Complex Adaptive System of Systems (CASoS) Engineering Initiative

http://www.sandia.gov/CasosEngineering/

SAND2011-1757P

Policy Analysis with Agents and Social Networks Using Opinion Dynamics (Example for use of an unhealthy product)

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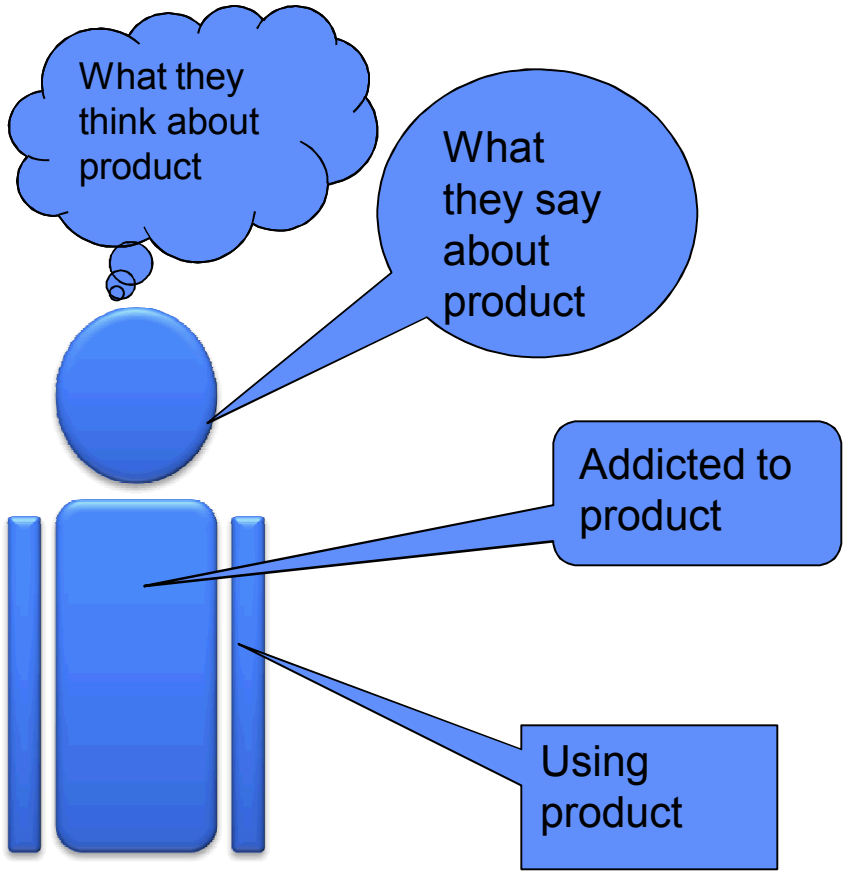
Individual Based Model

- **Captured Components**
  - Individual: Opinions, behaviors, addiction
  - Network: Topologies, media, interventions
- **Dynamics**
  - Psychosocial: Exchanging beliefs, ideas, and opinions, how the opinions and behaviors of others affect the opinions of the individual
  - Psychobehavioral: How those opinions affect the behavior of the individual
  - Psychophysiological: How addiction and other physiological states affect opinion and behavior

Four Components of Agency



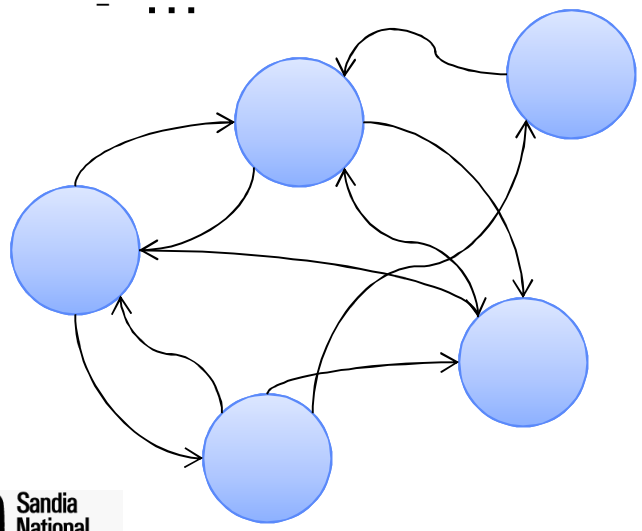
- Internal (Actual) Opinions
  - Actual opinion about product
  - Risk associated with product
- External (Effective) Opinions
  - Effective opinion about product
- Internal States
  - Level of addiction
  - Risk affinity
- External Behaviors
  - Product use

Relevance to Product Policy in Communities and Populations

- How do opinions about product use spread in communities?
  - Normative perception of product use
  - Product use initiation and quit clusters
- How are these affected by industry advertising, counter-marketing campaigns, health-related education?
  - Graphic warning labels
  - Product industry “community outreach”
  - Fact-based education/information (e.g., ingredient publication)
- What role do personal psychological and physiological factors play in community-scale product use behaviors?
  - Addiction
  - Aspiration-driven behaviors

What is a Social Network in the Real World?

- Created by individual actions
- Defined by the exchange of information and resources
- No single topology captures all interactions
  - Contact networks
  - Friendship networks
  - Advice networks
  - …



What is a Social Network Computational Interpretation?

- Algorithmically Generated Networks
  - Different topologies isolate characteristics of different real world networks
  - Vary size, density, centralization, etc., to experimentally determine most important characteristics for each phenomenon (advertising, education, availability, peer pressure, …)
- Real World Networks
  - National Longitudinal Study of Adolescent Health (Add Health)
  - Other existing networks
  - Custom designed studies
- Statistically Generated Communities
  - Statistically generated populations consisting of multiple, overlapping networks (families, schools, workplaces, …)

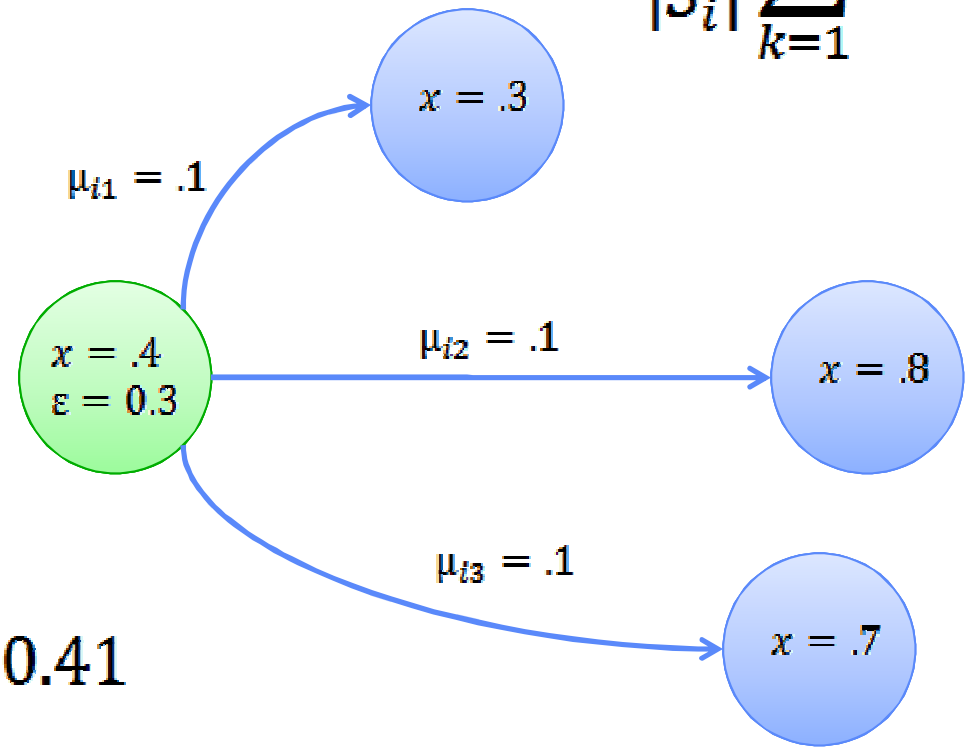
The Opinion Dynamics Model

- Derived from statistical physics models of magnetic particle alignments in 2D lattices
- Grew into a family of related techniques
- All update the opinion of a given person based on interactions with that person's neighbors
- Opinion in the current model is a variable capturing an individual's opinion about and attitude towards product use
  - Product use helps people cope with stress
  - Product use is cool, sophisticated
  - Product use helps fit in socially
  - Product use is convenient
  - Product use is harmful to health

Opinion Dynamics in Action

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

$$x_i^{t+1} = x_i^t + \frac{1}{|S_i|} \sum_{k=1}^{|S_i|} \mu_{ik}(x_k^t - x_i^t)$$

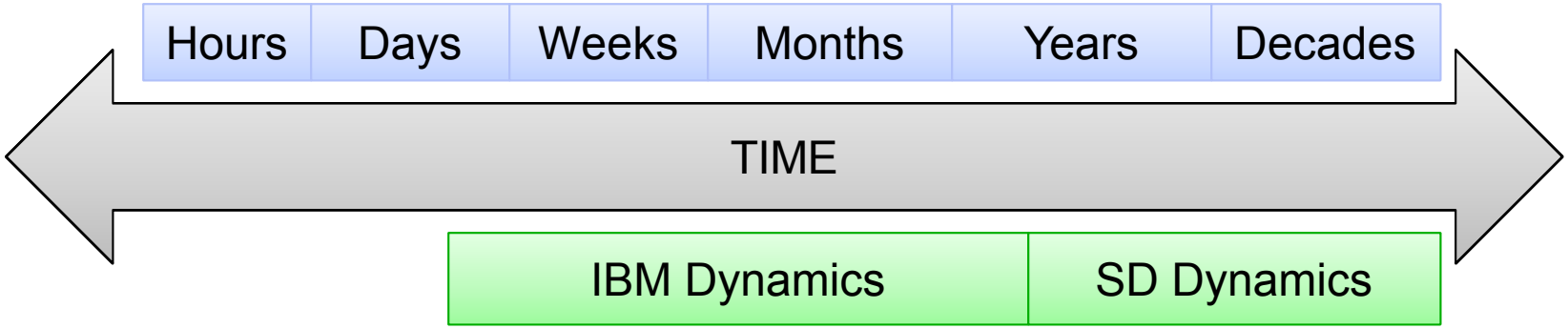


S_i: Set of out-degree neighbors
ε: Tolerance
μ: Plasticity

$$x_i^{t+1} = 0.41$$

What is t?

- Depends on the parameters
- Depends on the context of the simulation run
  - Theoretical: tendencies and trends (What happens if…?)
  - Empirical: Depends on data calibration (generally speaking, weeks to a few years)



Policy Analysis

- Health related campaigns and counter-marketing
  - Advertising and educational campaigns that affect opinions
  - Effects of campaigns that affect individual tolerances
- Effects of ad rotation in a campaign with attenuation
- Effects of addiction modeled as behavioral hysteresis

Effects of Campaigns Affecting Opinion vs Tolerance

- Opinion: Directly affect people's beliefs about product use
  - Branded cigarette advertising campaigns
  - Health consequences of product use
- Tolerance: Affect people's susceptibility to arguments that differ from their own current opinions
  - Product-industry donations to community-focused cultural, educational, and civil rights organizations
  - Campaigns focusing on corporate disinformation practices

Opinion Based Campaigns – Model Details

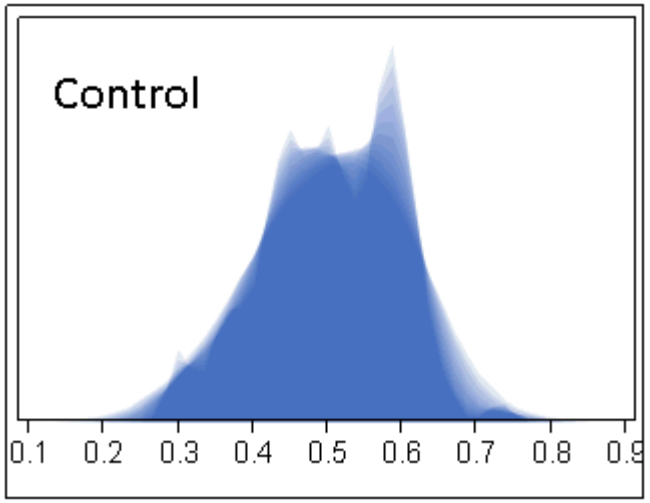
- Model Components
  - Industry advertising node trying to raise opinion
  - Health-based campaign trying to lower opinion
  - Centrality and connectivity parameters for each
- Policy Levers
  - Strength and effectiveness of campaigns
  - Regulation of industry advertisements
  - Complementary campaigns using mild and strong ads

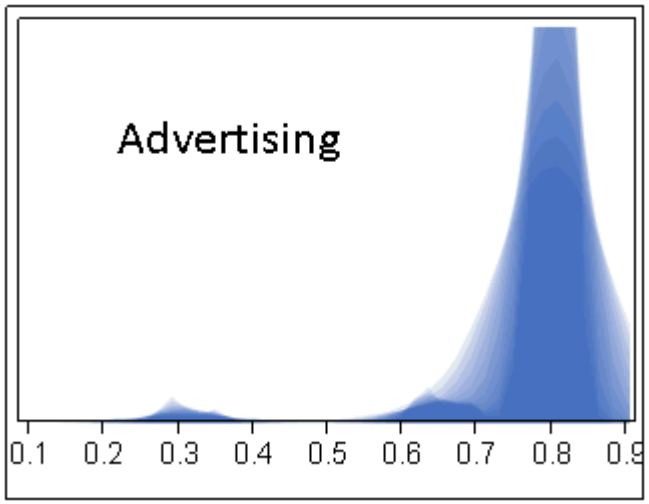
Experimental Results - Effects of Campaigns Affecting Opinion

- How Advertisements and Educational Campaigns Influence Networks by Changing Opinions
  - Aggressive campaigns can be effective, but can also alienate and polarize; mild campaigns can appeal to a wider range of people, but alone can be ineffective in changing behavior
  - Campaigns can act synergistically to move network incrementally in a particular direction while individually appealing to distinct audiences
  - Conflicts between advertising and educational campaigns will be won on the basis reaching important individuals and clusters

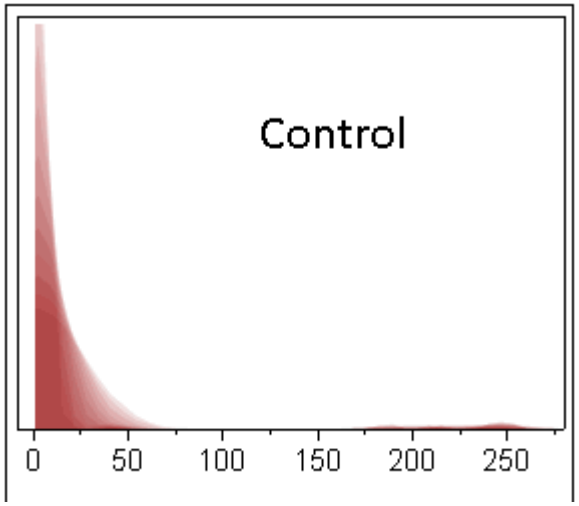
Effects of Competing Campaigns on Opinion and Behavior

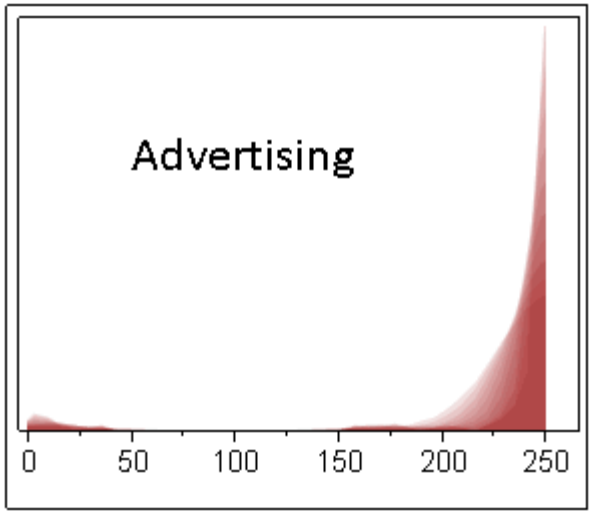
Opinion





Product Use Behavior





Advertising and educational campaigns competing for the same network

These examples show results where the educational campaign has the advantage in connecting to influential nodes. In experiments that reversed the advantage, the results were also reversed.

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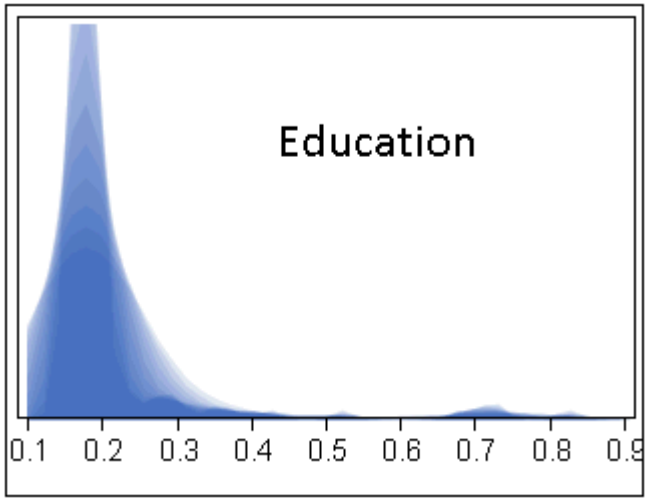
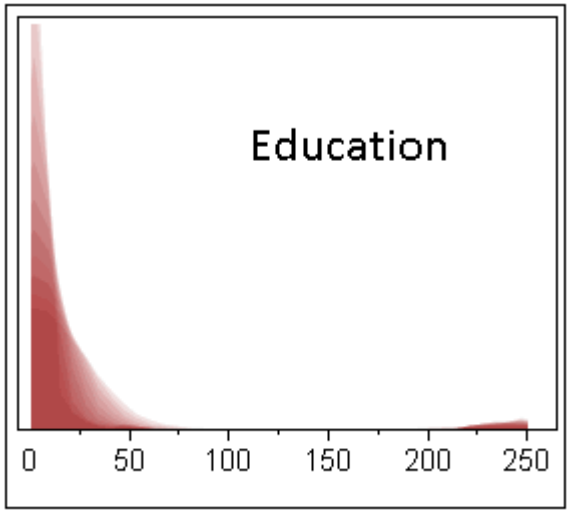
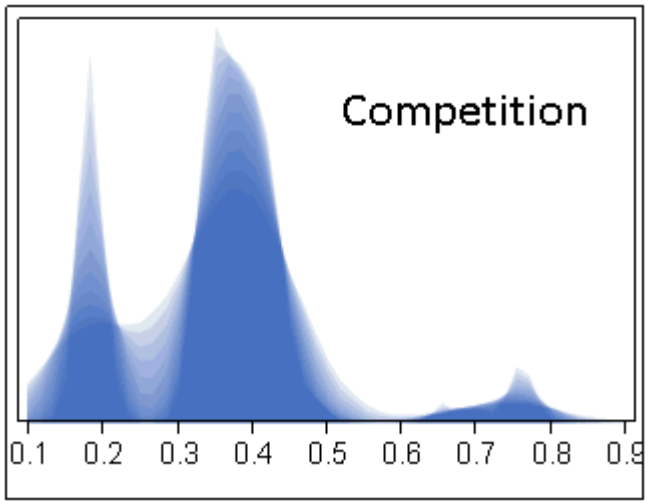
Effects of Competing Campaigns on Opinion and Behavior

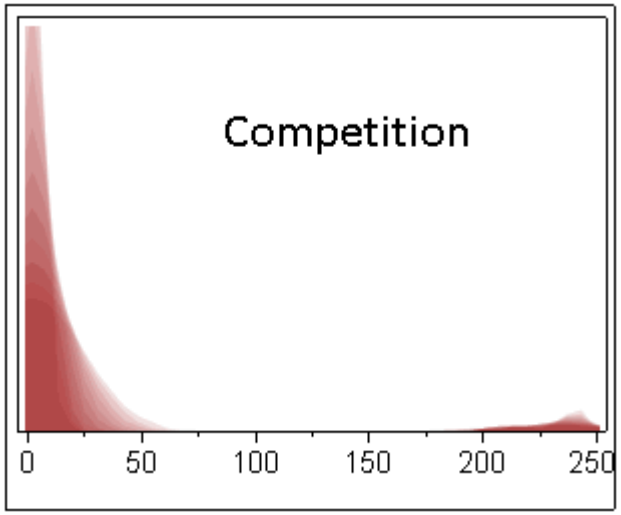
Opinion

Product Use Behavior









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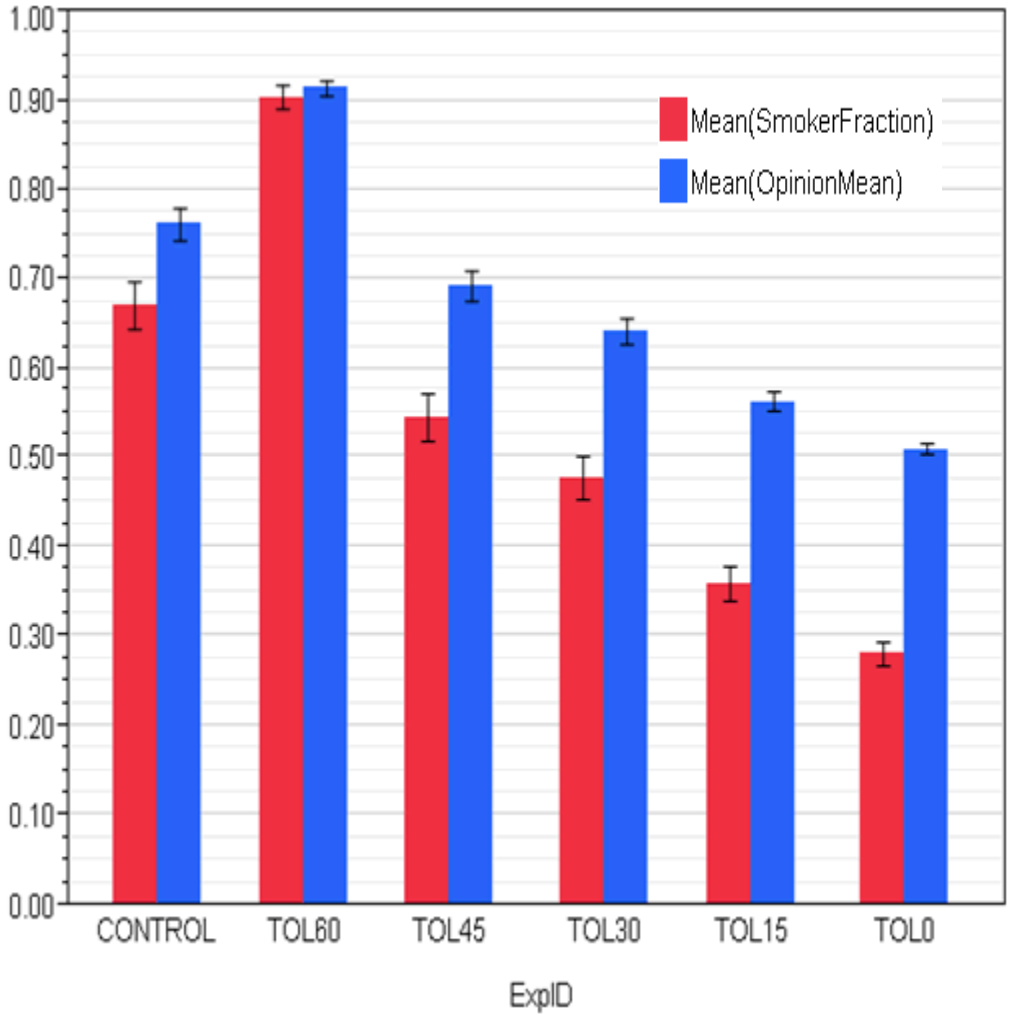
Experimental Results - Effects of Campaigns Affecting Tolerance

- How Advertisements and Educational Campaigns Influence Networks by Changing Tolerance
  - Lowering tolerance values prevents the spread of opinion, inoculates against future advertisements
  - Raising tolerance values increases network-wide vulnerability to advertisements
  - Combining tolerance-related campaigns with education creates a potent mechanism for social change

Effects of Tolerance Campaign



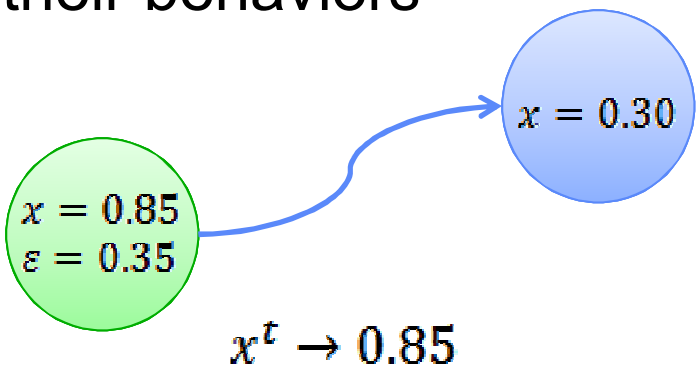
- Product industry ad campaign attached to top Page ranked nodes
- Campaigns to lower/raise tolerances attached to high betweenness nodes

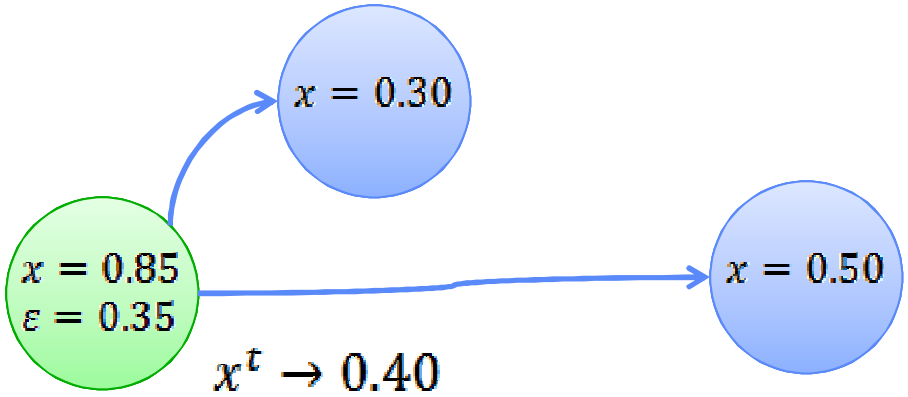
Warning Advertisement Rotation – Model Details

- Model Components
  - Ad strength
  - Ad rotation
  - Attenuation rate
- Policy Levers
  - Change ad strength
  - Rotation schedule

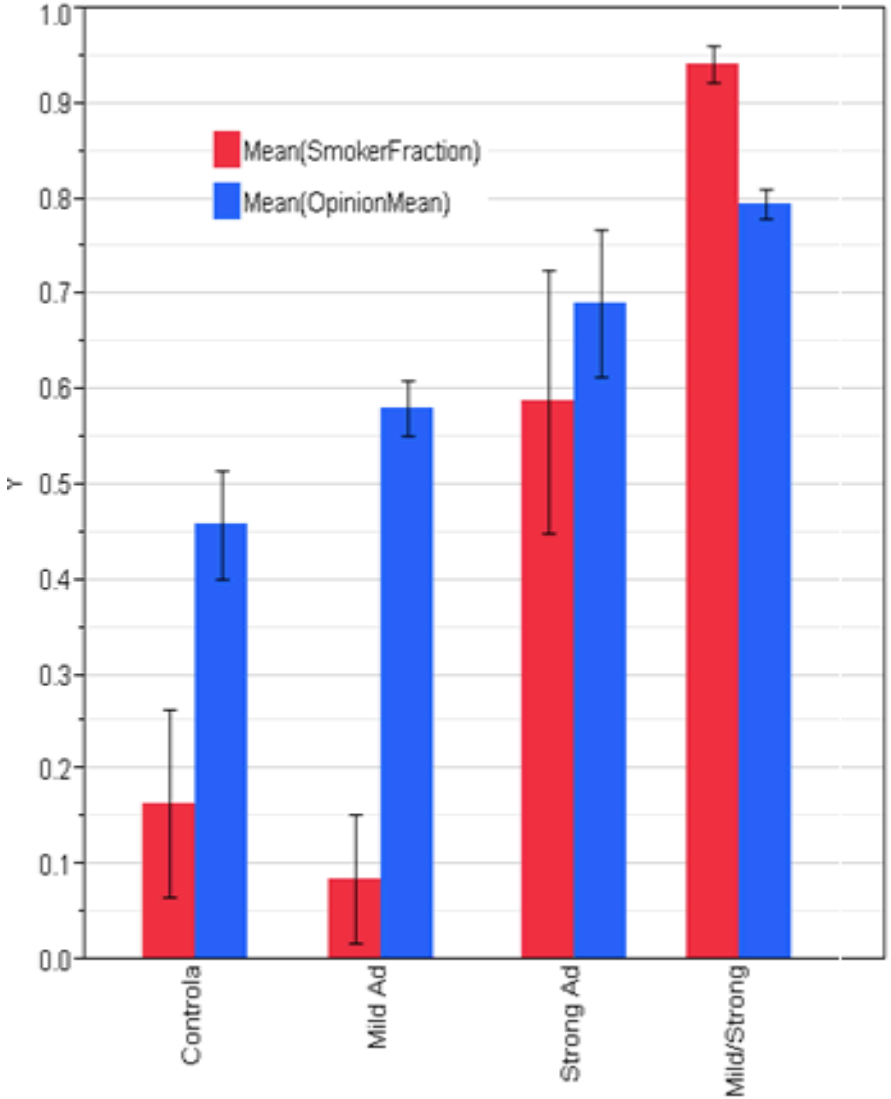
Complementary Campaigns

- Lack of tolerance to different opinions and antagonistic reactions can bound effectiveness of campaigns
- People are most likely to be influenced by opinions already close to their own
- Complementary campaigns combine a campaign with a mild opinion (to influence without alienation) with a campaign to influence people strongly enough to change their behaviors





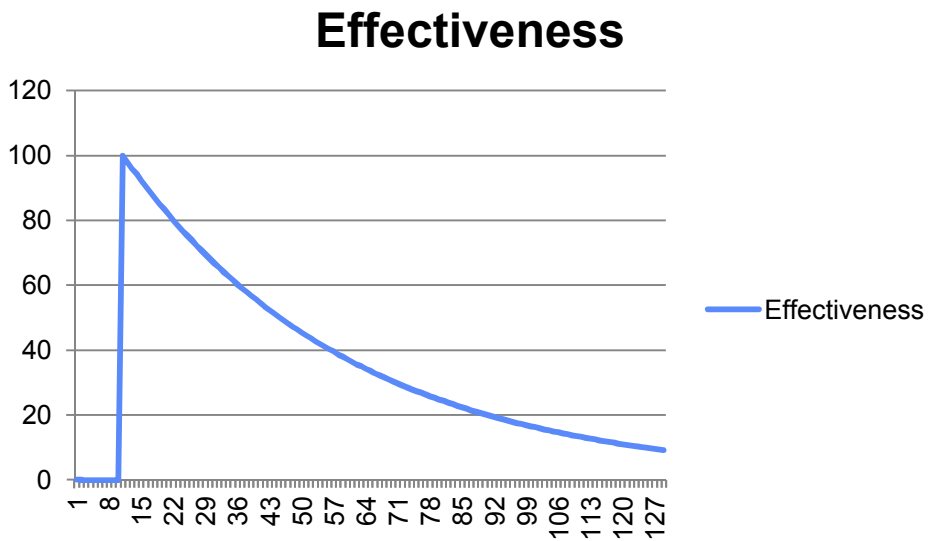
Complementary Campaigns by Industry



- Campaigns can be designed to create synergistic effect
- Strong campaigns outside of people's "tolerance windows" have limited effectiveness
- Mild campaigns might be too light to affect observed behavior, but can act to prepare the ground

Warning Advertisement Rotation

- Marketing research demonstrates decline in effectiveness of individual campaign components over time
- In these experiments, campaign effectiveness is a pulse function with geometric decay
- Effectiveness is used to attenuate plasticity in opinion model

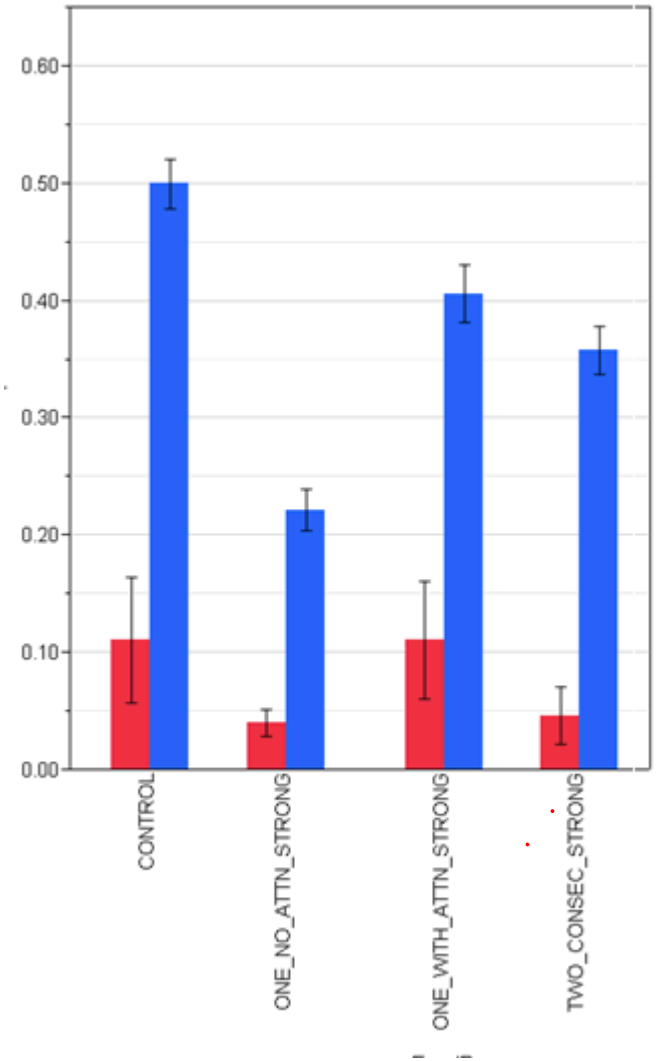


Experimental Results – Warning Ad Rotation

- Rotation is necessary to delay effects of attenuation
- Attenuation quickly decreases the ability of an advertising or educational campaign to affect the network, proportional to penetration
- Importance of rotation depends on how often exposure occurs and rate of attenuation

Effects of Warning Advertisement Attenuation

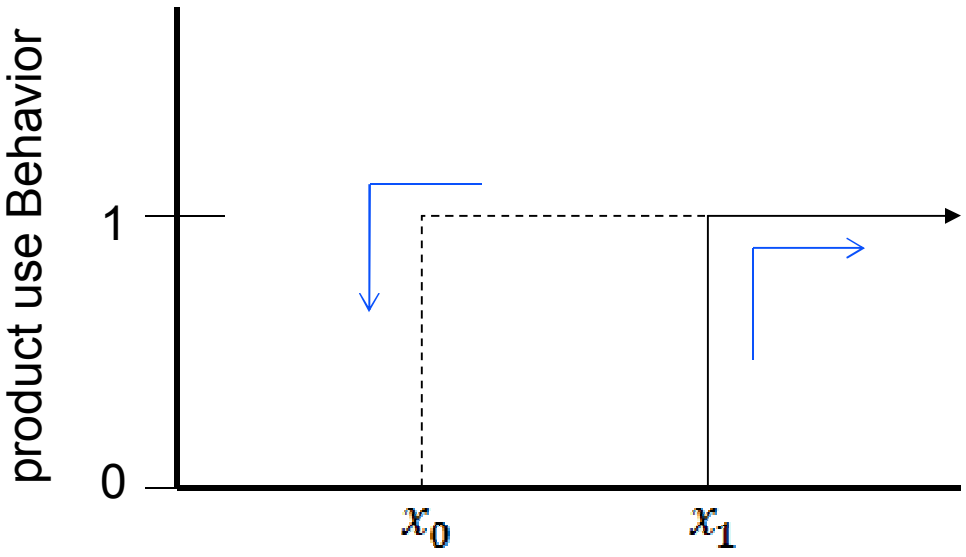
- Attenuation can have a strong effect on ideal versus real world results
- Rotation of warning labels can help to mitigate these effects



Product Addiction/Addictive Habit Model Details

- Model Components
  - Behavioral mapping to opinion
    - Start product use when opinion passes initiation threshold
    - Quit when opinion falls below cessation threshold
- Policy Levers
  - Make it easier to quit: cessation threshold
    - Reduce addiction to product in individuals
    - Increase availability of alternatives, help groups
  - Make it harder to start: initiation threshold
    - Raise monetary costs associated with product use
    - Raise time/effort costs associated with product use (e.g., restricted sales, clean air laws)
  - Increase education / counter-marketing efforts
    - Reduce opinions further (More and stronger campaigns)

Initiation, Cessation, and Hysteresis



x_1 Initiation Threshold

x_0 Cessation Threshold

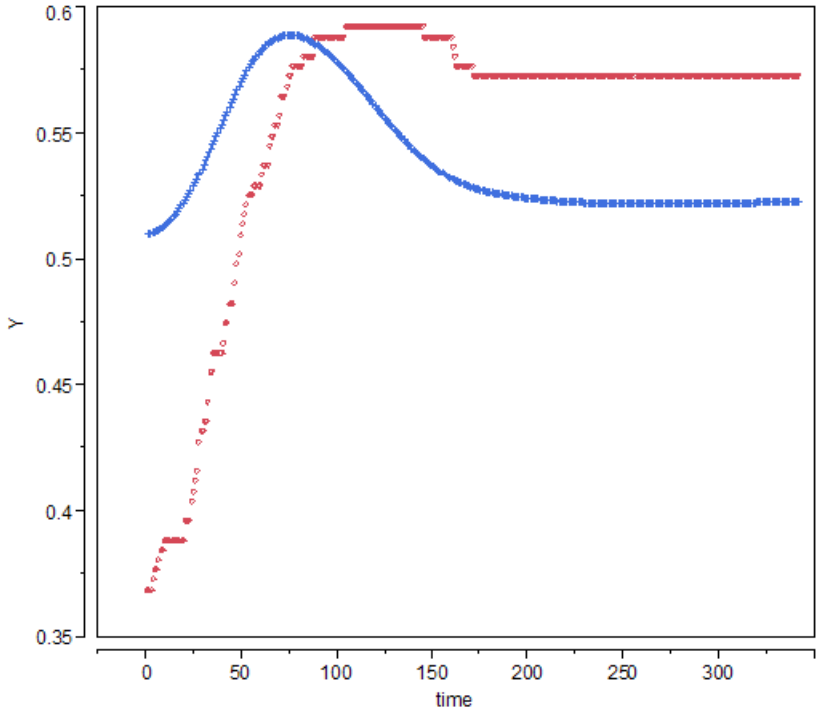
Δx Hysteresis Effect

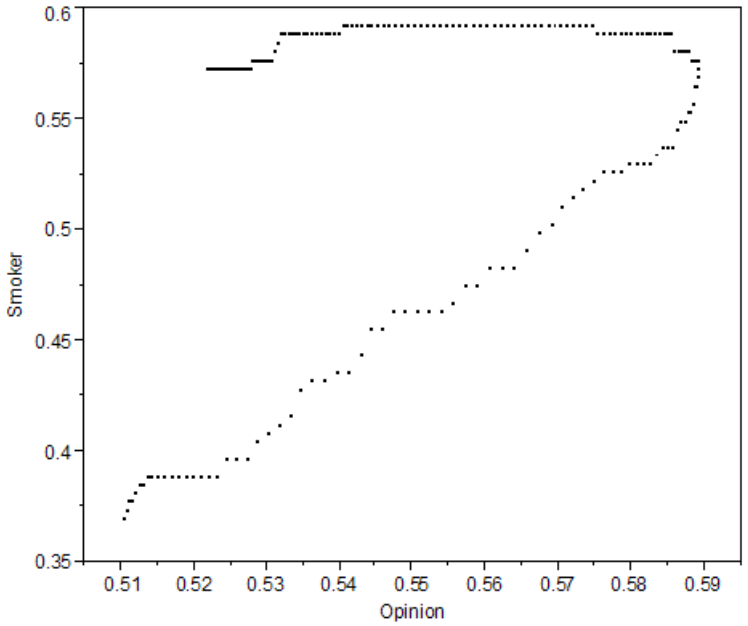
- If the individual's opinion about product use passes the initiation threshold, the person will become a product user
- If the individual's opinion falls below the cessation threshold, the person will quit product use
- The magnitude of the hysteresis effect represents strength of addiction

Experimental Results - Addictiveness Effects on Network Based Cessation Campaigns

- Number of product users who would otherwise change based on educational campaign proportional to addictedness of individuals
- Increased addictiveness of products/product habit means stronger educational campaigns necessary to reach target quit level
- Decreasing addictiveness of products/product habit can mean increasing number of quitters with a constant level of effort in educational campaigns

Hysteresis Illustrations





- Industry Ads through t=75 gets people addicted
- Educational campaign starting at t=75 pulls down opinion but has limited effect on product use behaviors

IBM Refinements

- Integrate model of explicit risk perception
- Multiple opinions and multiple products
- Refined psychological model
- Refined physiological model
- Refined behavioral model
- Getting to zero – mixing policy cocktails with new ideas
  - Community based bottom-up strategies (e.g., activism)

Model Refinements

- Psychological Model
  - Integrate additional ideas into network flows and decision making
    - Effects of age, gender, SES
  - Non-orthogonal ideas
    - Campaigns can be used to create correlations between ideas (e.g., product use and individual choice)
- Physiological Model
- Behavioral Model
  - Availability of alternatives
  - Homophily, dynamic networks, clique formation

Getting to Healthy: Community Level Activism

- What are the effects of activism in social networks?
- Individuals with opinions falling below a threshold value actively recruit contacts
- Resulting increase in degree of low opinioned agents moves network results in potentially greater propagation of low opinions

Backup Slides

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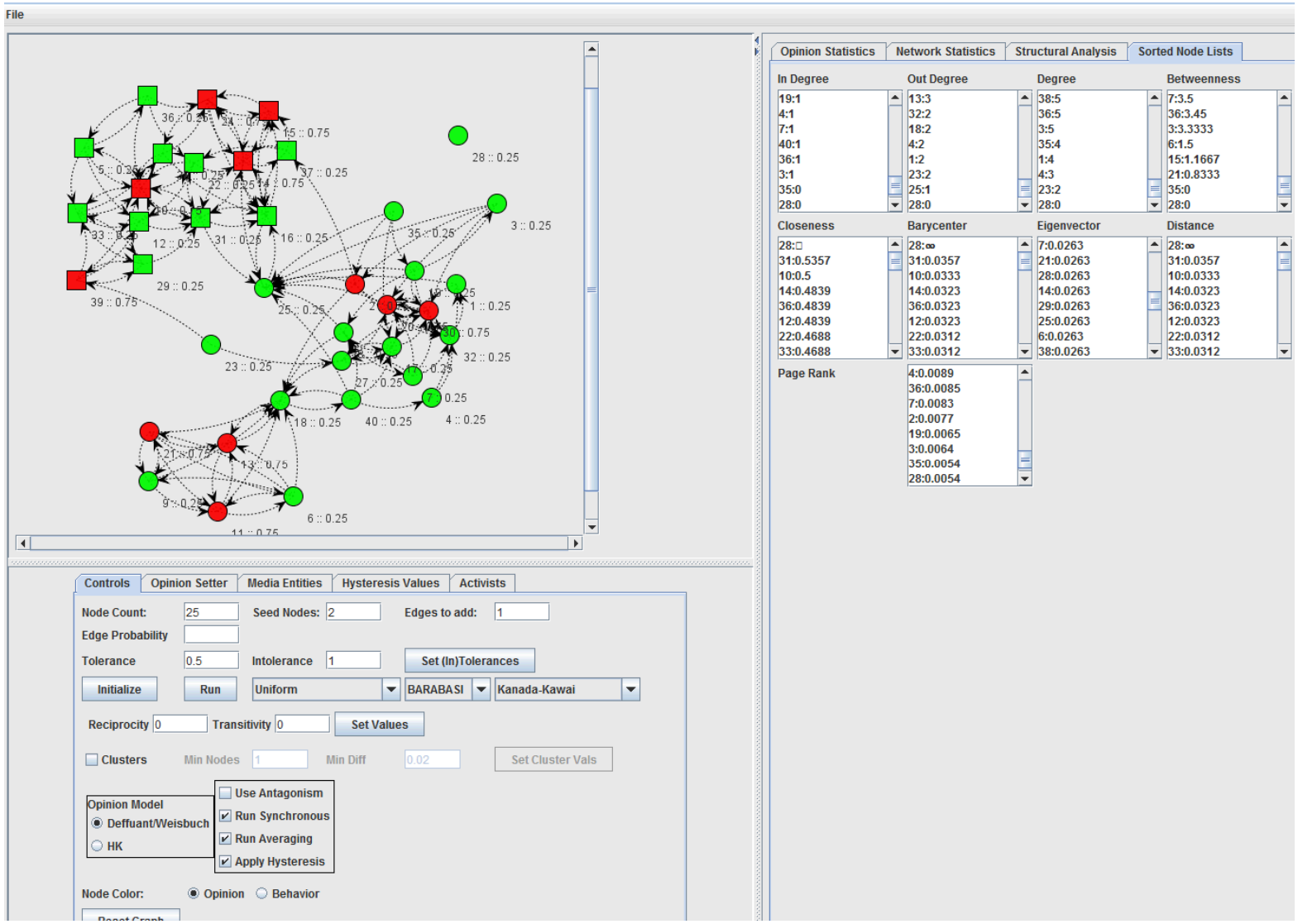
Topology Illustration



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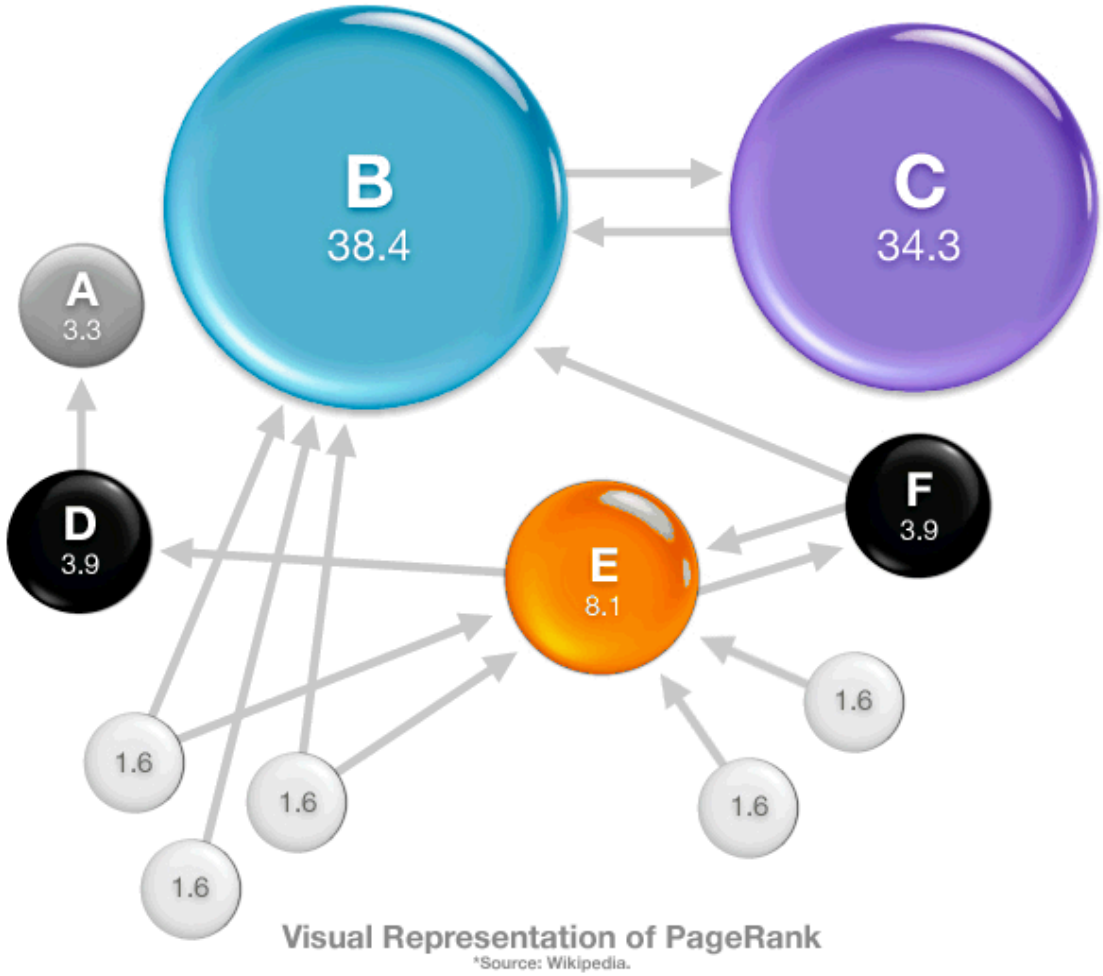
Page Rank Centrality



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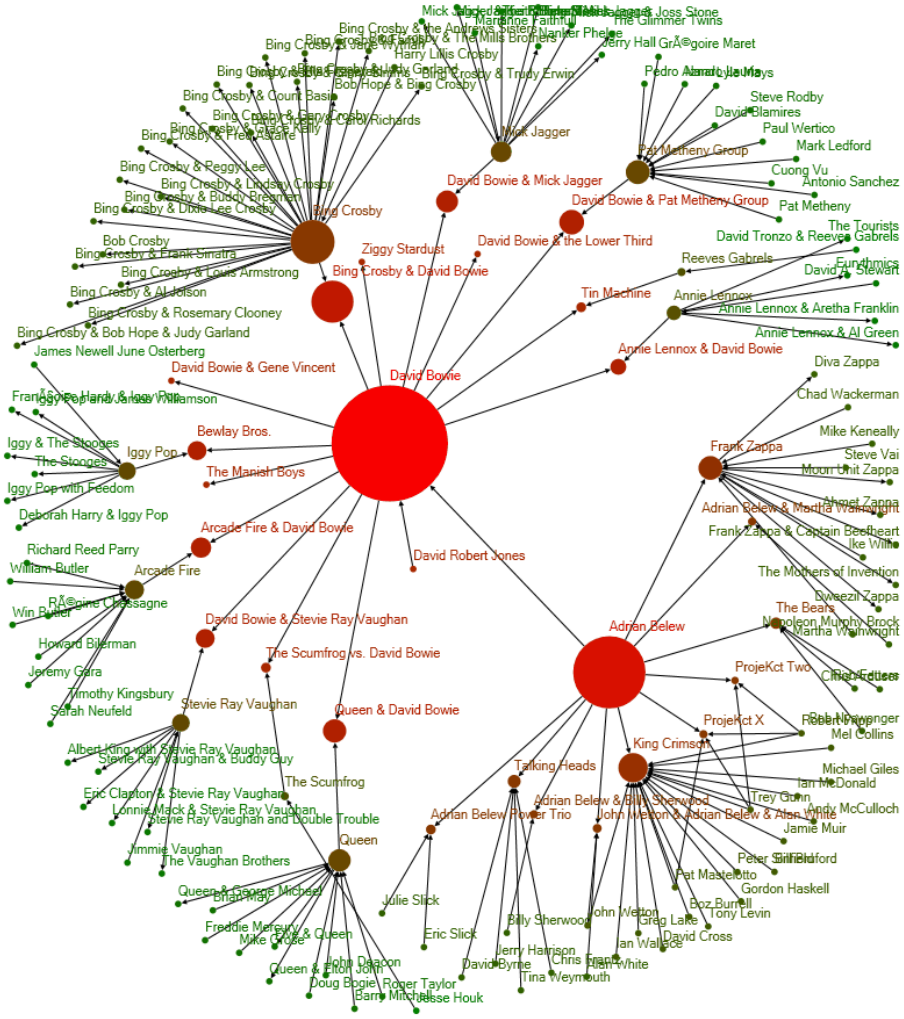
Betweenness Centrality



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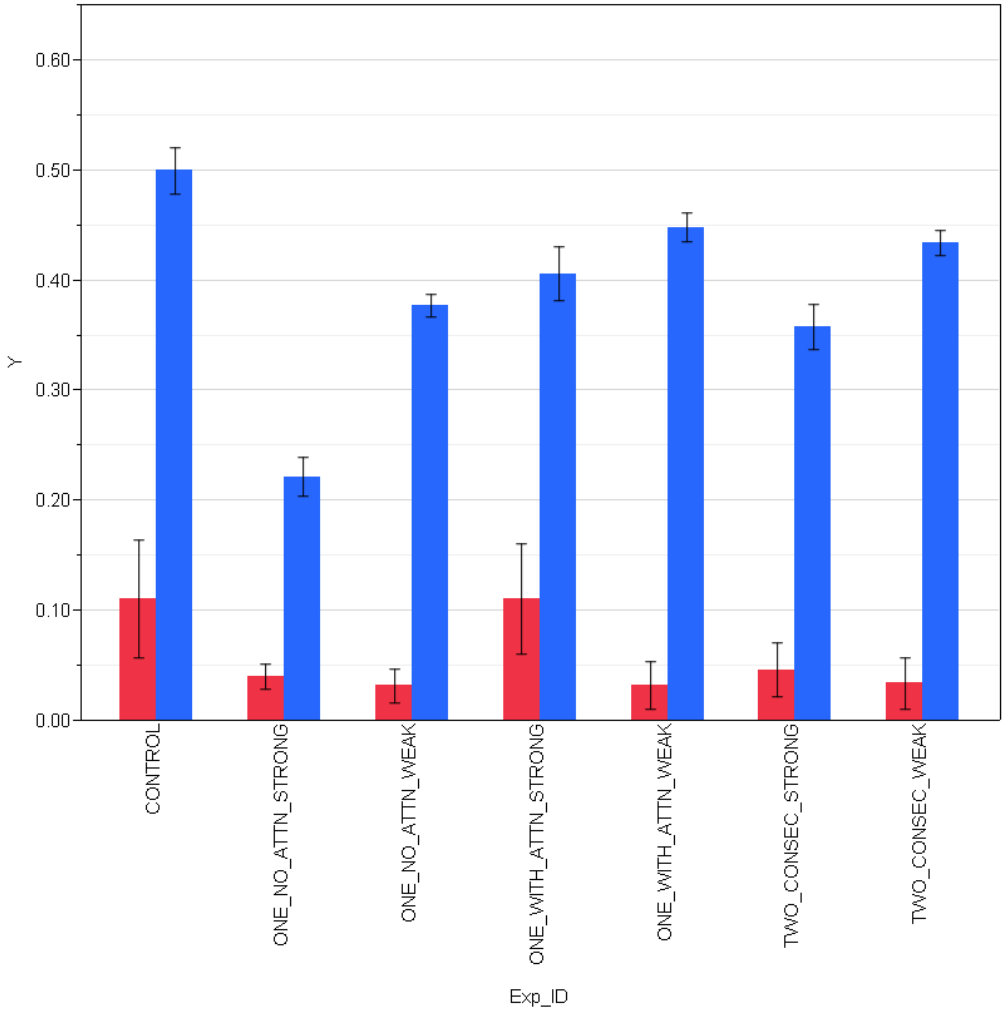
Ad Rotation for Attenuation



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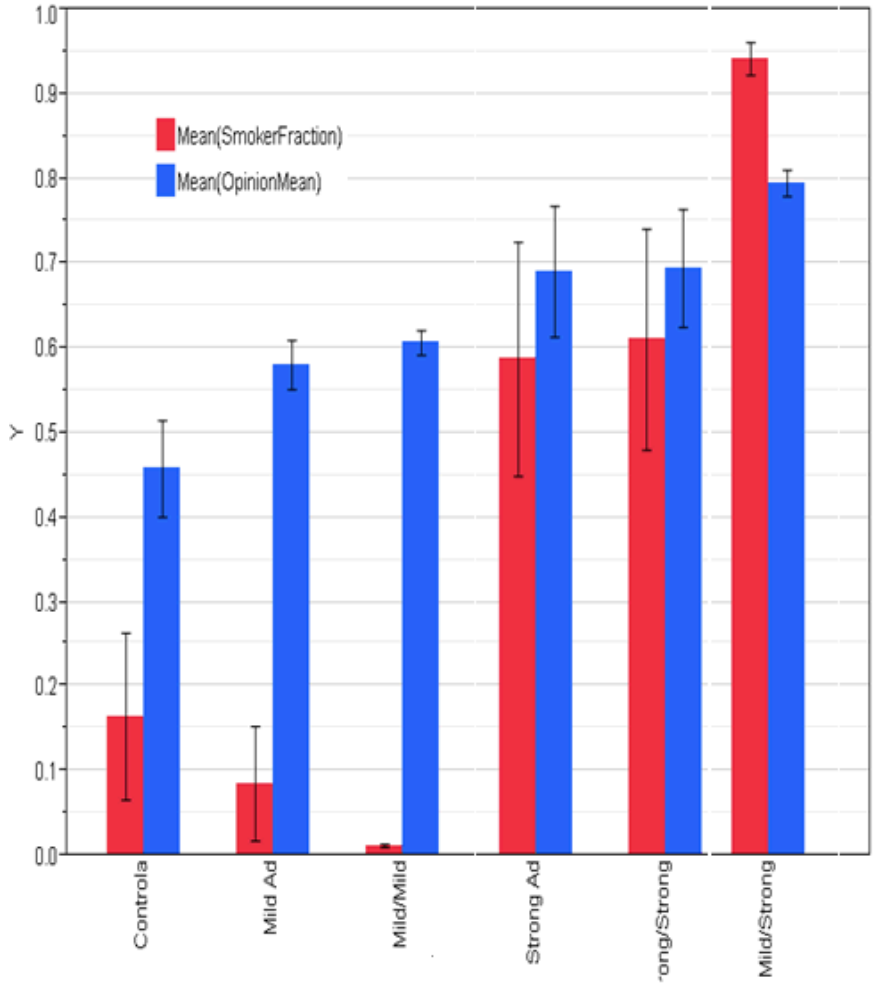
Complementary Ads Results



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