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Using SnapDragon to Examine a Two-Tobacco-Product System: The Potential Impact of Risk Perception on Tobacco Use Prevalence

June 26, 2014

***SnapDragon: Social Network Analysis for Policy on Directed Graph Networks**

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Status Update on SnapDragon Model

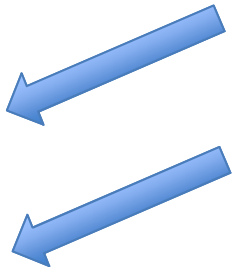
- In February
  - Provided an overview of the SnapDragon model
  - Presented model testing results for single-product version
    - Demonstrated how we might model multiple products
      - Risk perceptions; dual use; switching
  - SnapDragon as a useful framework for examining tobacco product use as an emergent behavior due to changes in products and regulations
- Today: Demonstrate 2-product model capability
  - Brief model overview
  - Model testing for two-product model, hypothetical scenarios
  - Model hypothesis testing

Compare two products for which risk perceptions differ:
Effects of risk perceptions, information, intervention timing on tobacco use.

Outline

Today

- Brief model overview
- Model testing for two-product model
- Model hypothesis testing
- Conclusions



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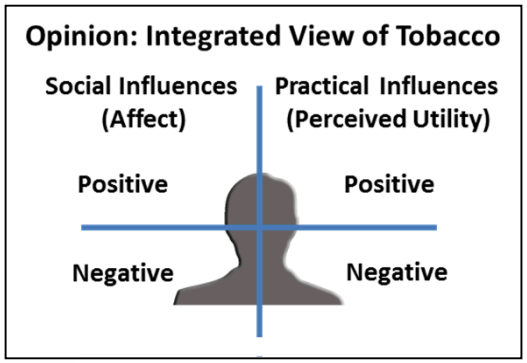
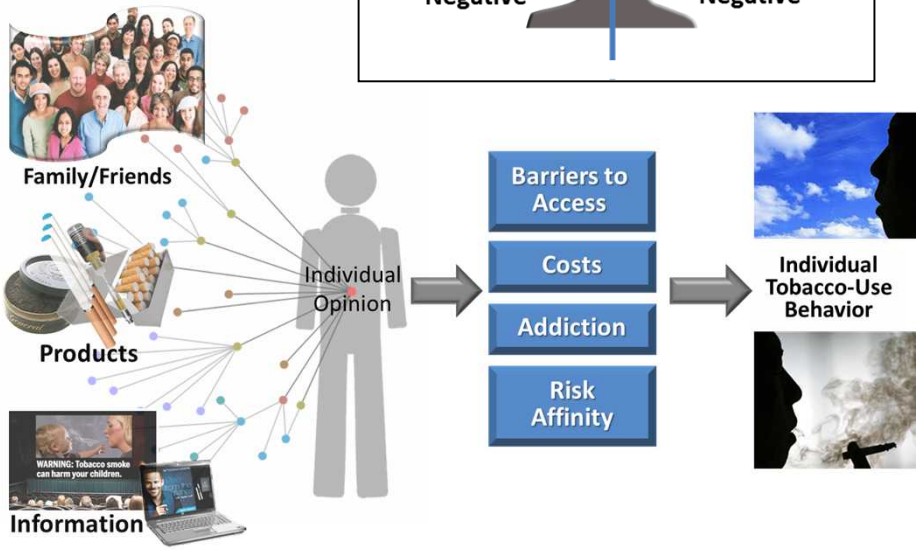
Review of SnapDragon

- SnapDragon: Opinion-driven behavior model of tobacco use
- Individuals initiate or quit tobacco use based on opinions about products (compared with threshold values)
- Opinions are influenced by social networks, by media (including marketing and public health campaigns)
  - Message reach can be variable, effective for sub-sets of population
  - Message strength can be variable
- Product attributes: Perceived risk, accessibility for a sub-population (product cost, age limits, availability)
- Sub-population attributes: Initial opinion, addiction factor (degree of addiction), risk affinity





Model helps us disaggregate a complex problem into (relatively simple) critical social variables; perturb with specific interventions and see what happens

Two–Product Model Testing

- Modeling Questions for Two-Product System
  - What are the effects of risk perception on differences in product prevalence?
  - How might interventions affect product prevalence? Quitting and switching?
  - What are the effects of intervention timing?
- Why these modeling questions?
  - Differences in risk-perception may influence tobacco product use
  - Information (from government, industry, social media, etc.) about the health effects of tobacco products may influence use

Introduction to Scenarios

- Our goal in these scenarios is to better understand the potential role that perceived risk may play under different conditions
- Model scenarios are necessary simplifications
  - Modeling allows disaggregation of a complex problem into tractable components
- Additional influences not specifically modeled in these scenarios:
  - Differences in products related to perceived utility, price point, barriers to access, sensory experience, etc.

Model-Testing Scenario Specifications

Scenario Description	Model Representation
Scenario 1: No Intervention	
• Products A and B are on the market. • Consumers perceive the risks of these products differently, as induced by industry marketing/social media/etc. • Messaging inflates perceptions of reduced risk of Product B use	• Product A on market with information messaging: - High-risk opinion • Product B on market with advertisements for - High product opinion - Low-risk opinion

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Scenario 2: Educational Intervention*	
• Information becomes available, Product B is not lower risk than Product A • Individuals are influenced if information is within their tolerance range	• Previous scenario plus information messaging on Product B - Low product opinion - High-risk opinion

* Interventions are initiated as network opinions form but before they become fully instantiated

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Scenario 3: Educational and Marketing Interventions*	
• Marketing intervention: remove low-risk messaging for Product B	• Previous scenario plus remove low-risk messaging - Stop messages with low-risk opinion of Product B - Continue educational message, product ads

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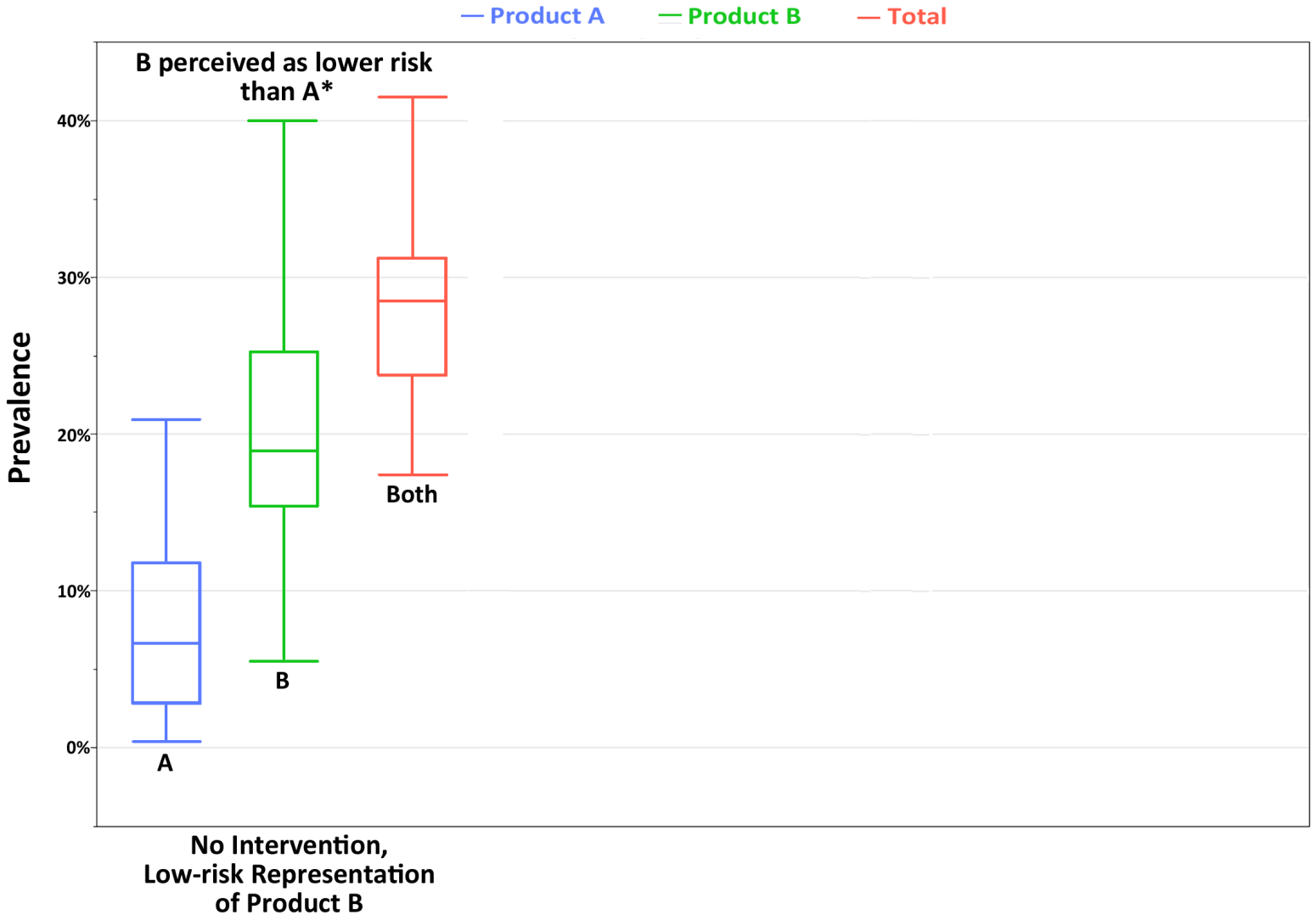
Model Testing Results: Intervention Impacts on Prevalence



*All other model parameters remain the same.

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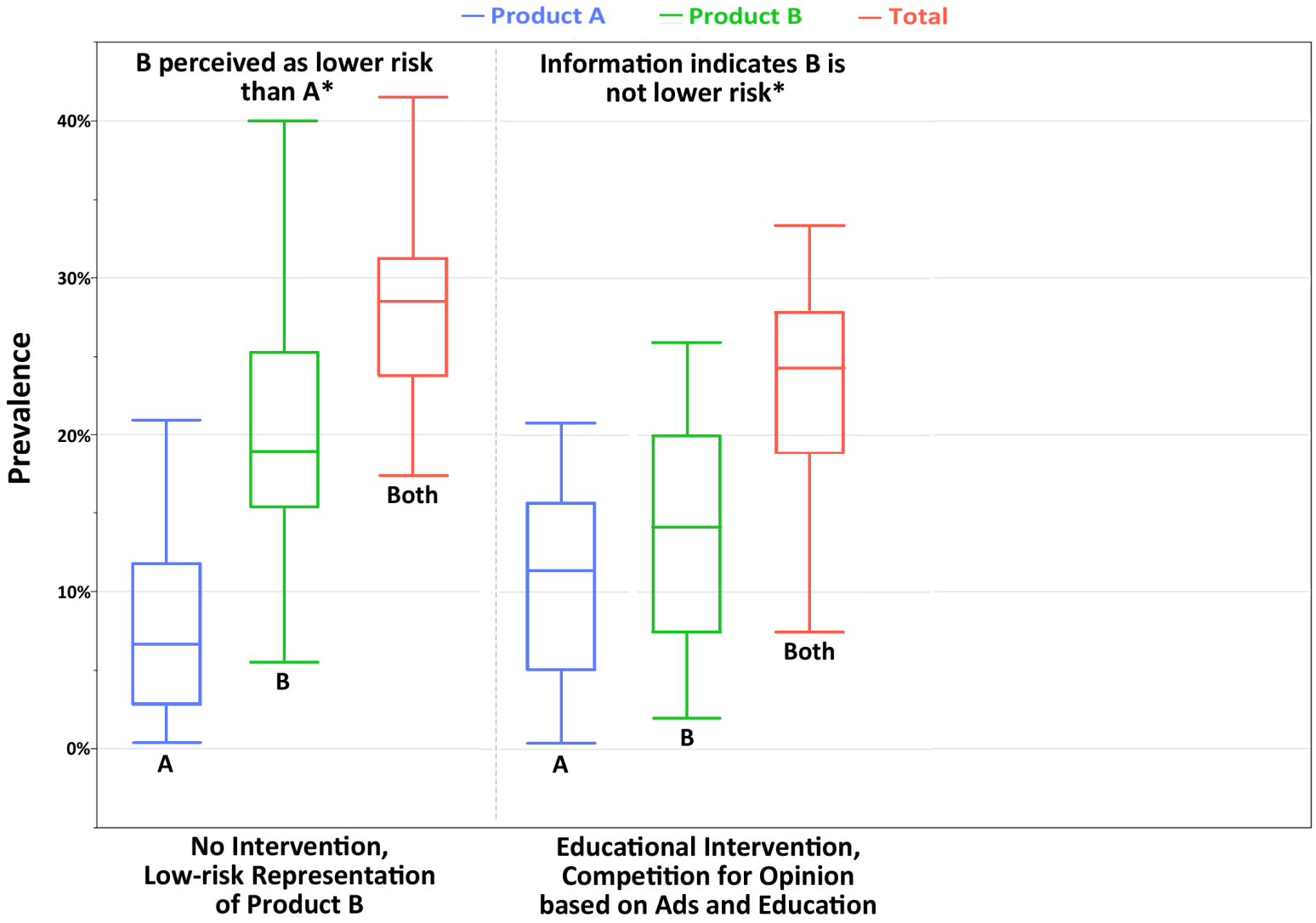

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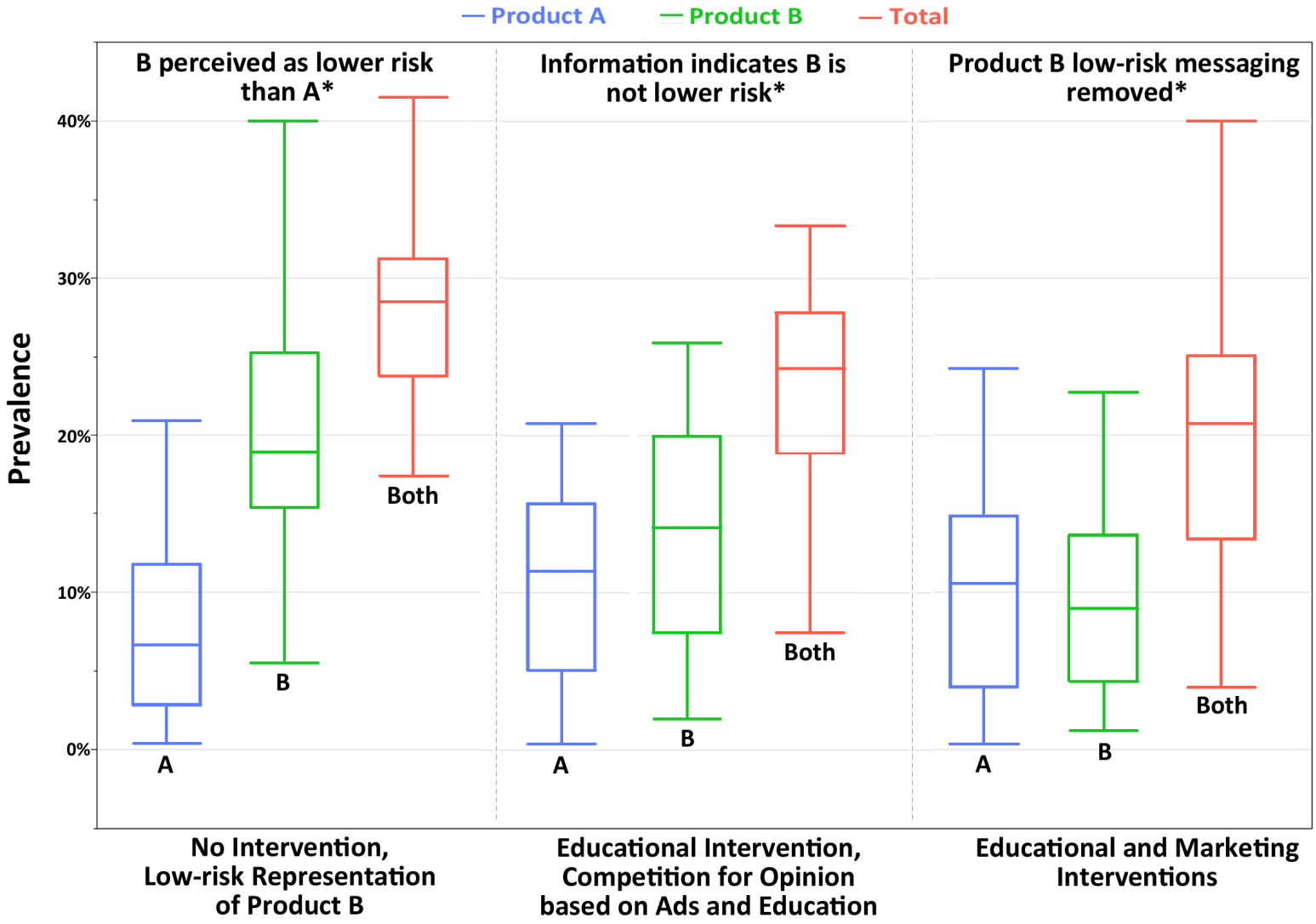

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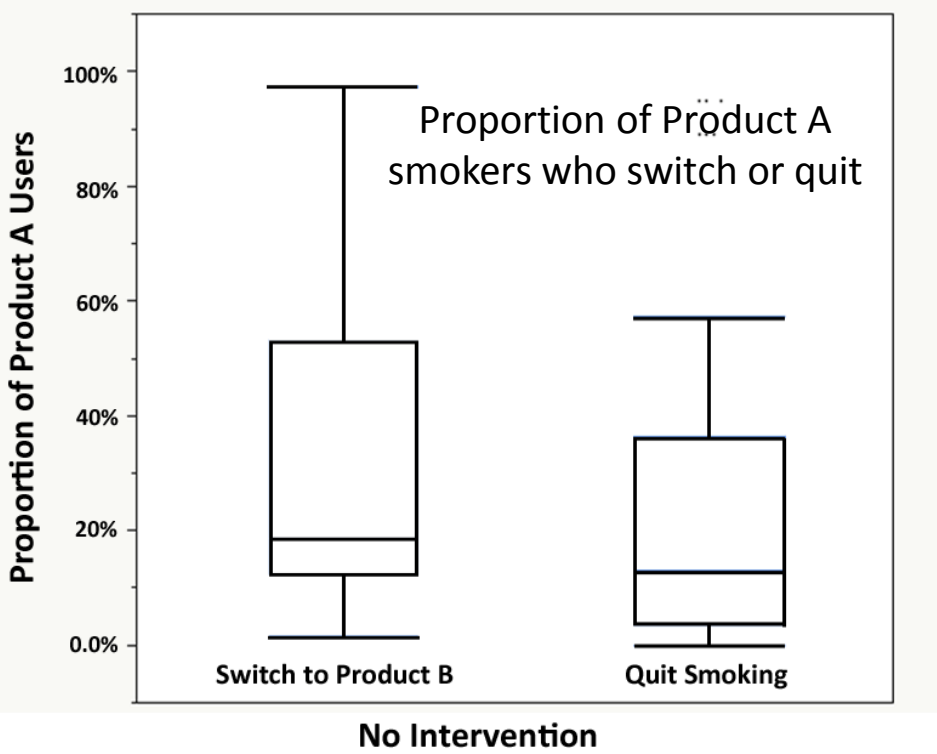
Model Testing Results: How Interventions Affect Behavior Changes



- No Intervention
  - Larger fraction switches than quits

Note: Scenarios assume that messaging and perceived risks are different for the two products; all other model parameters are the same.

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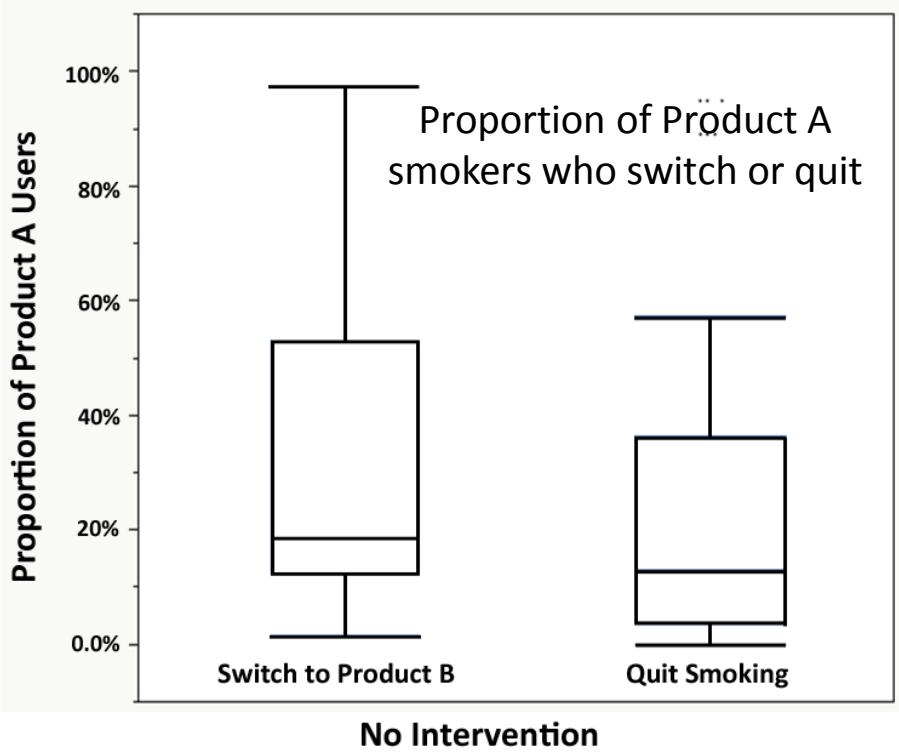
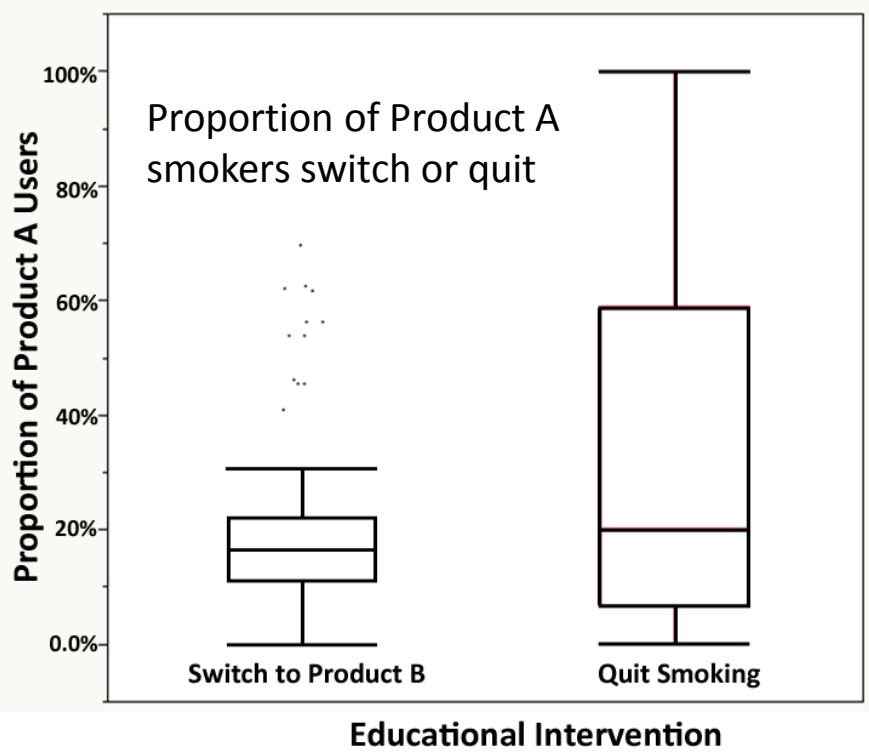
Model Testing Results: How Interventions Affect Behavior Changes





- No Intervention
  - Larger fraction switches than quits
- Educational Intervention
  - Likely to decrease switching, increase quitting. Distributions change.

Note: Scenarios assume that messaging and perceived risks are different for the two products; all other model parameters are the same.

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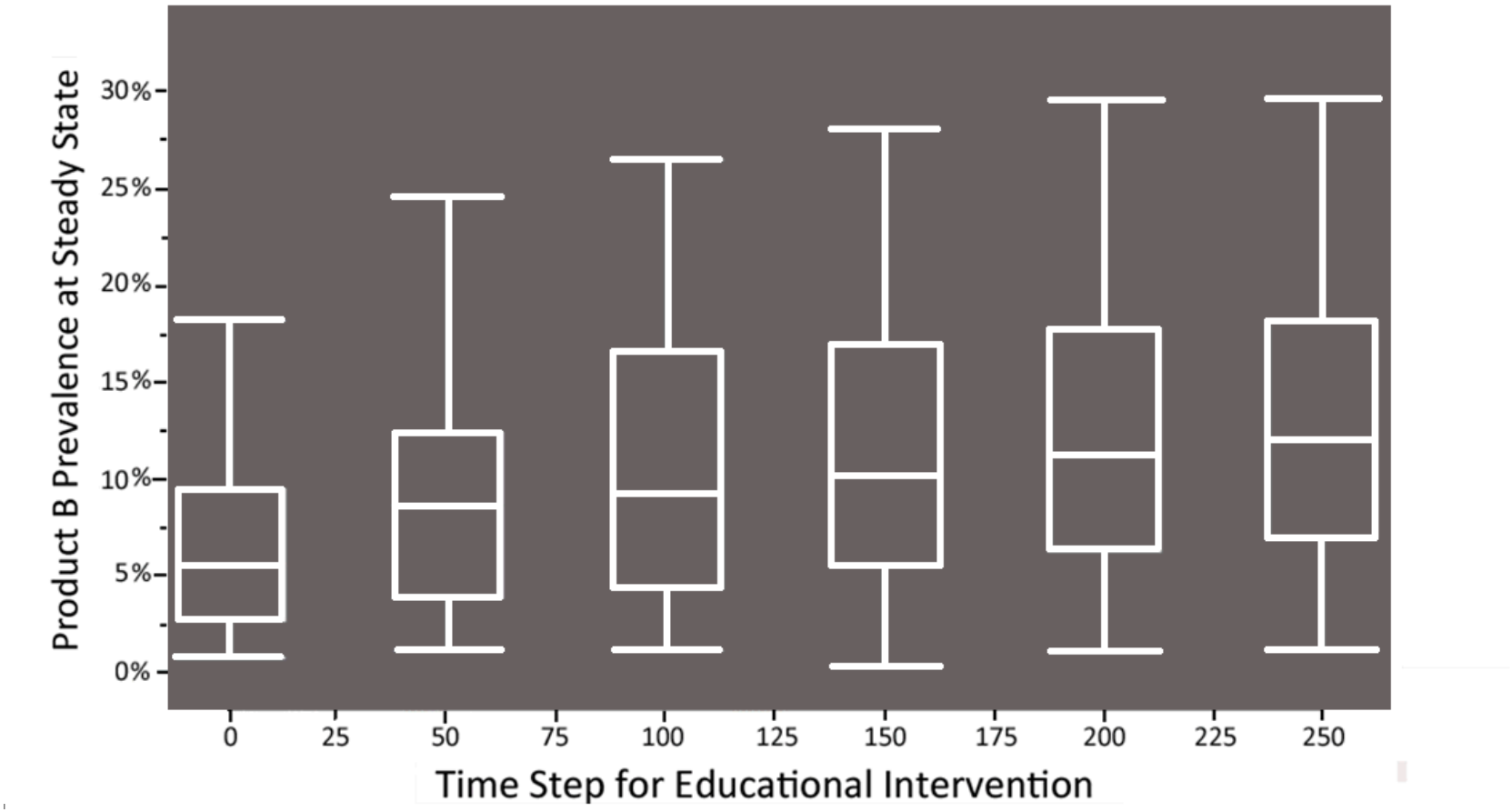
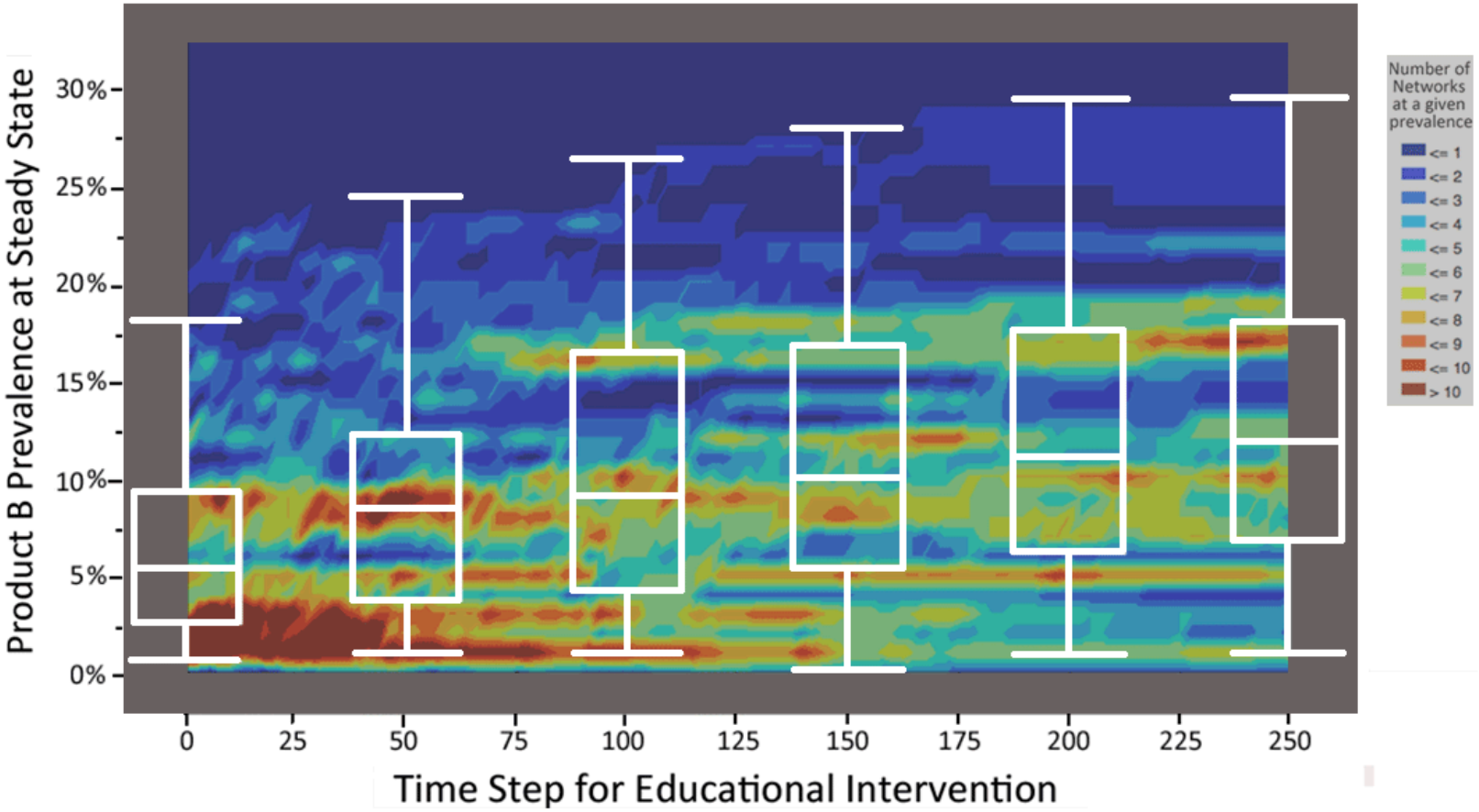
Model Testing: Impacts of Early Interventions



At time step 0-1: Begin ads promoting product B (low risk, high opinion)
X-Axis: Indicates start time for educational message about Product B (high risk, low opinion)

Interventions are more effective when implemented early

Model Testing: Impacts of Early Interventions



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Interventions are more effective when implemented early

Dynamics Not Reflected in these Results

- Dynamics of product use and product appeal
  - A feedback loop between product use and product opinion would allow representation of these dynamics
    - Progression from lower- to higher-perceived risk products may not be fully captured
    - Initiation of a lower-perceived-risk product may increase the probability that an individual progresses to use of a higher-perceived-risk product
- Higher-fidelity dynamic networks for initiation / addiction / cessation
  - Representation of individuals entering/leaving the network
    - Evolution of networks affect initiation and cessation decisions
    - Message signals decay over time
  - Changes in individual addiction level over time
- Health outcomes
  - Changes in prevalence may result in positive or negative health outcomes depending upon actual product risk

Summary (Two-Product Model Results)

- The model useful for examining relative changes in product prevalences in a two-product system. Examined changes in product prevalences due to:
  - Differences in risk perception
  - Interventions (marketing, education)
  - Timing of interventions
  - Messaging can target each product or product attribute
- Scenario results obtained with the two-product model
  - New product with low-risk messaging can gain a foothold in market
  - Informational messages can be effective
    - Countering low-risk opinion and high product opinion for Product B partially offsets “low-risk” product appeal
    - Early implementation
    - Marketing interventions (e.g., removal of “low-risk” messaging)

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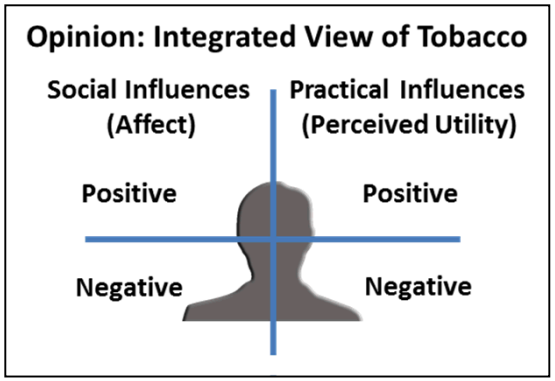
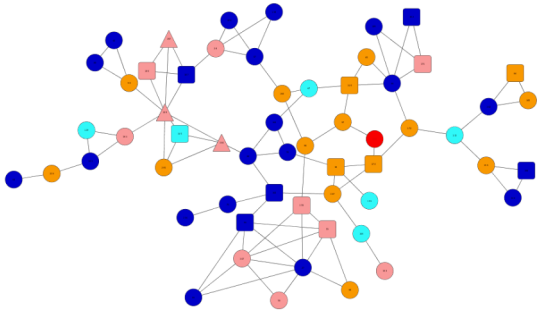
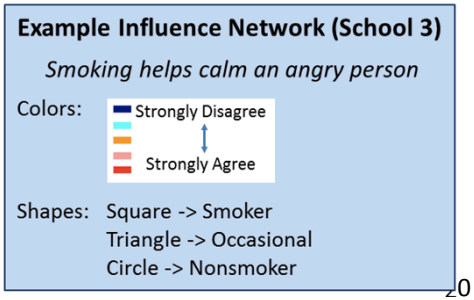
Network Survey Data for Snapdragon Validation

- Valente et al. 2014* collected longitudinal data on 1,200 students in five LA High Schools
- In third year of the study, surveys included 20 questions on tobacco opinion collaboratively developed by the SnapDragon and USC teams
- Preliminary data provide critical information on network topologies and opinion
  - Opinion can be mapped to behavior
  - Some assortativity** seen in social networks due to shared opinions





Do these data support underlying model hypotheses?



*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)

**Assortativity: "…[T]he tendency for vertices in networks to be connected to other vertices that are like (or unlike) them in some way." M. Newman, Phys. Rev. E 67, (2003).

Survey Results: Smoking Correlates with Opinion

- Ranking of Opinion Survey Questions by Predictive Power
  1. If one of my best friends were to offer me a cigarette, I would smoke it.
  2. Using tobacco would help when I'm feeling stressed.
  3. Smoking helps calm an angry person down.
  4. Smoking can help kill time if there's nothing to do.

- Questions on positive perceived utility are the most predictive of smoking behavior

- The top four questions are:
  - 85% predictive for classifying current nonsmokers
  - 80% predictive for classifying current smokers using out-of-sample observations
  - The overall classification error is 16%

Consistent with opinion-to-behavior mapping in SnapDragon

Survey Results: Tobacco Opinion Assortativity

Question	School 1	School 2	School 3	School 4	School 5
2	-0.38*	0.41	0.41	0.32	0.18
3	0.23	0.44	0.44	0.51	0.50
4	0.36	0.13	0.13	0.29	0.48

- There is assortativity on opinion for positive utility questions
- For comparison
  - Assortativity ranges from -1.0 (perfect negative correlation) to 0 (no correlation) to 1.0 (perfect positive correlation).
  - Values of 0.80 – 0.88 were obtained for assortativity on gender
  - values of 0.10 – 0.71 obtained for assortativity on smoking on these data
- All p-values (probability that observed relationship is due to chance) were less than .01 with one exception

Consistent with influence-network hypothesis of SnapDragon

* p-value of 0.87 indicates that this result is not statistically significant

**Did or did not smoke at all in past 12 months

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Conclusions and Future Directions

- Model provides a tool to visualize and evaluate impacts of new product introduction, relative perceived risks and interventions
  - Objective evaluation of impacts of marketing, tobacco-control interventions
- Data on social networks and opinion:
  - Are consistent with assortativity of opinion, opinion-to-behavior mapping structure of the SnapDragon model
  - Support the relevance of social networks to the analysis of smoking behaviors
  - Longitudinal data needed to assess capability to predict future changes
- Continued verification and validation will increase model fidelity and utility
  - Data focus on opinion over time, opinion correlations among peers

Back-up Slides

Individual Opinion: Bounded-Confidence Formulation

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

$$N_i \in S_i : \left|x_k(t) - x_i(t)\right| \leq \varepsilon_i$$

Update Rule: *Adjust individual agent's opinion by mean scaled opinion differences of opinion and neighbors' opinions within tolerance limits*

S_i Set of out degree neighbors

ε_i Tolerance (Do you influence me?)

μ_i Plasticity (How much you influence me)

x Opinion (My integrated view)

$N_i(t)$ Subset of S_i within tolerance bounds at time t

k number of neighbors within tolerance bounds

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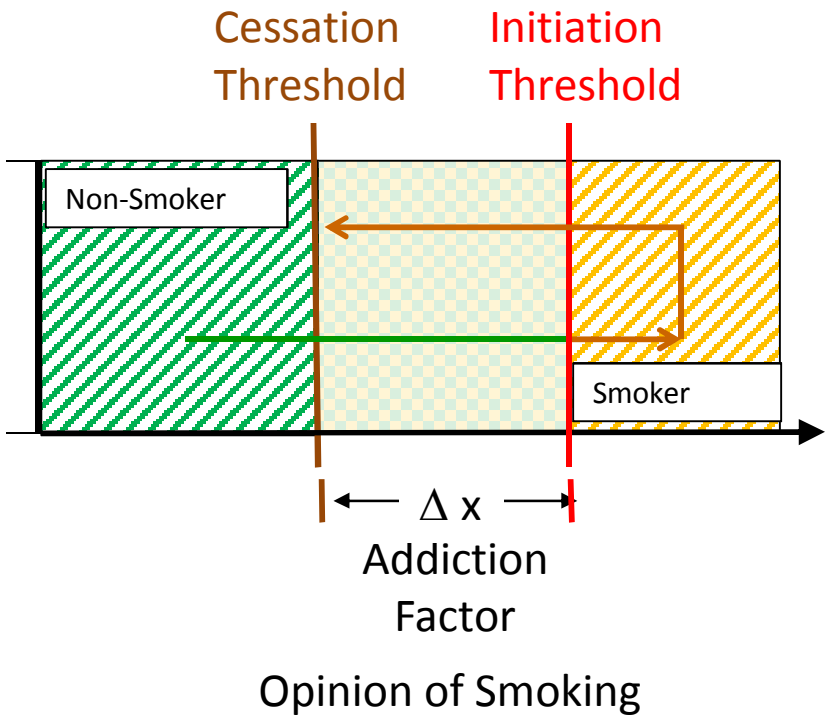
Mapping of Opinion to Behavior

- Smoking behavior is a function of opinion, initiation and cessation thresholds
- Because of addiction, behavior is path dependent
- Effect of addiction is represented by a cessation threshold
  - A smokers opinion must fall below cessation threshold to overcome addiction



The addiction factor is the difference between the initiation and cessation thresholds

Risk Perception and Risk Affinity

- Opinion disaggregated into product-based opinion (positive and negative affective components and positive utility expectations) and risk perception (associated health consequences)
  - Model the impact of product-specific lowered risk perception
  - Model effectiveness of risk-based messages
  - Both are open to social network and media influences
- Agent-specific variable representing risk affinity (risk tolerance)
  - Individuals can vary in the degree to which they discount perceived risks both between and within demographic profiles (e.g., youth versus adults)

Initiate if : Opinion - Risk Perception > Initiation threshold - Risk Affinity

Quit if: Opinion - Risk Perception < Cessation threshold – Risk Affinity

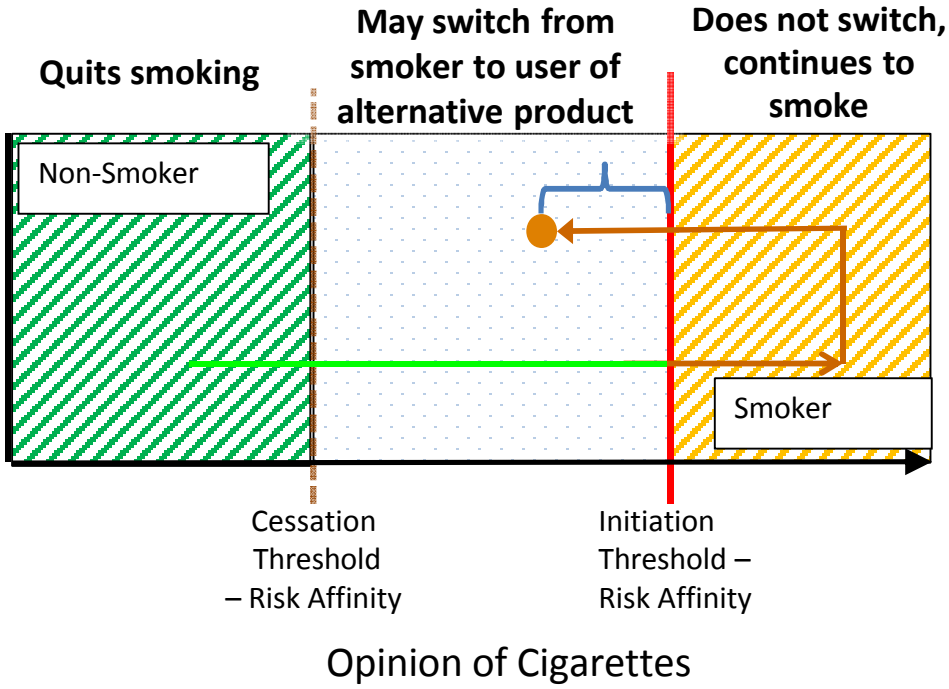
If you are between thresholds and have been a smoker:

Then: Either keep smoking due to addiction, or switch

The greater the dissatisfaction with current product, the more likely to switch

Modeling Product Switching

- Assessment of a Product B will be based:
  - On that product's properties considered independently, PLUS
  - Opinion is "boosted" because Product B is a potential way out of addiction-driven use of Product A
- Modeling motivated switch
  - Add the amount of "regret" a person associates with Product A to their opinion of Product B.
  - Applies only to individuals who use Product A due to addiction
  - Applies only to initiation
- Addiction is to nicotine and so it carries over to the new product



Switch when: $\text{opinion}_{\text{ProductB}} - \text{risk perception}_{\text{ProductB}} + (\text{initiation threshold}_{\text{cig}} - \text{opinion}_{\text{cig}} - \text{risk perception}_{\text{cig}})$

$> \text{initiation threshold}_{\text{ProductB}} - \text{risk affinity}$

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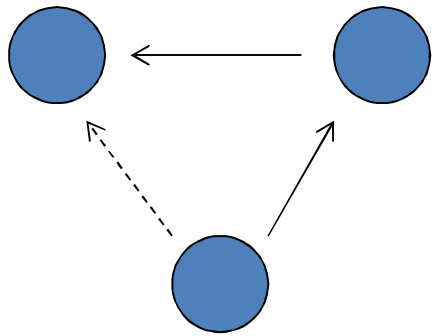
Background: assortative mixing

- Assortative mixing: the bias in favor of connections between network nodes with similar characteristics
- Assortative mixing can be attributed to three main ideas
  - Homophily: tendency of individuals to associate and bond with similar others
  - Social influence: occurs when one's emotions, opinions, or behaviors are affected by others
  - Transitivity: friends of a friend



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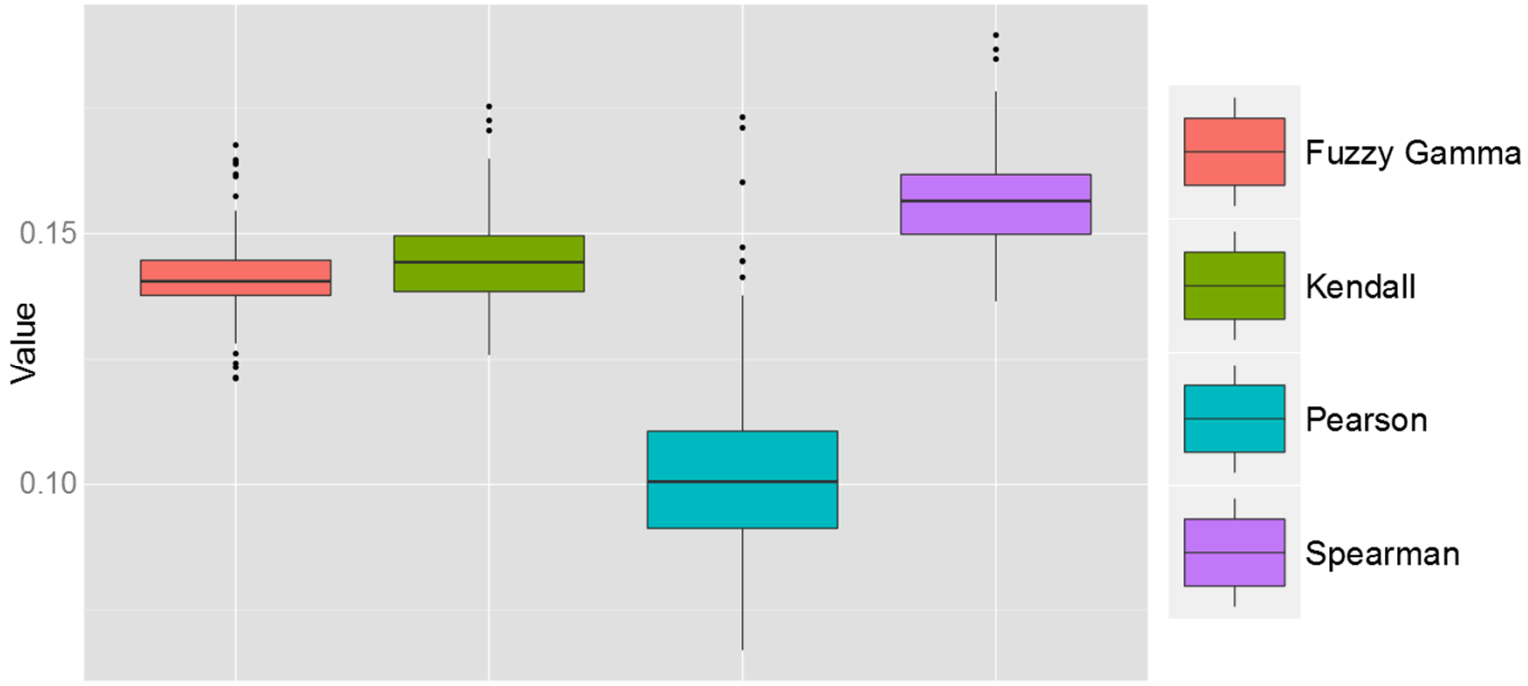
Statistical Methods for Assortativity

- Pearson product-moment correlation coefficient
  - Measure of linear statistical dependence between two continuous variables, not robust when normality is violated
- Spearman's rank correlation coefficient
  - Nonparametric measure of statistical dependence using a monotonic function. Ranked version of Pearson
- Kendall rank correlation coefficient (τ_b)
  - τ_b is a common rank correlation coefficient that takes into account ties, a pair $\{(x_i, y_i), (y_j, y_j)\}$ is said to be tied if $x_i = x_j$ or $y_i = y_j$
- Fuzzy gamma rank correlation coefficient
  - Gamma rank correlation coefficient is a well-known rank correlation measure frequently used between two ordinal variables
  - to increase the robustness of the coefficient when dealing with noisy data, a fuzzy order relation is used

Comparing Robustness of Statistical Methods

- Distributions after perturbing a single node from our network with an extreme value (outlier)
- Fuzzy gamma rank correlation coefficient gives us the most robust estimation of correlation based on smoking behavior



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Key Parameter Values and Distributions

	Product A	Product B	Agents
Initial opinion	Uniform [0, 1] continuous	Uniform [0, 1] continuous	
Initial perceived risk	Uniform [0, 1] continuous	Uniform [0, 1] continuous	
Initiation threshold	0.75	0.75	
Addiction factor			Homogeneous 0.3
Risk Affinity			Normal Mean 0.2 SD 0.05

Initial assumptions for purpose of developing hypothetical scenarios

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Model-Testing Scenario Specifications

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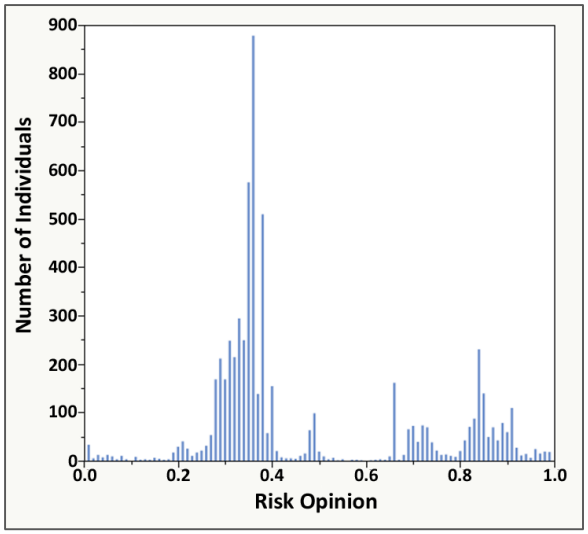
• Products A and B are on the market. • Consumers perceive the risks of these products differently, as induced by industry marketing/social media/etc. • Information inflates perceptions of reduced risk of Product B use	• Product A on market with information messaging: - High-risk opinion (0.625) • Product B on market with advertisements for - High product opinion (0.775) - Low-risk opinion (0.35)
Scenario 2: Educational Intervention*	
• Information becomes available, Product B is not lower risk than Product A • Individuals are influenced if information is within their tolerance range	• Previous scenario plus information messaging on Product B - Low product opinion (0.375) - High-risk opinion (0.675)
Scenario 3: Educational and Marketing Interventions*	
• Marketing intervention: remove low-risk messaging for Product B	• Previous scenario plus remove low-risk messaging - Stop messages with low-risk opinion of Product B - Continue educational message, product ads

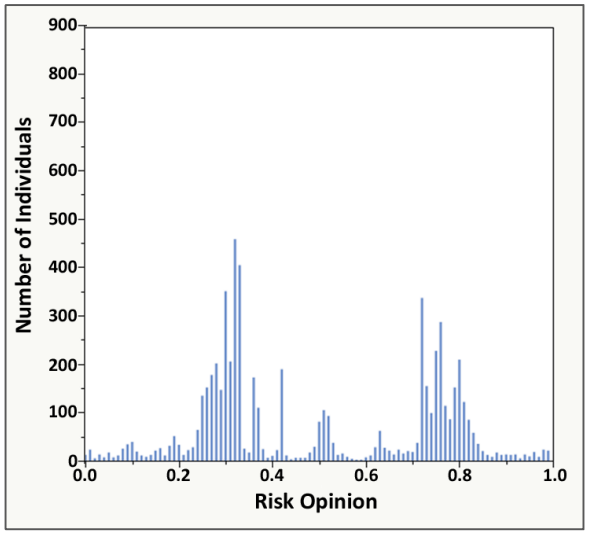
* Interventions are initiated as network opinions form but before they become fully instantiated

Scenarios: Steady State Results

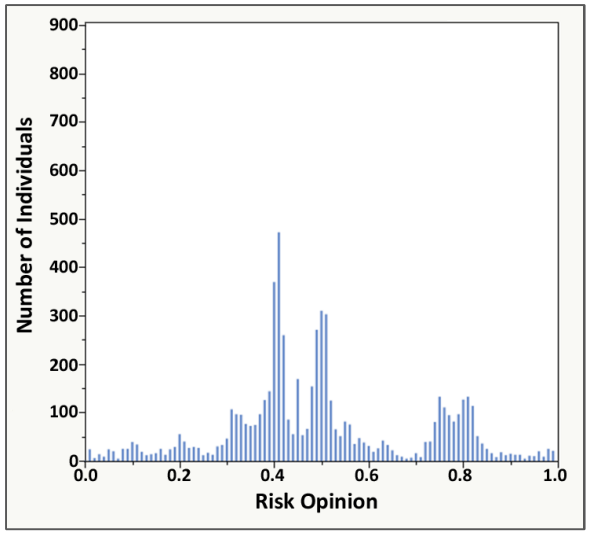
Different scenarios lead to different risk-opinion distributions



Risk Opinion Distribution for "Low-Perceived-Risk" Products in the presence of Lower-Risk Advertising



With addition of Educational Intervention



With Educational and Marketing Interventions

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