

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

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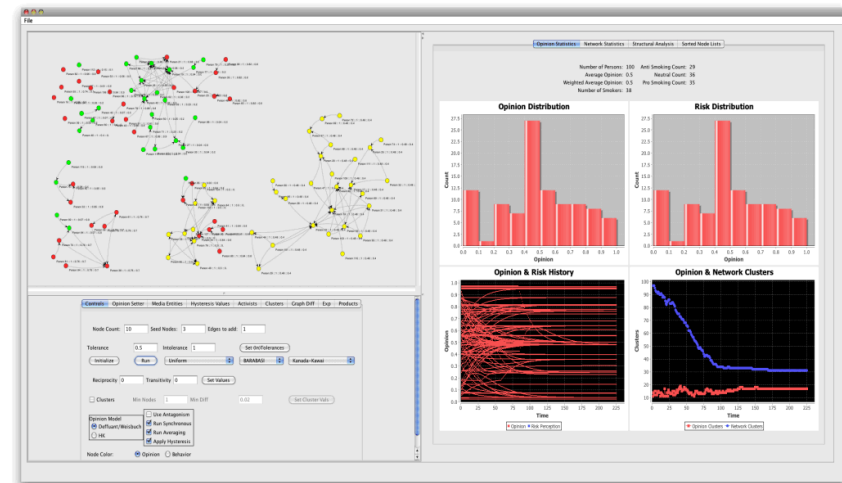
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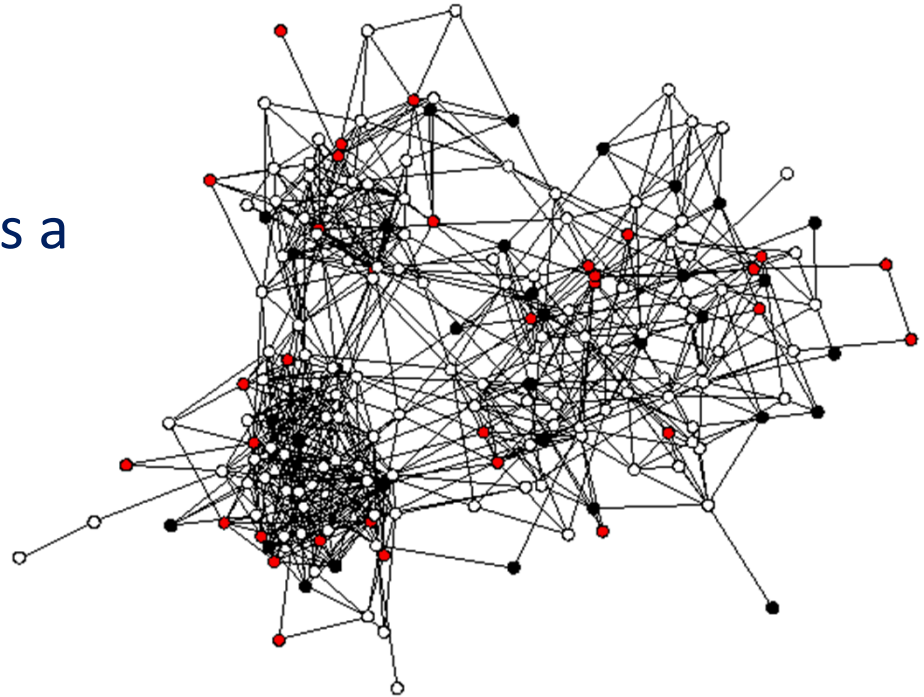
# What is SnapDragon?

- 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

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“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.”

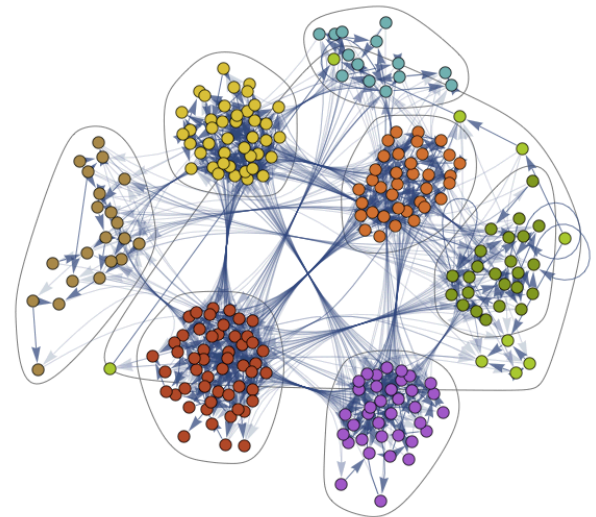
# Social Network Analysis in Tobacco Research

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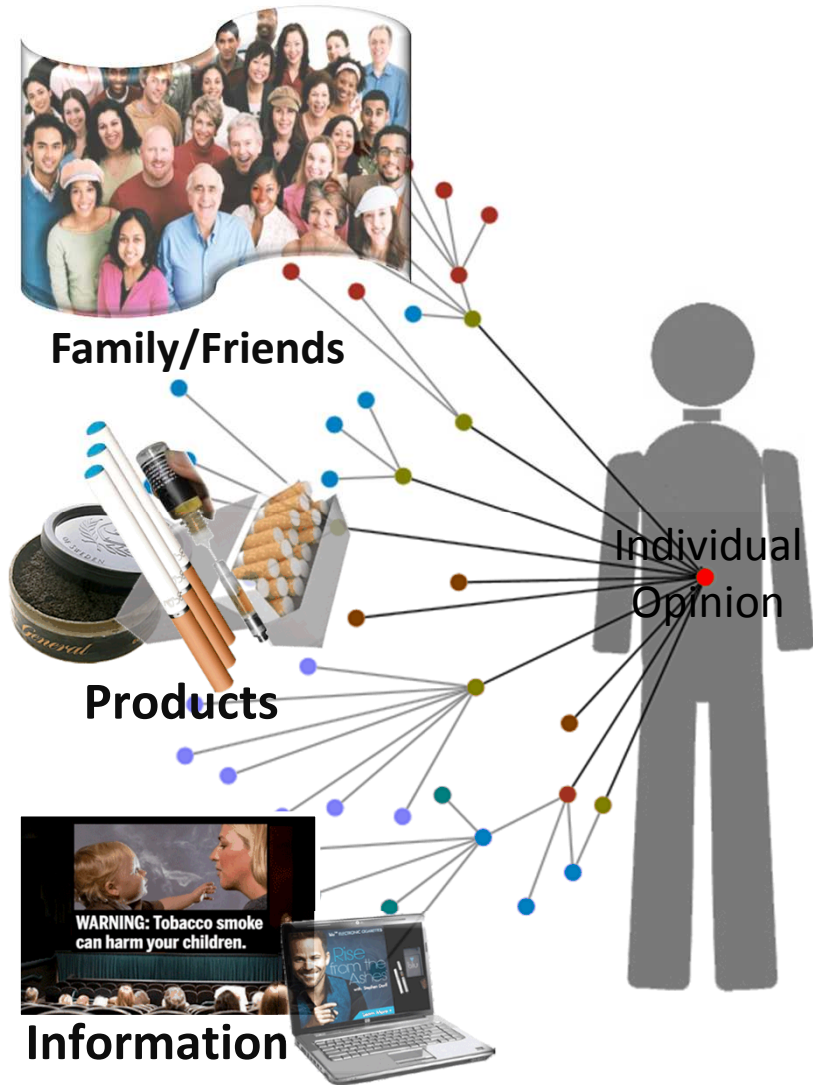
- Unger and Chen (1999) found that friends and family members who smoked influence age of initiation
- Alexander et al. (2001) looked at network influences on adolescent smoking,
  - Smoking by best friends or > 50% of friends was predictive of adolescent smoking
  - Schools with high prevalence of smoking 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)

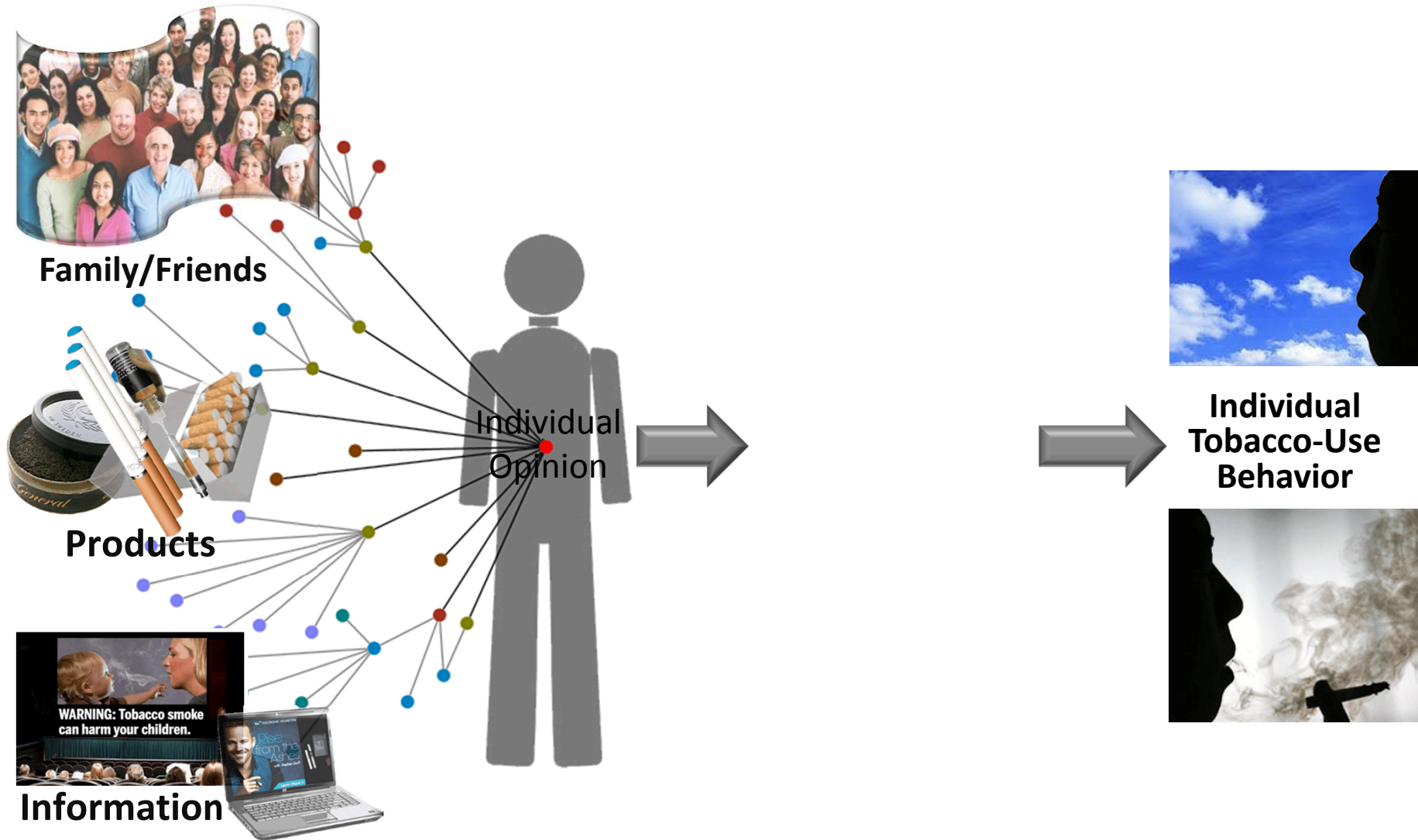


# Conceptual Model: Network Influences Individual Opinions



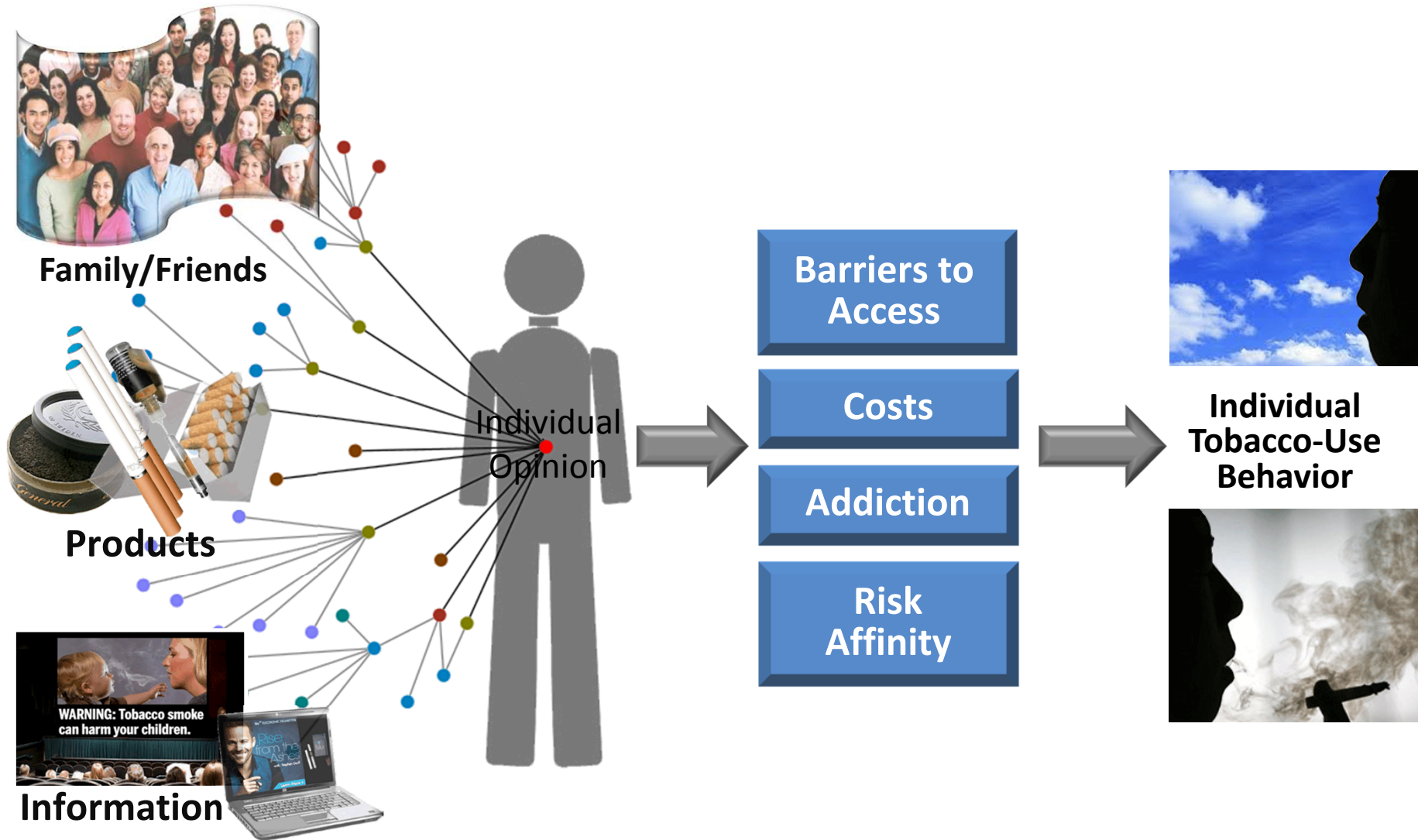


# Opinion Drives Behavior Transitions



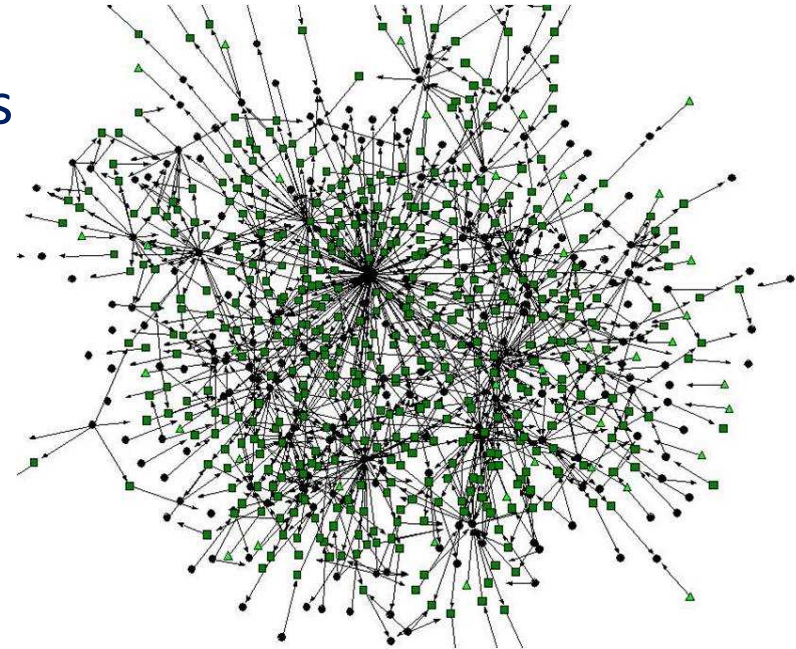


# Many Factors Contribute to Behavior Change



# 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.*

$S_i$ : Set of out-degree neighbors

$N_i$  Out-degree neighbors within tolerance

$\varepsilon$ : Tolerance

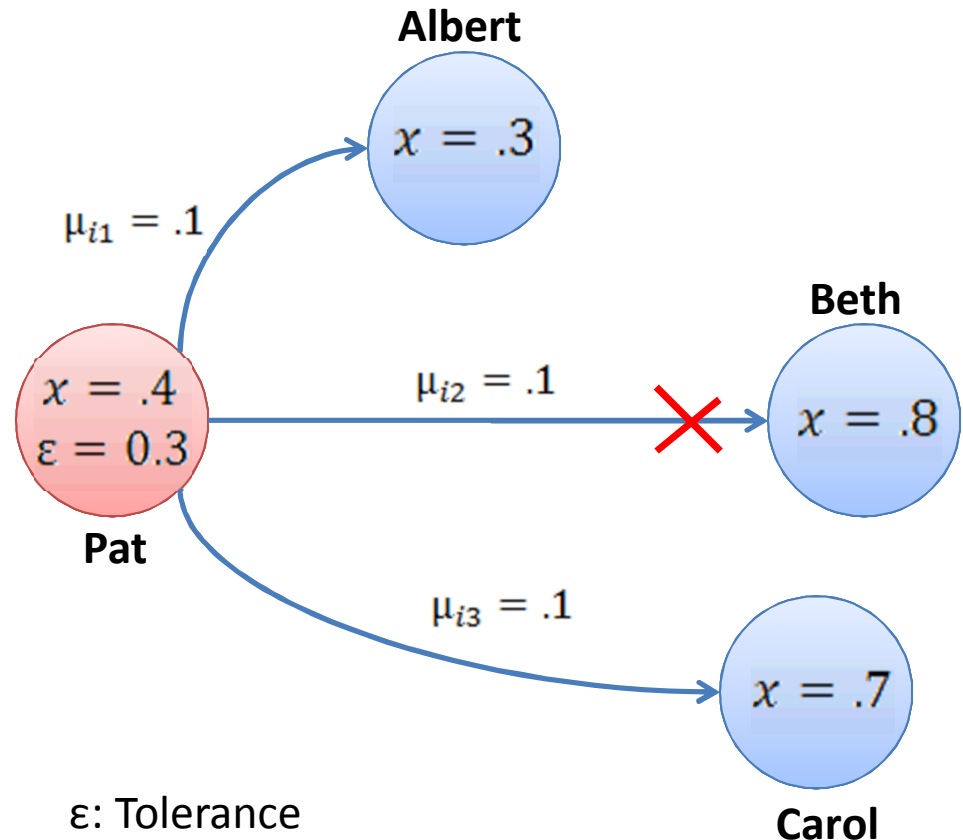
$\mu$ : Plasticity

$x$ : 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



$$x_i(t) = 0.40$$

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

$\varepsilon$ : Tolerance

$\mu$ : Plasticity

$x$ : Opinion

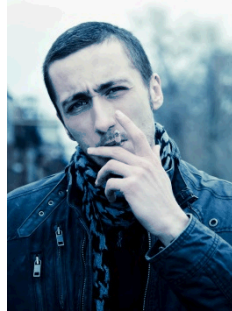
(integrated view of tobacco use)

# Opinion: Integrated View of Tobacco

## Social Influences (Affect)

Positive

- Sophisticated
- Cool
- Group identity
- Adult
- Independence



## Practical Influences (Perceived Utility)

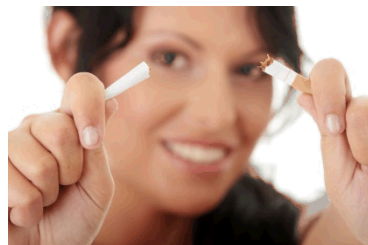
- Stress relief
- Concentration
- Avoiding the effects of withdrawal
- Weight control



Positive

Negative

- Déclassé
- Smell/taste
- Corporate



- Disease
- Addiction
- Dangers of Environmental Tobacco Smoke

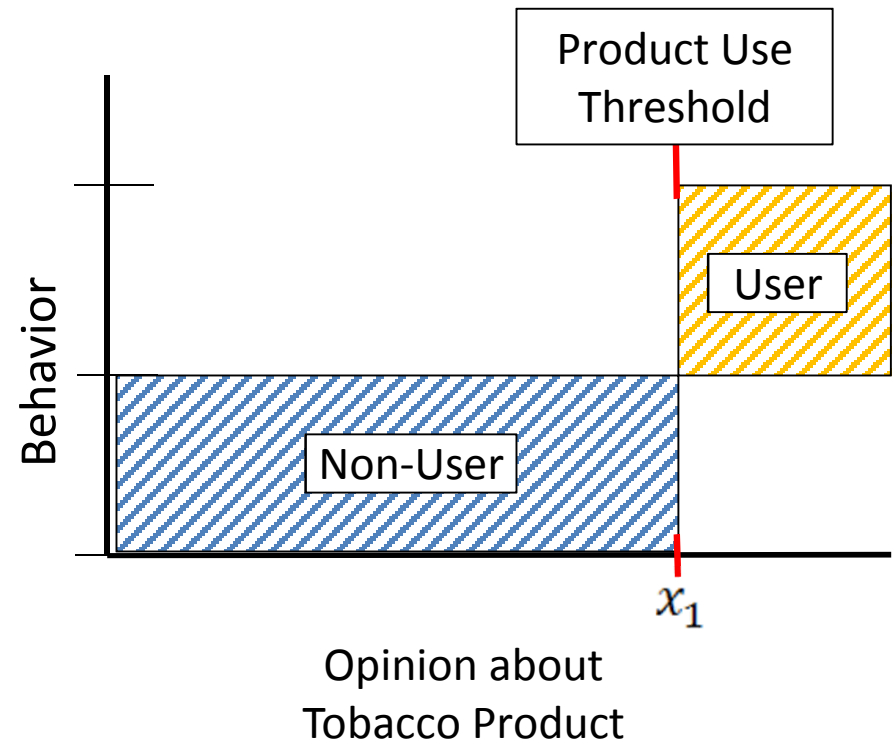


Negative



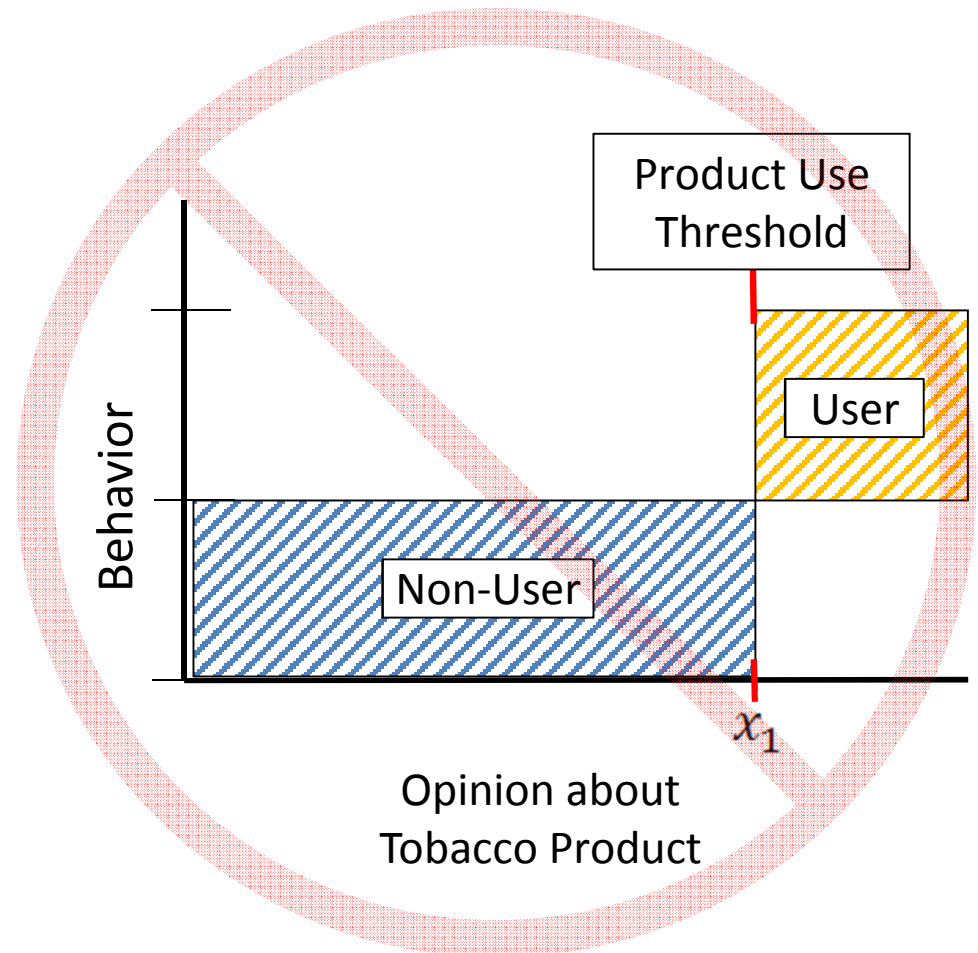
# Simple Opinion to Behavior Mapping

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



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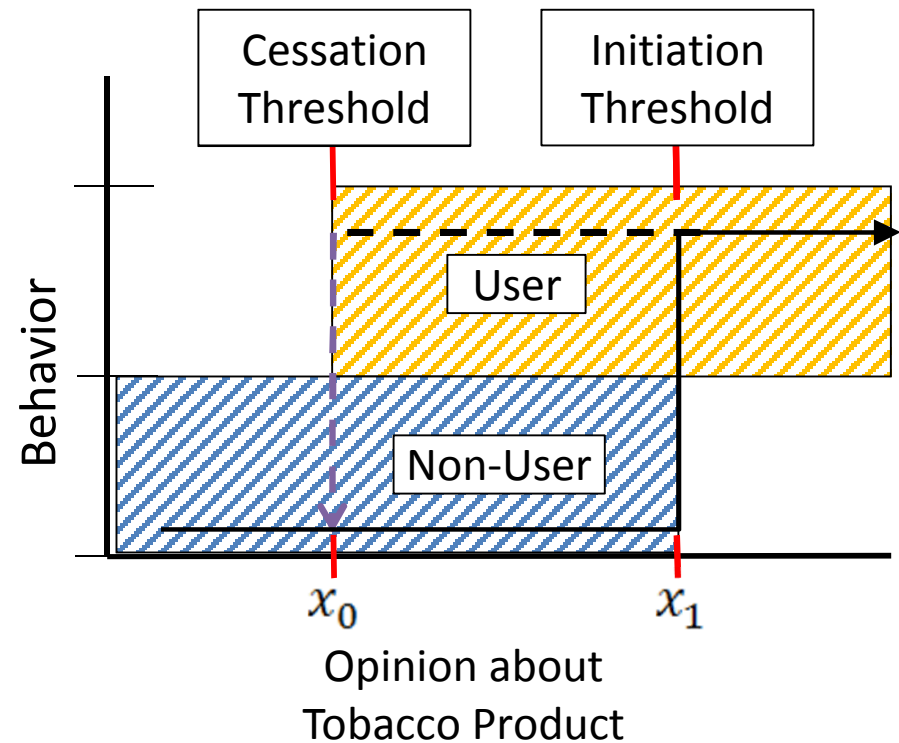


**But** this mapping does not capture effects of addiction



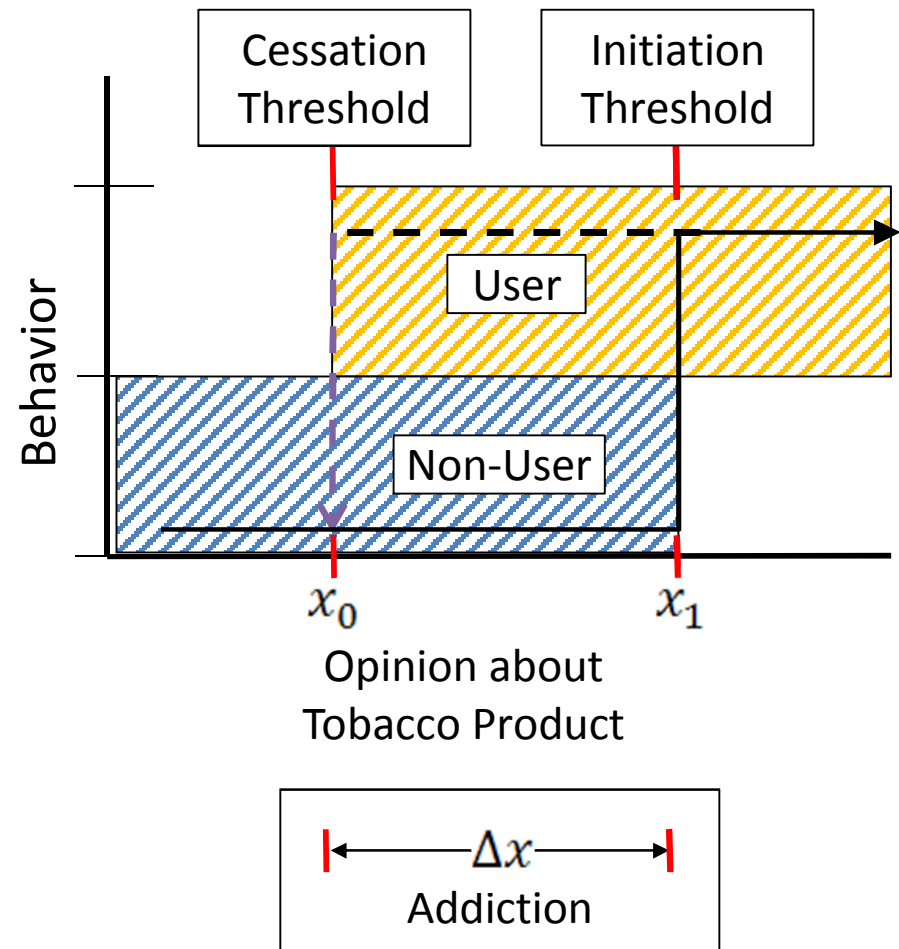
# Opinion to Behavior Mapping with Addiction

- 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

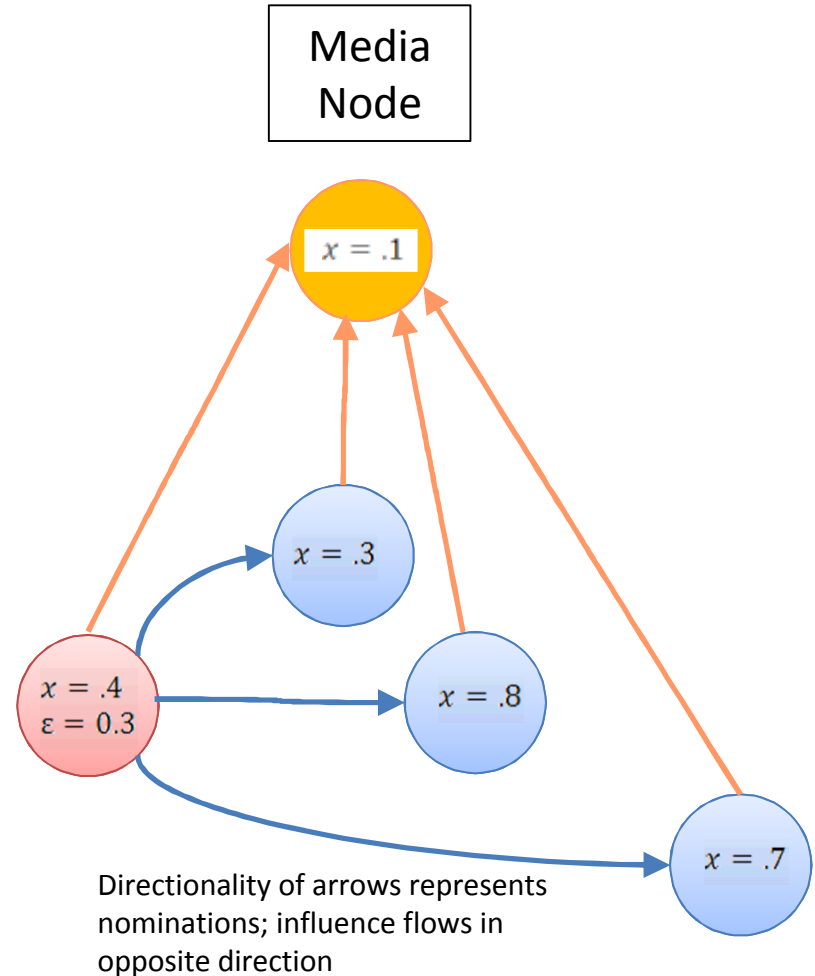
- Individual tobacco-use behavior is path-dependent (hysteretic)
- Start using tobacco when opinion exceeds initiation threshold (solid line)
- Quit using tobacco when opinion falls below cessation threshold (dashed line)
- Magnitude of the hysteresis effect represents strength of addiction



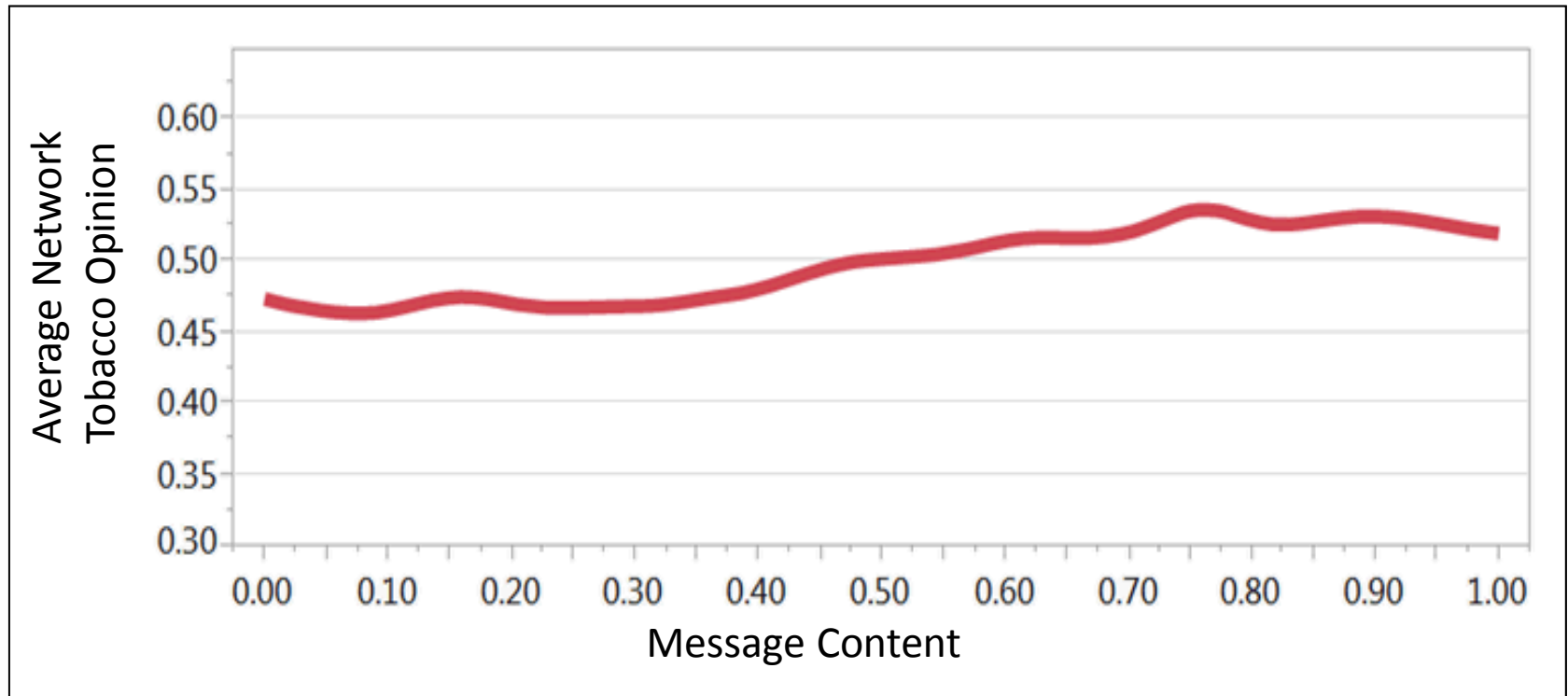
# Modeling Media and Education

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



# 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

- 10,000 model runs
- 250-agent network

# Asking Questions with SnapDragon

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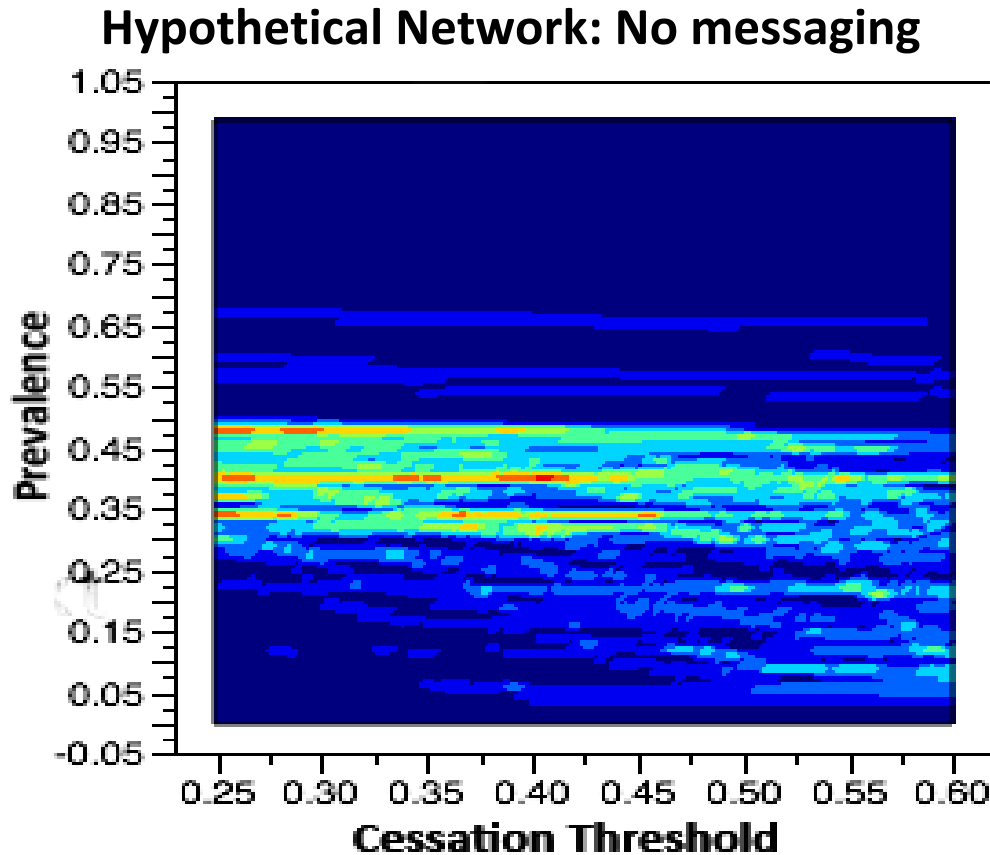
- Example question:

*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

# Example Analysis Results - Influence of Quit-line Support (Increase Cessation Threshold) on Smoking Prevalence



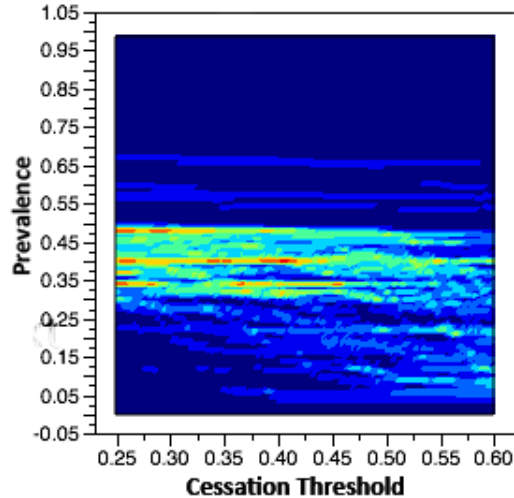
*In a hypothetical network in which there is no knowledge of the harms of tobacco products, changes in the cessation threshold may yield only minor changes in smoking prevalence (people are not trying to quit)*

3-D histograms of model outputs:

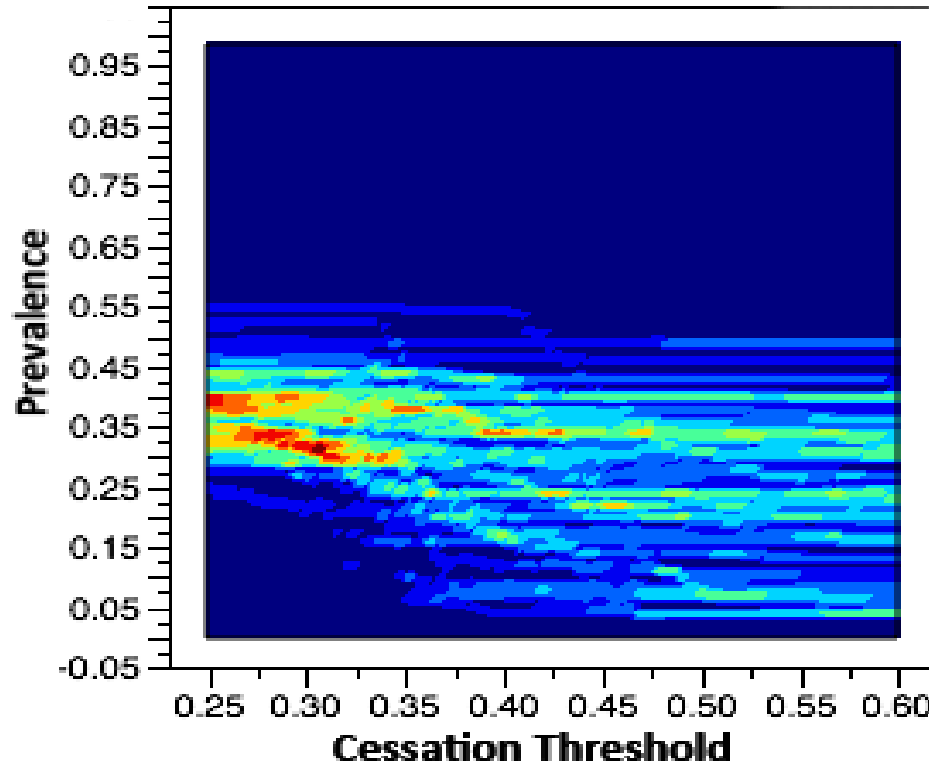
Each graphic illustrates 10,000 simulations of 250-node networks

# Example Analysis Results - Influence of Quit-line Support on Smoking Prevalence: Add Public Health Messaging

No media



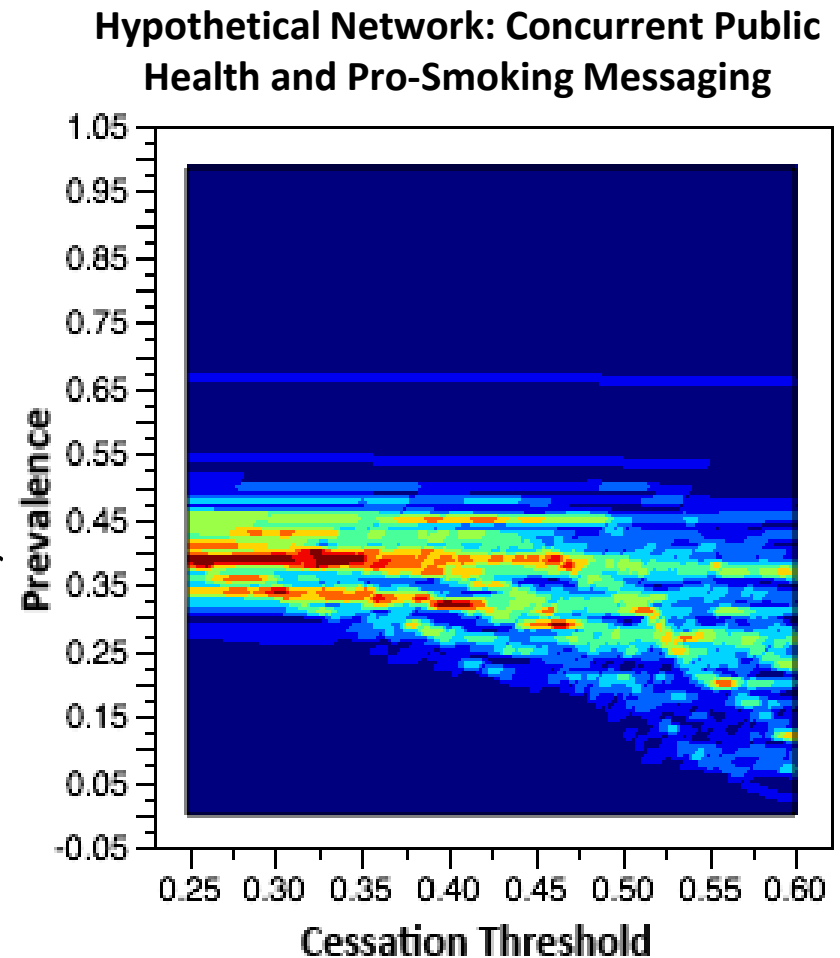
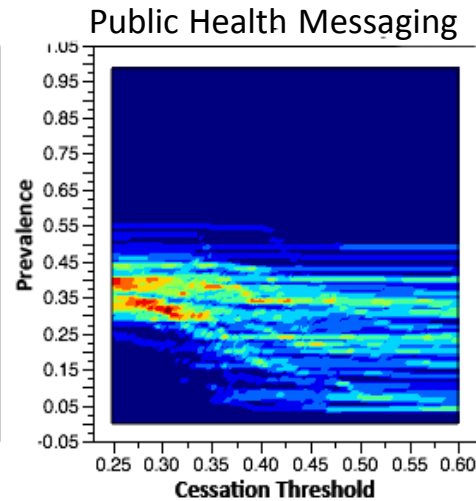
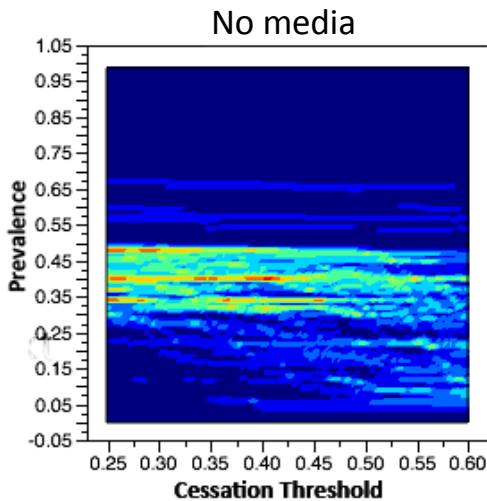
Hypothetical Network: Public Health Messaging



*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.*



# Example Analysis Results - Influence of Quit-line Support on Smoking Prevalence: Add Public Health & Pro-Smoking Messaging



*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)*

# Parameterize Model to Test Tobacco Control Measures

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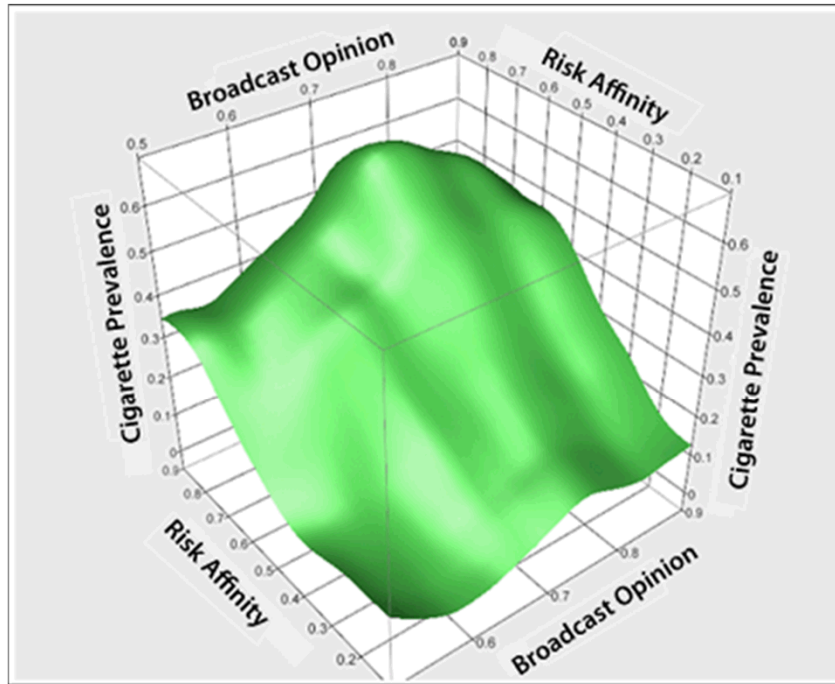
Intervention	Model Adjustment
Provide cessation support	Raise the cessation threshold
Decrease access through age limits, and enforce regulations	Raise the initiation threshold for specified age group or population
Decrease access through indoor air laws, or taxes	Raise the initiation and cessation thresholds for a specified age group or population
Increase health consciousness	Add education node(s)

# Modeling Risk to Address Multiple Products

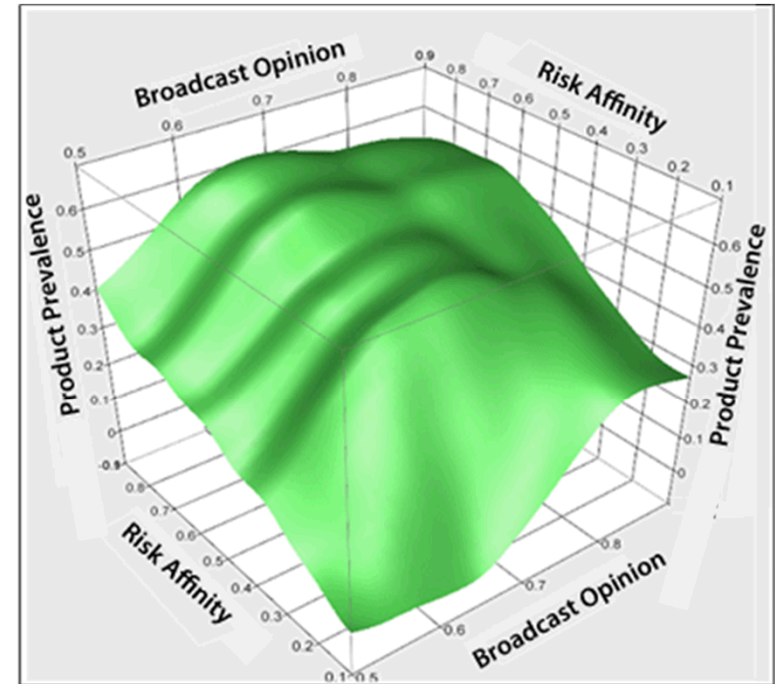
- Risk is a key component in modeling behavior change in multiple-product regimes
  - Risk affinity: Property of individuals
  - Risk perception: Property of a class of products
- Assumptions:
  - Risk-tolerant individuals neglect potential harm and will use products with high perceived risk
  - Risk 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



Cigarettes



Lower Perceived Risk Product

- 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

# SnapDragon Verification and Validation

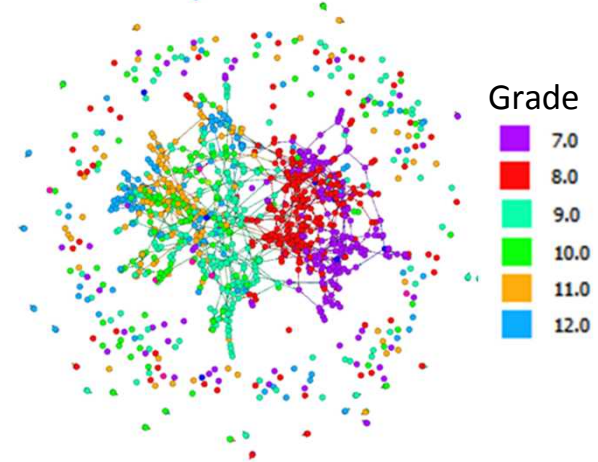
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- Iteratively verify model additions as model is developed
  - Incrementally adding features by layering complexity only as needed
  - Exhaustive use of testing and sensitivity analysis to confirm model responses
- Ongoing Testing and Validation of 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

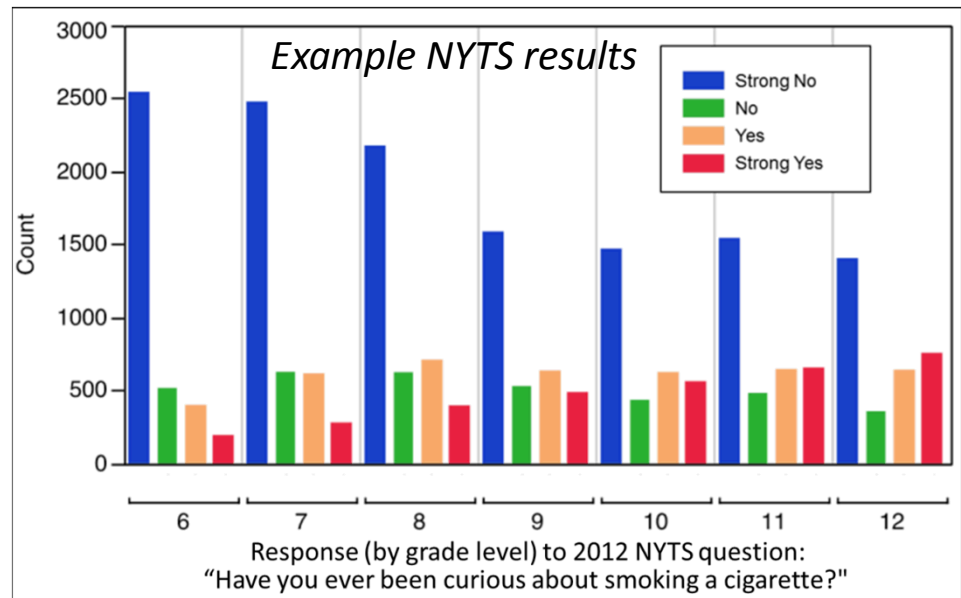
# SnapDragon Validation Data Needs

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

*Example adolescent network by grade-level from Add Health data*



*Example NYTS results*



\* Add Health: National Adolescent Health Survey

\*\* NYTS: National Youth Tobacco Survey

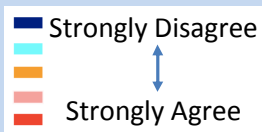
# Promising New Data

- 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

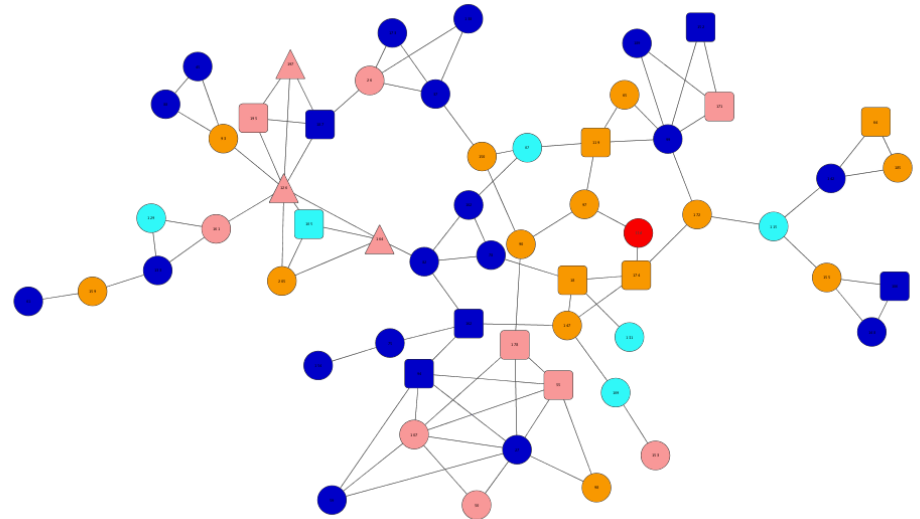
## Example Influence Network (School 3)

*Smoking helps calm an angry person*

Colors:



Shapes: Square -> Smoker  
Triangle -> Occasional  
Circle -> Nonsmoker

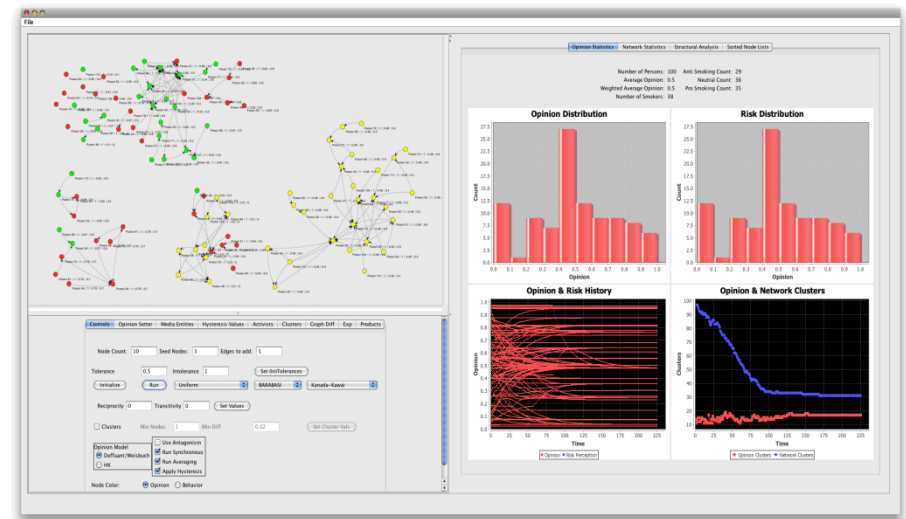


\* From Variations in network boundary and type: A study of adolescent peer influences, Thomas W. Valente et al., [in press: *Social Networks, an international journal of structural analysis*]. Support for this research was provided by NIH/NCI grant #[CA157577-02S1](#) (Valente, PI)



# 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