can model tobacco use within a social network
  - Information about tobacco product use flows through network
  - Changes in attitudes toward tobacco products influence behavior
- Can incorporate media influences
- Can model multiple products through risk perception
- Potential applications
  - What-if workbench to examine scenario outcomes
  - Generate endogenous transition rate values for traditional models
  - Illustrate possible interactions among regulatory, media and market influences
Thank You