Social Network Analysis: Statistical Models of Networks Part 1

EPIC - SNA, Columbia University

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University of Minnesota

Stochastic Actor Oriented Models (SOAM)

References and Places for More Information

Stochastic Actor Oriented Models (SOAM)

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Stoachastic Actor Oriented Model

- A model for estimating the change in network structure over time from panel data
- Based on the idea that indivuals choose to add or subtract ties myopically based on network structure and exogenous variabls
- Details to follow. . .

Stochastic Actor Oriented Models (SOAM)

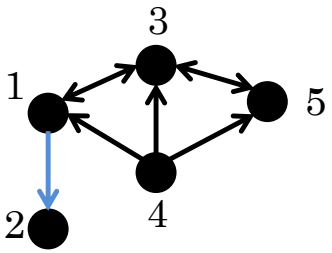
We'll approach the model in the following steps:

1. The general form of the model
   - Network Functions
   - Behavior Functions
2. The simulation & estimation engine
   - Assumptions of the model
     - Homogeneity – temporal/structural/behavioral
   - Goodness of Fit Statistics
3. Empirical Examples
   - "Separating selection from influence"

jimi adams. EPIC - SNA 2017. Columbia University Origin: Snijders TAB, van de Bunt G, Steglich CEG. Introduction to Stochastic Actor-Based Models for Network Dynamics. Social Networks 2010;32:44-60.

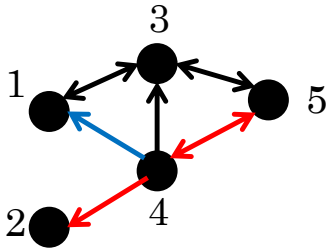
Stochastic Actor Oriented Models (SOAM)

1. Model Form



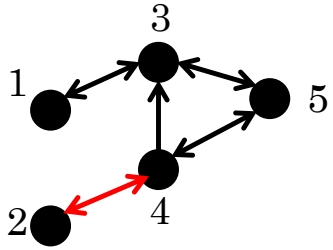
	1	1	0	0
0		0	0	0
1	0		0	1
1	0	1		1
0	0	1	0	

t_0



	0	1	0	0
0		0	0	0
1	0		0	1
1	1	1		1
0	0	1	1	

t_1



	0	1	0	0
0		0	1	0
1	0		0	1
0	1	1		1
0	0	1	1	

t_2

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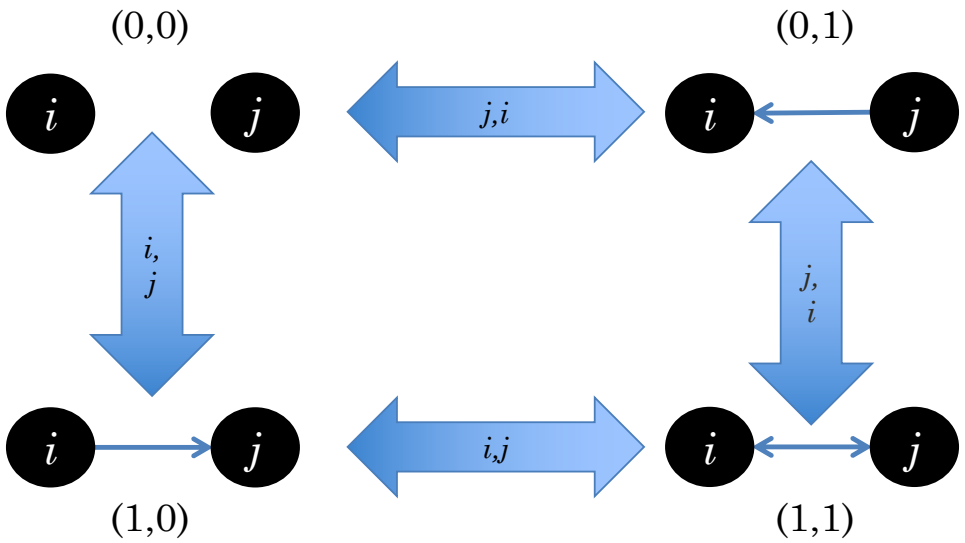

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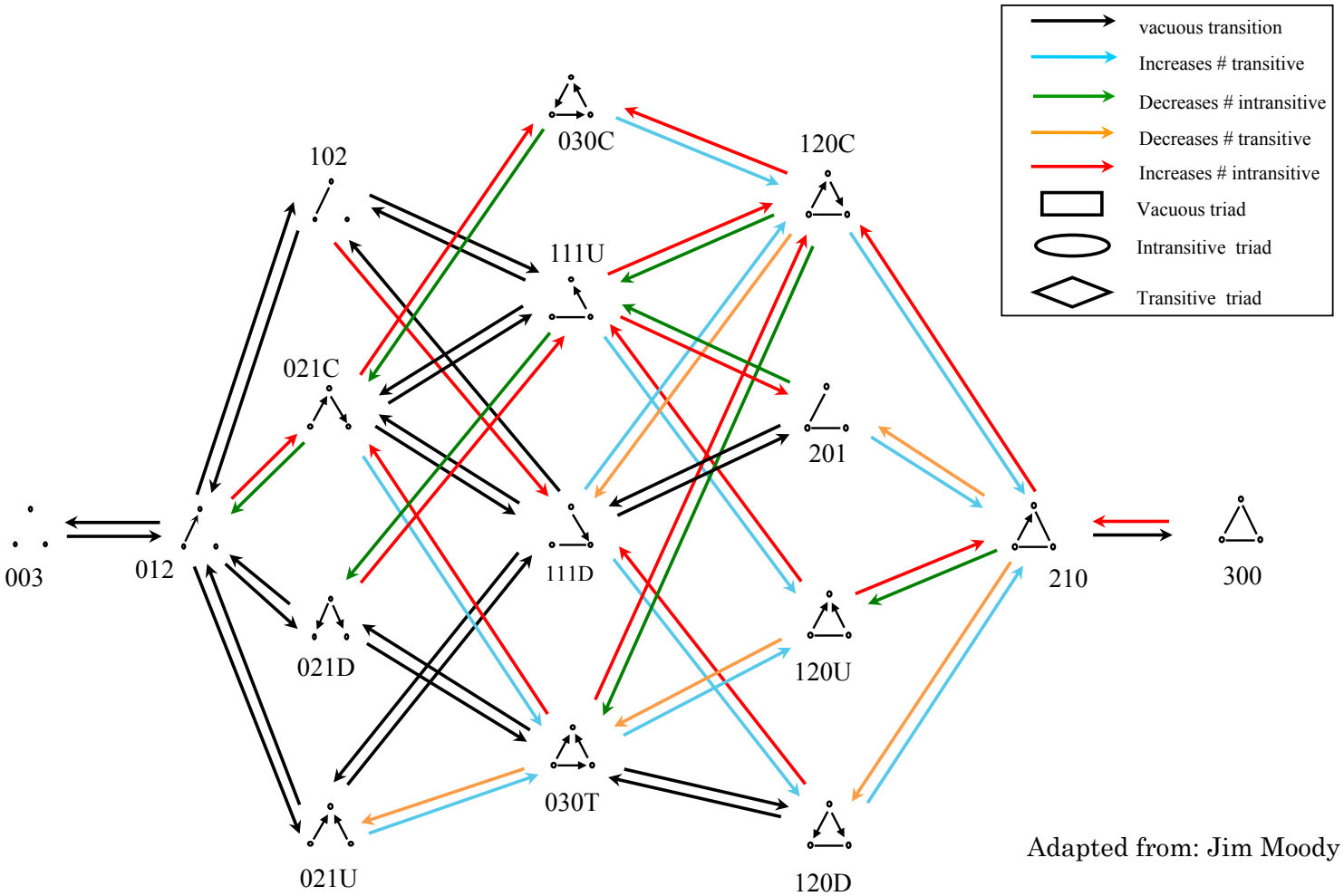

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Stochastic Actor Oriented Models (SOAM)

1. Model Form

Actor oriented: individuals make choices based on maximizing individual functions.

- 2 domains of decisions:
  1. decisions about network ties
     - selection, deselection
  2. decisions about own behavior.
  - Conditionally independent, *given the current state*
- for each decision domain two submodels:
  1. When can actor make a decision? (rate function)
  2. Which decision actor makes? (objective function)

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Stochastic Actor Oriented Models (SOAM)

1. Model Form

- Modeling Configurations
  - (x,z)(t) contains adjacency matrix X and vector(s) of behavioral variables Z at time t
- Stochastic process
  - Co-evolution is modeled by specifying transition probabilities between states $(x,z)(t_1)$ & $(x,z)(t_2)$

	Timing of decisions	**Decision rules**
Network evolution	Network rate function	Network objective function
Behavioural evolution	Behavioral rate function	Behavioral objective function

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Stochastic Actor Oriented Models (SOAM)

1. Model Form

$$f_i(\beta, x) = \sum_k \beta_k s_{ki}(x) + \varepsilon(x, z, t, j)$$

	Timing of decisions	Decision rules
Network evolution	Network rate function	Network objective function
Behavioural evolution	Behavioral rate function	Behavioral objective function

- $f_i(\beta, x)$ is the value of the network objective function for actor (i), given:
  - the current set of parameter estimates (β), and
  - state of the network (x).
  - For k effects, represented as s_{ki}, which may be based on
    - the network (x) or
    - individual attributes (z)
  - Estimated with some random disturbance (ε) associated with x, z, t & j
- Which can be formulated (remember ERGM model) as conditional probabilities:

$$\Pr(x(i \to j) \mid x, z) = \frac{\exp\left(f_i^{net}(\beta^{net}, x, z, t, j)\right)}{\sum_{k \in \{1,\ldots,N\}} \exp\left(f_i^{net}(\beta^{net}, x, z, t, k)\right)}$$

- Where:
  - $x(i \to j)$ is the network obtained from x by changing tie to actor j;
  - $x(i \to i)$ formally stands for keeping the network as is

Stochastic Actor Oriented Models (SOAM)

1. Model Form

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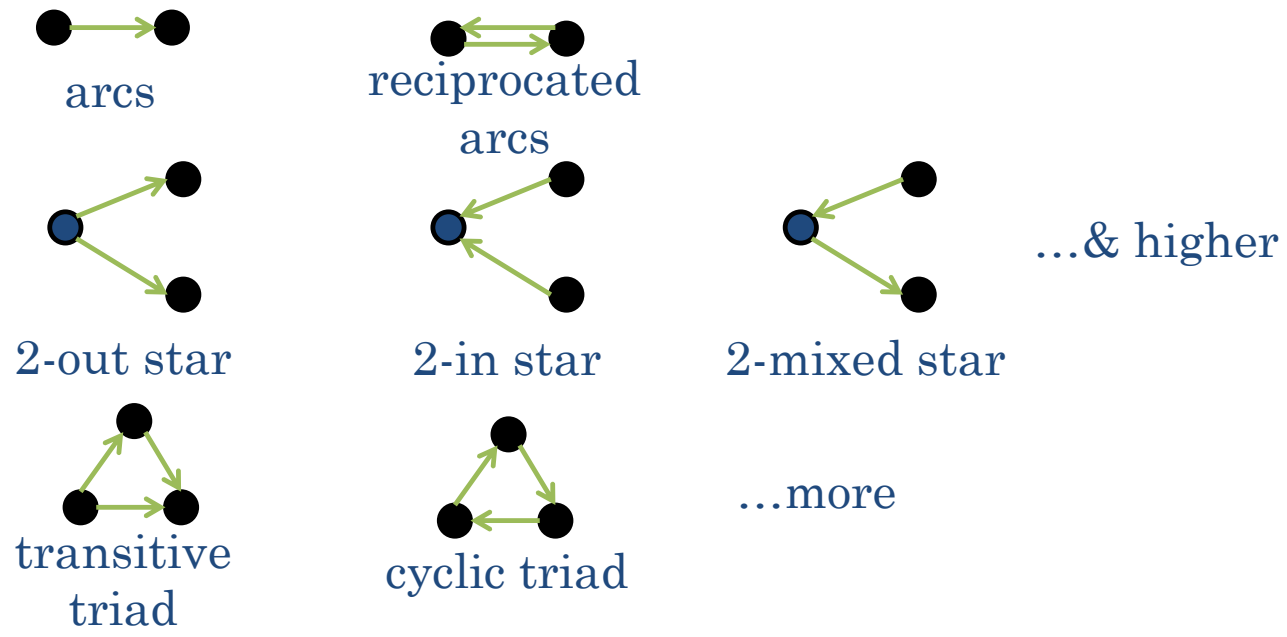
	Timing of decisions	Decision rules
Network evolution	Network rate function	Network objective function
Behavioural evolution	Behavioral rate function	Behavioral objective function

- Like ergms, the $f_i(\beta,x)$ is a (typically linear) combination of network endogenous effects, with parameters as effect weights

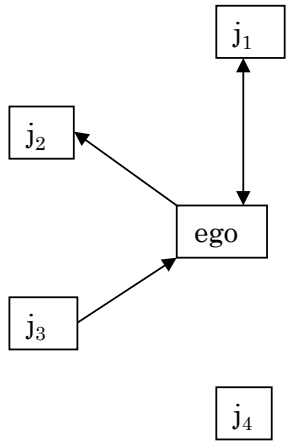


Stochastic Actor Oriented Models (SOAM)

A Simple Example

	outdegree	reciprocity
$f_{ego}(\beta,x) =$	$-2 \sum_j x_{ij}$	$+ 1.8 \sum_j x_{ij} x_{ji}$

	Outdegree	Reciprocity	Sum
	b = -2	b = +1.8	
Current	-2 * 2 = -4	1.8 * 1 = 1.8	-2.2
Drop tie to j_1	-2 * 1 = -2	1.8 * 0 = 0	-2
Drop tie to j_2	**-2 * 1 = -2**	**1.8 * 1 = 1.8**	**-.2**
Add tie to j_3	-2 * 3 = -6	1.8 * 2 = 3.6	-2.4
Add tie to j_4	-2 * 3 = -6	1.8 * 1 = 1.8	-4.2



Given the current state of the network, ego is most likely to drop their tie to j_2.

Remember actor oriented, so only evaluating changes for outgoing ties.

Stochastic Actor Oriented Models (SOAM)

1. Model Form

$$f_i(\beta, x) = \sum_k \beta_k s_{ki}(x) + \varepsilon(x, z, t, j)$$

Effect	Network Statistic	Effective Transitions in Network[a]	Verbal Description
1. Outdegree	$\sum_j \mathbf{x}_{ij}$		Overall tendency to have ties
2. Reciprocity	$\sum_j \mathbf{x}_{ij}\mathbf{x}_{ji}$		Tendency to have reciprocated ties
3. Preferential attachment	$\sum_j \mathbf{x}_{ij}\sqrt{\sum_h \mathbf{x}_{hj}}$		Tendency to attach to popular others (with decreasing marginal sensitivity to alter's popularity)
4. Transitive triplets	$\sum_j \mathbf{x}_{ij} \sum_h \mathbf{x}_{ih}\mathbf{x}_{hj}$		Tendency toward triadic closure of the neighborhood (linear effect of the number of indirect ties)
5. Transitive ties	$\sum_j \mathbf{x}_{ij} \max_h(\mathbf{x}_{ih}\mathbf{x}_{hj})$	 (*number* of intermediaries is irrelevant)	Tendency toward triadic closure of the neighborhood (binary effect of indirect ties)
6. Actors at distance 2	$\sum_j (1 - \mathbf{x}_{ij}) \max_h(\mathbf{x}_{ih}\mathbf{x}_{hj})$	 (*number* of intermediaries is irrelevant)	Tendency to keep others at social distance 2 (negative measure of triadic closure)
7. Balance	$\sum_j \mathbf{x}_{ij}\text{strsim}_{ij}$		Tendency to have ties to structurally similar others (structural balance)
8. 3-cycles	$\sum_j \mathbf{x}_{ij} \sum_h \mathbf{x}_{jh}\mathbf{x}_{hi}$		Tendency to form relationship cycles (negative measure of hierarchy)
9. Betweenness	$\sum_j \mathbf{x}_{ij} \sum_h \mathbf{x}_{hi}(1 - \mathbf{x}_{hj})$	 (*no direct link* from left to right actor)	Tendency to occupy an intermediary position between unrelated others (broker position)

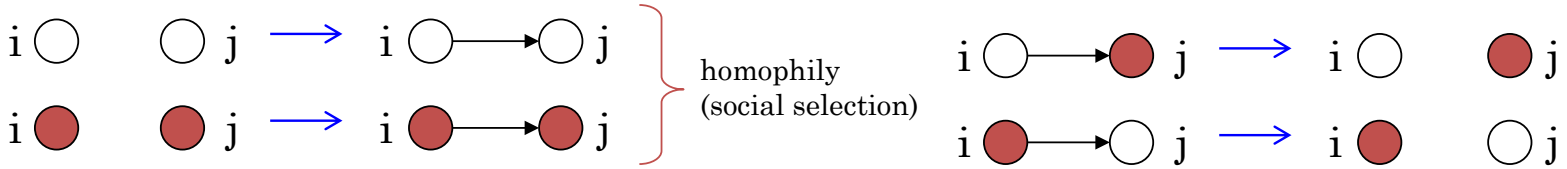
Stochastic Actor Oriented Models (SOAM)

1. Model Form

- Modeling **selection** and influence
  - Influence/selection estimate sources of measured behavioral similarity:

$$sim_{ij} := \frac{1-|z_i - z_j|}{max_z - min_z}$$

- Similarity of actor i to all network neighbors : $\sum_j x_{ij} sim_{ij}$
- Actor i has two ways of increasing friendship similarity:
  1. choosing *j*'s w/ same behavior as *i* (or deselecting dissimilar alters):



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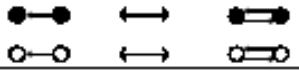
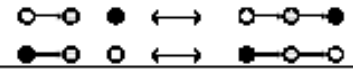
Stochastic Actor Oriented Models (SOAM)

1. Model Form

$$f_i(\beta, x) = \sum_k \beta_k s_{ki}(z)$$

10. Covariate alter	$\sum_j \mathbf{x}_{ij}(\mathbf{z}_j - \bar{\mathbf{z}})$		Main effect of alter's behavior (covariate determines popularity in network)
11. Covariate ego	$\sum_j \mathbf{x}_{ij}(\mathbf{z}_i - \bar{\mathbf{z}})$		Main effect of ego's behavior on tie preference (covariate determines activity in network)
12. Covariate similarity	$\sum_j \mathbf{x}_{ij}\mathrm{sim}_{ij}$		Tendency to have ties to similar others (homophile selection on covariate, linear in score differences)
15. similarity × reciprocity	$\mathbf{x}_{ij}\mathbf{x}_{ji}\ \mathrm{sim}_{ij}$		preference for reciprocated ties to similar others
16. between dissimilar alters	$\sum_h (1-\mathrm{sim}_{jh})\mathrm{between}(i;jh)$		preference for being in an intermediary position between unrelated, dissimilar others (brokerage potential)
17. similarity × dense triads	$\sum_h \mathrm{group}(ijh)\left(\mathrm{sim}_{ij}+\mathrm{sim}_{ih}\right)$		preference for being part of behaviorally similar cohesive subgroups
18. behavior × peripheral	$\mathbf{z}_i \sum_{hk} \mathrm{peripheral}(i;jhk)$		behavior-specific preference for unilaterally attaching to cohesive subgroups
19. similarity × peripheral	$\sum_{hk}\left(\mathrm{peripheral}(i;jhk) \times(\mathrm{sim}_{ij}+\mathrm{sim}_{ih}+\mathrm{sim}_{ik})\right)$		preference for unilaterally attaching to behaviorally similar cohesive subgroups

* In the *effective transitions* illustrations, it is assumed that the behavioral dependent variable is dichotomous and centered at zero; the color coding is ○ = low score (negative), ● =high score (positive), ○ =arbitrary score. The tie $\mathbf{x}_{ij}$ from actor i to actor j is the one that changes in the transition indicated by the double arrow. Illustrations are not exhaustive.

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Stochastic Actor Oriented Models (SOAM)

1. Model Form

	Timing of decisions	Decision rules
Network evolution	Network rate function	Network objective function
Behavioural evolution	Behavioral rate function	Behavioral objective function

$$f_i^z(\beta, x, z) = \sum_k \beta_k^z s_{ki}^z(x, z) + \varepsilon(x, z, t, \delta)$$

- $f_i(\beta^z, x, z)$ is the value of the behavioral objective function for actor (i), given:
  - the current set of parameter estimates (β), and
  - i's current behavior (z)
  - state of the network (x).
  - For k effects, represented as s_{ki}, which may be based on
    - the network (x) or
    - individual attributes (z)
  - Estimated with some random disturbance (ε) associated with x, z, t &δ
- Choice probabilities analogous to network part, but focusing on how behavior change would alter the objective function.

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1. Model Form

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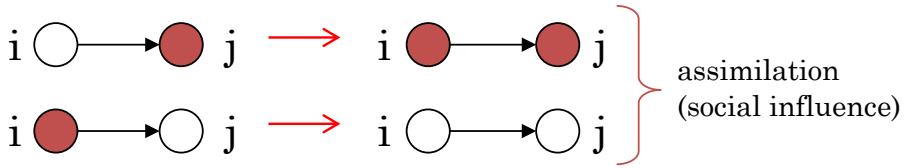
  - Influence/selection estimate sources of measured behavioral similarity:

$$sim_{ij} := \frac{1 - |z_i - z_j|}{max_z - min_z}$$

- Similarity of actor i to all network neighbors : $\sum_j x_{ij} sim_{ij}$
- Actor i has two ways of increasing friendship similarity:
  1. choosing *j*'s w/ same behavior as *i* (or deselecting dissimilar alters):

  2. Adopting behavior of dissimilar *j*'s

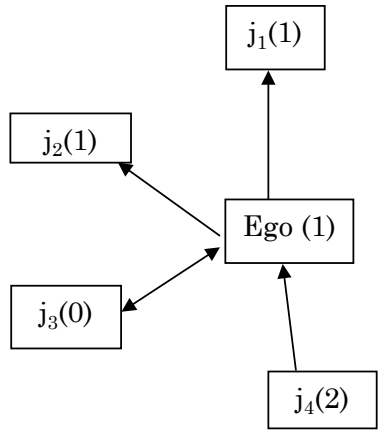


Stochastic Actor Oriented Models (SOAM)

A Simple Example

$$f_{ego}^{z}(\beta, x, z) = -0.5 * v_{ego} + 1.1 * z_{age} v_{ego} + 1.0 * sim^{z}$$

	Linear	Age	sim^z	Sum
Stay at 1	-.5 * 1 = -.5	1.1 * 1 = 1.1	**1*0.95=0.95**	**1.45**
Decrease behavior to 0	-.5 * 0 = 0	1.1 * 0 = 0	**1*0.35=0.35**	**0.35**
Increase behavior to 2	**-.5 * 2 = -1**	**1.1 * 2 = 2.2**	**1*-0.55=-0.55**	**0.65**



$\sum_j x_{ij}(sim_{ij}^Z - \overline{sim^Z})$ $\quad sim_{ij}^Z = 1 - |z_i - z_j| / \Delta_Z$, $\Delta_Z = \max_{ij} |z_i - z_j| = 2$ $\quad \overline{sim^Z}$ = similarity expected by chance

(1) Dyad	(2) sim_{ij}^Z	(3) $x_{ij}(sim_{ij}^Z - \overline{sim^Z})$
Ego, j_1	1 - | 1 - 1 | / 2 = .5	1 (.5 - .05) = .45
Ego, j_2	1 - | 1 - 1 | / 2 = .5	1 (.5 - .05) = .45
Ego, j_3	1 - | 1 - 0 | / 2 = 0	1 (0 - .05) = .05
Ego, j_4	1 - | 1 - 2 | / 2 = 0	0 (0 - .05) = 0
		sum = .95

Do this for all possible dyads to compute $\overline{sim^Z}$ = .05

Given the current state of the network, ego is most likely to stay at level 1.

change to 0

(1) Dyad	(2) sim_{ij}^Z	(3) $x_{ij}(sim_{ij}^Z - \overline{sim^Z})$
Ego, j_1	1 - | 0 - 1 | / 2 = 0	1 (0 - .05) = -.05
Ego, j_2	1 - | 0 - 1 | / 2 = 0	1 (0 - .05) = -.05
Ego, j_3	1 - | 0 - 0 | / 2 = .5	1 (.5 - .05) = .45
Ego, j_4	1 - | 0 - 2 | / 2 = -.5	0 (-.5 - .05) = 0
		sum = .35

change to 2

(1) Dyad	(2) sim_{ij}^Z	(3) $x_{ij}(sim_{ij}^Z - \overline{sim^Z})$
Ego, j_1	1 - | 2 - 1 | / 2 = 0	1 (0 - .05) = -.05
Ego, j_2	1 - | 2 - 1 | / 2 = 0	1 (0 - .05) = -.05
Ego, j_3	1 - | 2 - 0 | / 2 = -.5	1 (-.5 - .05) = -.45
Ego, j_4	1 - | 2 - 2 | / 2 = .5	0 (.5 - .05) = 0
		sum = -.55

Stochastic Actor Oriented Models (SOAM)

1. Model Form

$$f^{z}_{ego}(\beta, x, z)$$

Effect	Network Statistic	Effective Transitions in Behavior[a]	Verbal Description
1. Shape: linear and quadratic	$(\mathbf{z}_i - \bar{\mathbf{z}})$ and $(\mathbf{z}_i - \bar{\mathbf{z}})^2$		*The two parameters together define a parabola shape of the objective function, allowing it to capture the basic shape of the observed distribution of the behavioral variable.*
2. Average similarity	$(\sum_j \mathbf{x}_{ij}\mathrm{sim}_{ij})/(\sum_j \mathbf{x}_{ij})$		Assimilation to neighbors' average behavior (small neighborhoods pull as much as big ones)
3. Sum of similarity	$\sum_j \mathbf{x}_{ij}\mathrm{sim}_{ij}$		Assimilation to neighbors' average behavior (size of neighborhood determines size of effect)
4. Average alters	$(\sum_j \mathbf{x}_{ij}(\mathbf{z}_j - \bar{\mathbf{z}}))/(\sum_j \mathbf{x}_{ij})$		Main effect of neighbors' average behavior (contagion/influence, but not necessarily assimilation)
5. Indegree × behavior	$(\mathbf{z}_i - \bar{\mathbf{z}})\sum_j \mathbf{x}_{ji}$		Effect of own popularity in the network on behavior
6. Outdegree × behavior	$(\mathbf{z}_i - \bar{\mathbf{z}})\sum_j \mathbf{x}_{ij}$		Effect of own activity in the network on behavior
7. Isolation × behavior	$(\mathbf{z}_i - \bar{\mathbf{z}})(1 - \max_j(\mathbf{x}_{ij}))$		Effect of being isolated in the network on behavior

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Stochastic Actor Oriented Models (SOAM)

A Model of Network Change

We'll approach the model in the following steps:

1. The general form of the model
   - Network Functions
   - Behavior Functions
2. The simulation & estimation engine
   - Assumptions of the model
     - Homogeneity – temporal/structural/behavioral
   - Goodness of Fit Statistics
3. Empirical Examples
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Stochastic Actor Oriented Models (SOAM)

2. Estimation & Fit (Assumptions)

- These are models for "state" based ties. That is, ties tend to "persist" but *are* change-able (adding **&** deleting).
  - Plausible for networks like friendship or enduring collaborations.
  - Not useful for "event" data (like phone calls, etc.)

- The stochastic process being modeled is the product of a Markov process, which infers:
  - The conditional probability distribution of X(t) for all future times $t > t_0$, given its values for the entire past $t_0 \leq t$, depends ***only*** on the current value $X(t_0)$.
  - Network endogenous processes matter.

- That Actor-Oriented part assumes actors control their outgoing ties (albeit influenced by peers/networks).
  - Doesn't allow for the modeling of undirected graphs.
  - Model questions about ego knowledge of alter characteristics being incorporated in the model must the theoretically justified.

Stochastic Actor Oriented Models (SOAM)

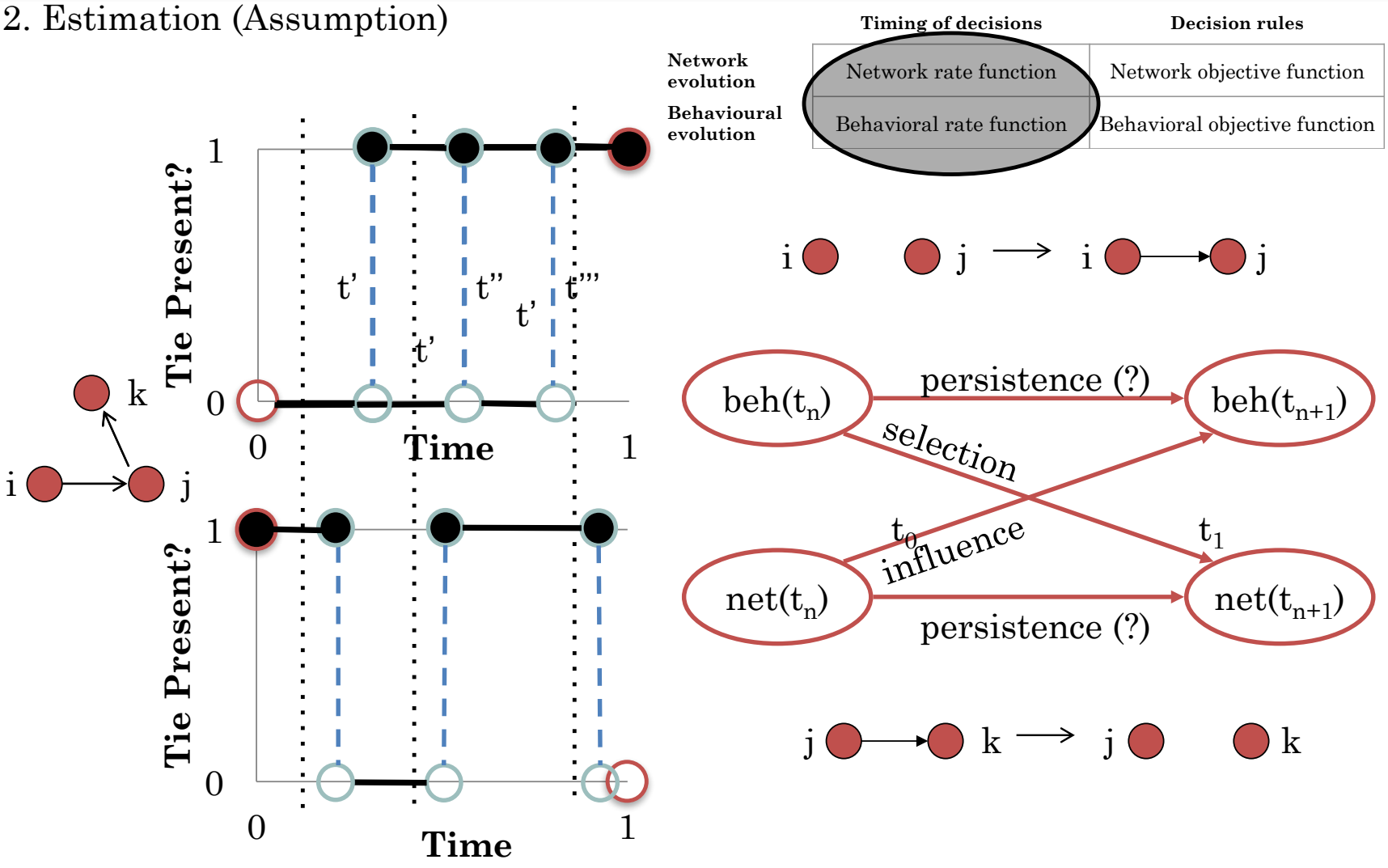
2. Estimation (Assumption)

	Timing of decisions	Decision rules
Network evolution	Network rate function	Network objective function
Behavioural evolution	Behavioral rate function	Behavioral objective function

- What's happening with time?
  - We aren't just modeling the network at time 1 as a function of the discrete network differences from time t-1 are we?
    - Short answer: NO.
  - Slightly longer answer: the model assumes that network change is continuous and the panel observations discrete snapshots of that process.
    - As such, the changes observed between $t_0 \rightarrow t_1$ are generated via a series of micro steps separated by an interval λ, which:
      - is $\ll t_1 - t_0$
      - allows for the observed amount of network and behavioral change to occur via decisions where ***no more than one tie/attribute changes at a time.***
        - $\lambda_{total} = \Sigma(\lambda_{net} + \lambda_{beh})$

Stochastic Actor Oriented Models (SOAM)

2. Estimation (Assumption)



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2. Estimation (Assumption)

	Timing of decisions	Decision rules
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- Modeling micro-steps
  - $\lambda_{total} = \Sigma(\lambda_{net} + \lambda_{beh})$, where:
  - λ_{net} is specified so as to reproduce the total observed network change between observed periods, and can be a factor of:
    - A simple rate (i.e., no difference across actors)
    - Node level covariates
    - Reciprocated degree
  - λ_{beh} is specified so as to reproduce the total observed network change, and assumes a constant per-term rate for periods from 1 to m-1
- Important to note here that if you have >2 observed periods, the SAB assumes the ALL effects other than the rate function are the same across each period.
  - Currently can test whether this is a faulty assumption, but no standard implementation of relaxing it at the moment.

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Stochastic Actor Oriented Models (SOAM)

3. Goodness of Fit

- First, examine parameter estimates and the reported t-statistics to ensure the model is being able to generate observed network change with the parameters you specified.
  - If not, respecify.
- Second, just like ERGM, we typically check a few statistics that are *NOT* explicitly included in the model.
  - Typical candidates:
    - In- & Out- degree distributions
    - Triad Census
    - Geodesic distribution

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Stochastic Actor Oriented Models (SOAM)

A Few Examples

Models of network processes.

	Model 1			Model 2			Model 3			Model 4		
	$\hat{\beta}$	SE	t	$\hat{\beta}$	SE	t	$\hat{\beta}$	SE	t	$\hat{\beta}$	SE	t
Rate Parameters												
Period 1	14.528	1.015	14.31***	15.138	1.060	14.29***	15.345	1.111	13.81***	14.957	1.037	14.43***
Period 2	14.482	.969	14.95***	14.656	1.007	14.56***	15.215	1.089	13.97***	15.330	1.122	13.66***
Period 3	11.484	.752	15.28***	10.997	.712	15.44***	11.356	.762	14.89***	12.029	.845	14.24***
Network Structural Processes												
Outdegree (Density)	−1.310	.036	36.49***	−1.781	.066	27.07***	−1.575	.041	38.61***	−1.322	.036	36.51***
Reciprocity	2.118	.064	33.35***	2.125	.061	34.95***	2.074	.058	35.95***	1.797	.073	24.55***
Reciprocity × Period	.012	.035	.34	−.112	.061	1.86†	−.106	.056	1.89†	−.123	.061	2.03*
Popularity				.073	.008	8.88***						
Popularity × Period				.011	.005	2.13*						
Transitive Triplets							.046	.004	11.50***			
Transitive Triplets × Period							.010	.004	2.48*			
Dense Triads										.228	.027	8.62***
Dense Triads × Period										.080	.033	2.45*
Controls												
Female Alter	.017	.044	.37	.033	.042	.78	.024	.045	.54	.017	.045	.37
Female Ego	−.003	.044	.06	.000	.045	.00	.008	.043	.19	.008	.047	.17
Female Similarity	.439	.031	14.21***	.467	.032	14.49***	.393	.031	12.53***	.403	.032	12.71***
Age Alter	.011	.005	2.32*	.007	.004	1.50	.008	.005	1.76†	.009	.005	1.98*
Age Ego	−.001	.005	.11	.000	.005	.02	−.004	.005	.80	−.003	.005	.60
Age Similarity	.220	.089	2.48*	.205	.085	2.41*	.188	.090	2.09*	.203	.092	2.20*
Repeat Alter	−.162	.149	1.09	−.205	.143	1.43	−.234	.148	1.58	−.224	.151	1.48
Repeat Ego	.082	.147	.56	.053	.150	.35	−.006	.151	.04	.035	.155	.23
Repeat Similarity	−.193	.127	1.52	−.179	.125	1.43	−.197	.127	1.55	−.197	.129	1.52
Classroom Presence Alter	.527	.129	4.09***	.330	.126	2.63**	.467	.126	3.70***	.473	.129	3.66***
Classroom Presence Ego	−.300	.133	2.25*	−.269	.136	1.98*	−.370	.129	2.86**	−.358	.135	2.66**
Classroom Presence Similarity	.407	.136	2.99**	.342	.140	2.45*	.273	.136	2.00*	.338	.136	2.49*
Score Test for Period Interaction (χ^2)[a]		.105			5.456*			5.938*			6.207*	

[a] Score tests all have df = 1.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Schaefer D, Light JM, Fabes RA, Hanish LD, Martin CL. Fundamental Principles of Network Formation Among Preschool Children

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A Few Examples

Table 3. Stochastic Actor-Based Model: Unstandardized Friend Selection Coefficients and Standard Errors (Meta-Analysis of Nine Schools, 988,142 Dyads)

	Model 1	Model 2	Model 3	Model 4
Depression				
Depression Similarity (Preference)	.52†	.29	.35	.19
	(.27)	(.27)	(.31)	(.29)
Alter Depression (Avoidance)		−.16***	−.18†	−.03
		(.05)	(.11)	(.05)
Ego Depression (Withdrawal)		−.18**	−.20	−.12*
		(.08)	(.13)	(.06)
Network Processes				
Outdegree	−2.15***	−2.17***	−3.13***	−3.96***
	(.23)	(.23)	(.31)	(.28)
Reciprocity				2.08***
				(.18)
Transitive Triplets				.53***
				(.07)
Popularity (square-root)				.35***
				(.03)

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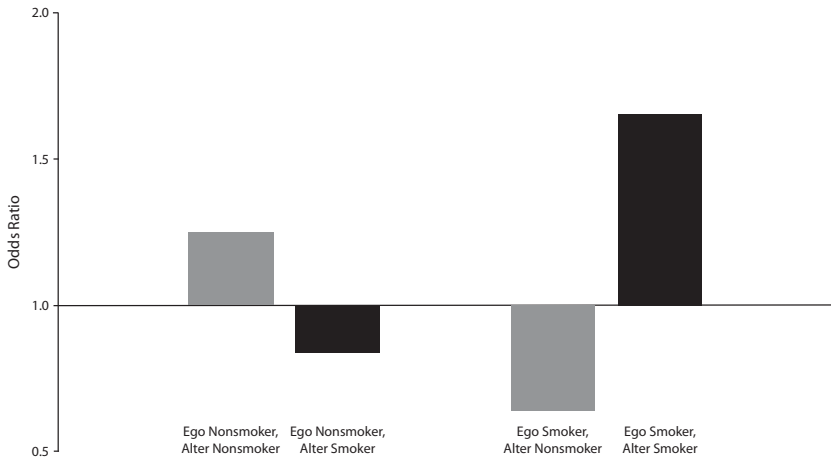

Note. Nonsmoker defined as no smoking in past 30 days; smoker defined as smoking ≥ 12 of the past 30 days. We calculated odds ratios relative to the odds of ego (i.e., respondent) selecting an alter (i.e., peer) with intermittent smoking (1–11 of the past 30 days). All other effects are held constant.

FIGURE 2—Odds ratios of friend selection on the basis of smoking frequency of ego and alter: National Longitudinal Study of Adolescent Health, 1994–1996.

TABLE 2—Estimates From Stochastic Actor-Based Model Testing Smoking and Friendship Coevolution With Add Health Sample: National Longitudinal Study of Adolescent Health, 1994–1996

Effect	b (SE)
Smoking behavior function	
Rate	2.065*** (0.270)
Linear shape	−0.107 (0.265)
Quadratic shape	1.162*** (0.186)
Female	0.155 (0.189)
Age	−0.005 (0.092)
Parent smoking	0.016 (0.218)
Delinquency	0.432* (0.183)
Alcohol	−0.102 (0.138)
GPA	−0.089 (0.132)
Average similarity	2.883*** (0.855)
In-degree	−0.041 (0.139)
In-degree squared	0.002 (0.012)
Friend selection function	
Rate	10.241*** (0.505)
Rate: truncated roster	−1.178** (0.452)
Out-degree	−3.935*** (0.170)
Reciprocity	1.916*** (0.085)
Transitive triplets	0.515*** (0.035)
Popularity (square root of In-degree)	0.290*** (0.037)
Extracurricular activity overlap	0.275*** (0.060)
Female	
Similarity	0.237*** (0.045)
Alter	−0.111* (0.046)
Ego	−0.039 (0.053)
Age	
Similarity	1.004*** (0.125)
Alter	−0.009 (0.029)
Ego	−0.037 (0.031)
Delinquency	
Similarity	0.147 (0.080)
Alter	−0.039 (0.040)
Ego	0.019 (0.043)
Alcohol	
Similarity	0.269** (0.101)
Alter	−0.028 (0.035)
Ego	−0.029 (0.039)
GPA	
Similarity	0.706*** (0.133)
Alter	−0.054 (0.035)
Ego	−0.019 (0.040)
Smoking	
Similarity	0.683*** (0.126)
Alter	0.130* (0.062)
Alter squared	0.023 (0.171)
Ego	−0.039 (0.055)

Note. GPA = grade point average.
*P < .05; **P < .01; ***P < .001 (2-tailed tests).

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A Dynamic Model of US Adolescents' Smoking and Friendship Networks.
American Journal of Public Health 2012;102(6):e12-e18.

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Figure 2: Smoking outcomes based on joint manipulation of peer influence (PI) and smoke alter (popularity) parameters[a]

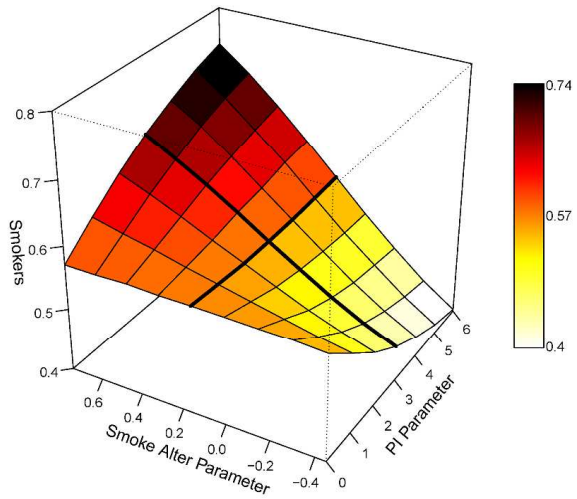
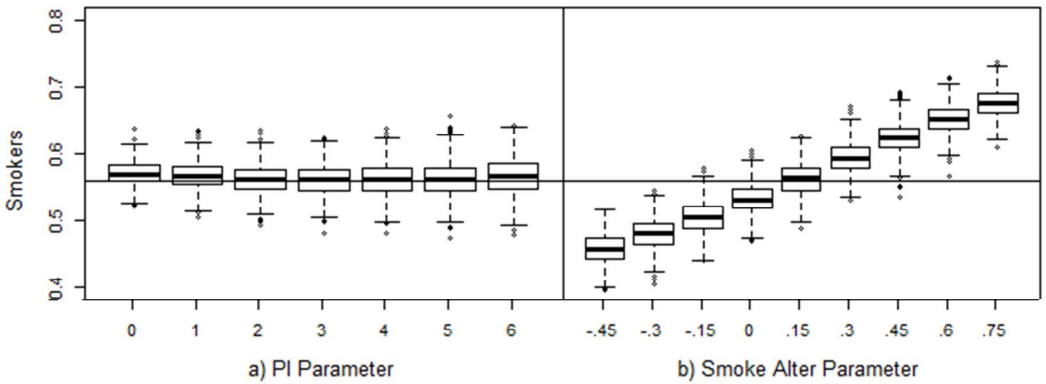


Figure 1: Simulated smoking outcomes based on independent manipulations of peer influen (PI) and smoking-alter (popularity) parameters[a]



[a] Horizontal lines in each panel represent the observed value of the outcome. Smokers is measured as the proportion of adolescents who smoke at time 2. Initiations is the proportion of nonsmokers observed at time 1 who became smokers at time 2. Cessations is the proportions of smokers observed at time 1 who did not smoke at time 2.

Schaefer DR, adams j, Haas SA. Social Networks and Smoking: Exploring the Effects of Peer Influence and Smoker Popularity through Simulations. *Health Education & Behavior,* 2013;40(S1):24-32.

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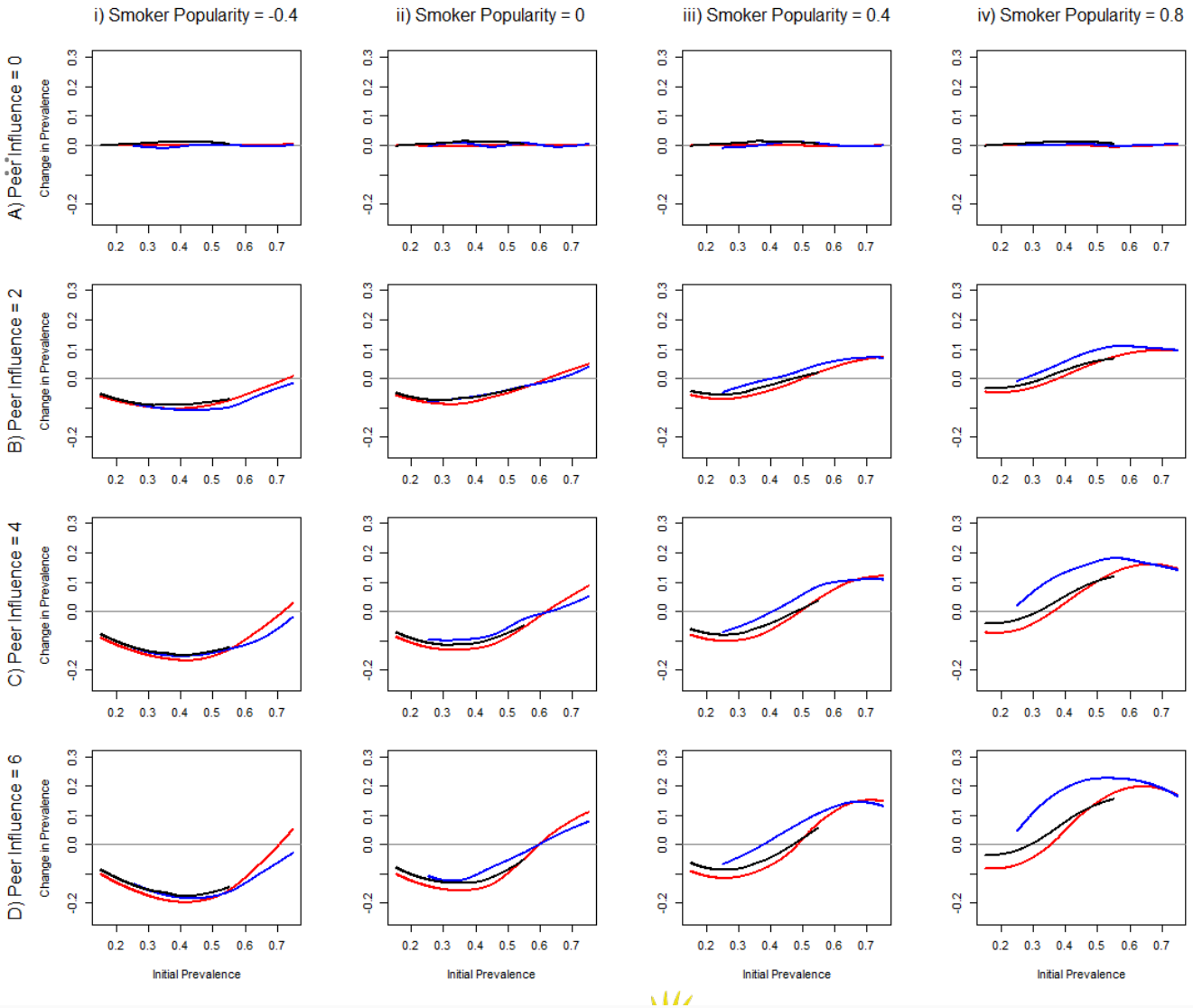
Smoking Distribution:
Empirically-Based,
Model-Based,
Random



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References and Places for More Information

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