Statistical Analysis of Networks

Coevolution of Networks and Behavior

Motivating Example

Evaluating peer-influence processes in a prison-based therapeutic community: a dynamic network approach

Derek A. Kreager[a,b,*], David R. Schaefer[c], Kimberly M. Davidson[a], Gary Zajac[b], Dana L. Haynie[d], George De Leon[e]

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[c] *Department of Sociology, University of California-Irvine, 3151 Social Sciences Plaza, Irvine, CA 92697, USA*
[d] *Department of Sociology, Ohio State University, 238 Townshend Hall, Columbus, OH 43210, USA*
[e] *New York University School of Medicine, 550 First Avenue, New York, NY, 10016, USA*

- What is a "therapeutic community"? What does it do?

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- If the causal mechanism hypothesized by the model is working, what should the network "look like"?

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- If the causal mechanism hypothesized by the model is working, what should the network "look like"?
  - Homophily!!!

Motivating Example

An engaged resident

Time t

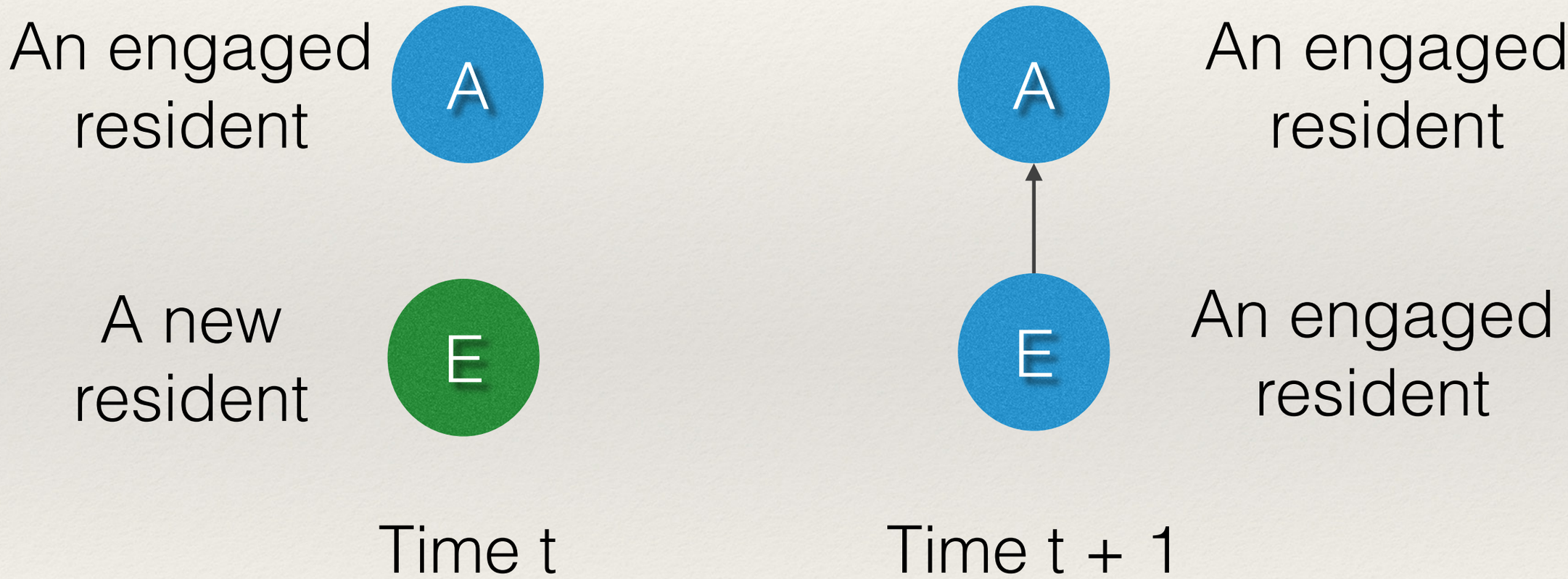
Motivating Example

An engaged resident

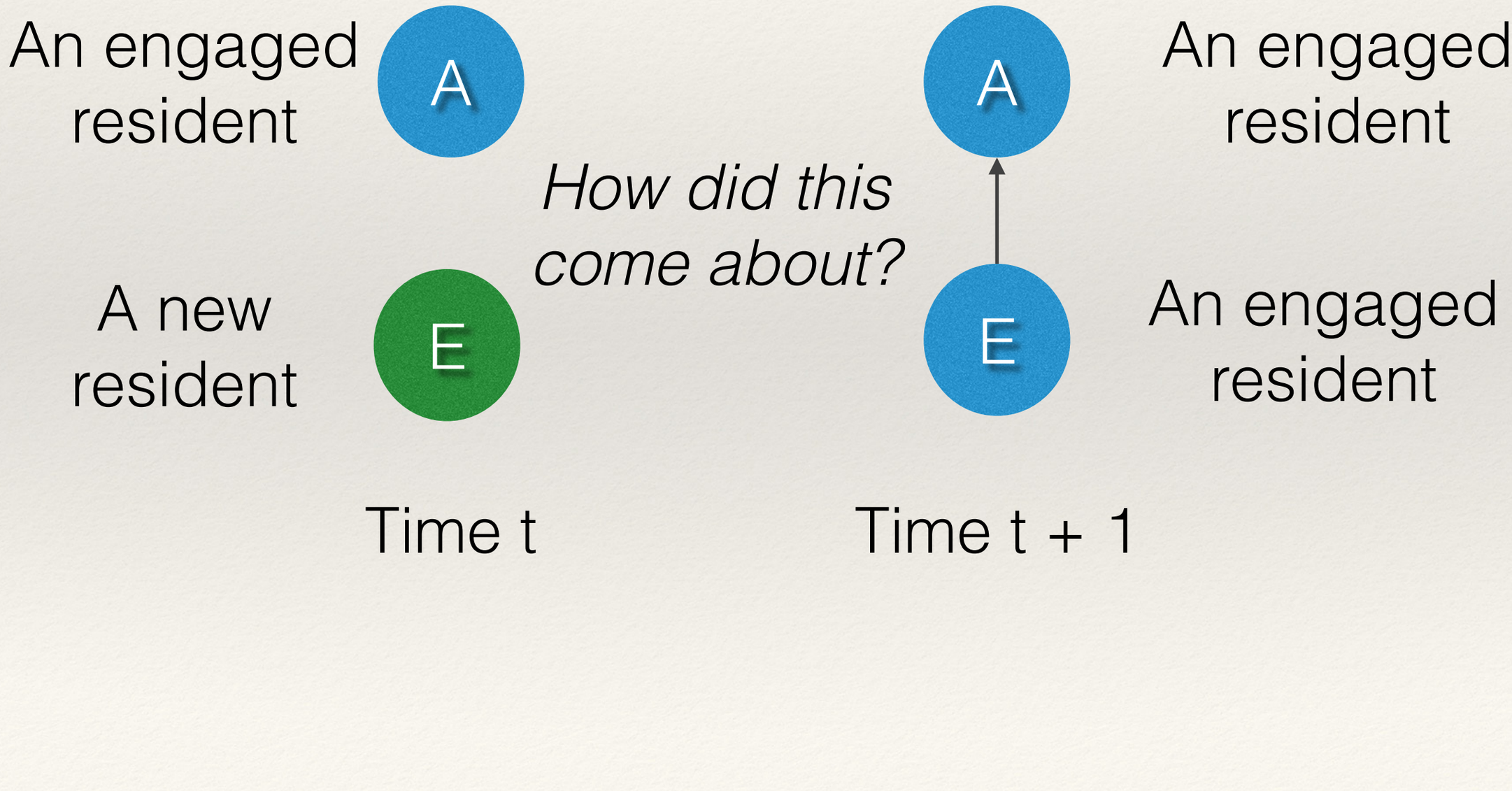
A new resident

Time t

Motivating Example



Motivating Example



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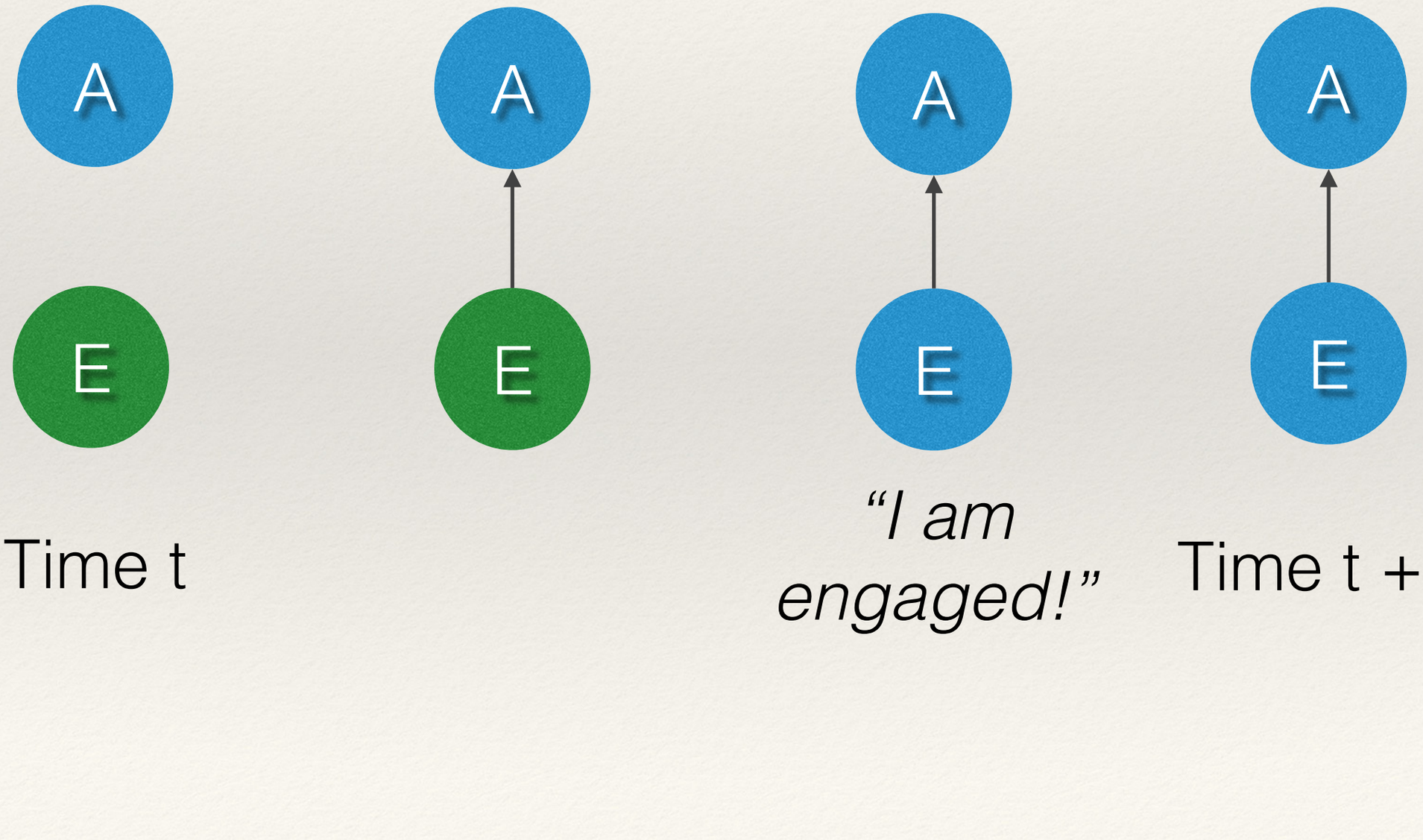
- The basic problem is that **homophily** is an outcome that can be generated through three different mechanisms:
  - Selection
  - Influence
  - Cross-dimensional selection

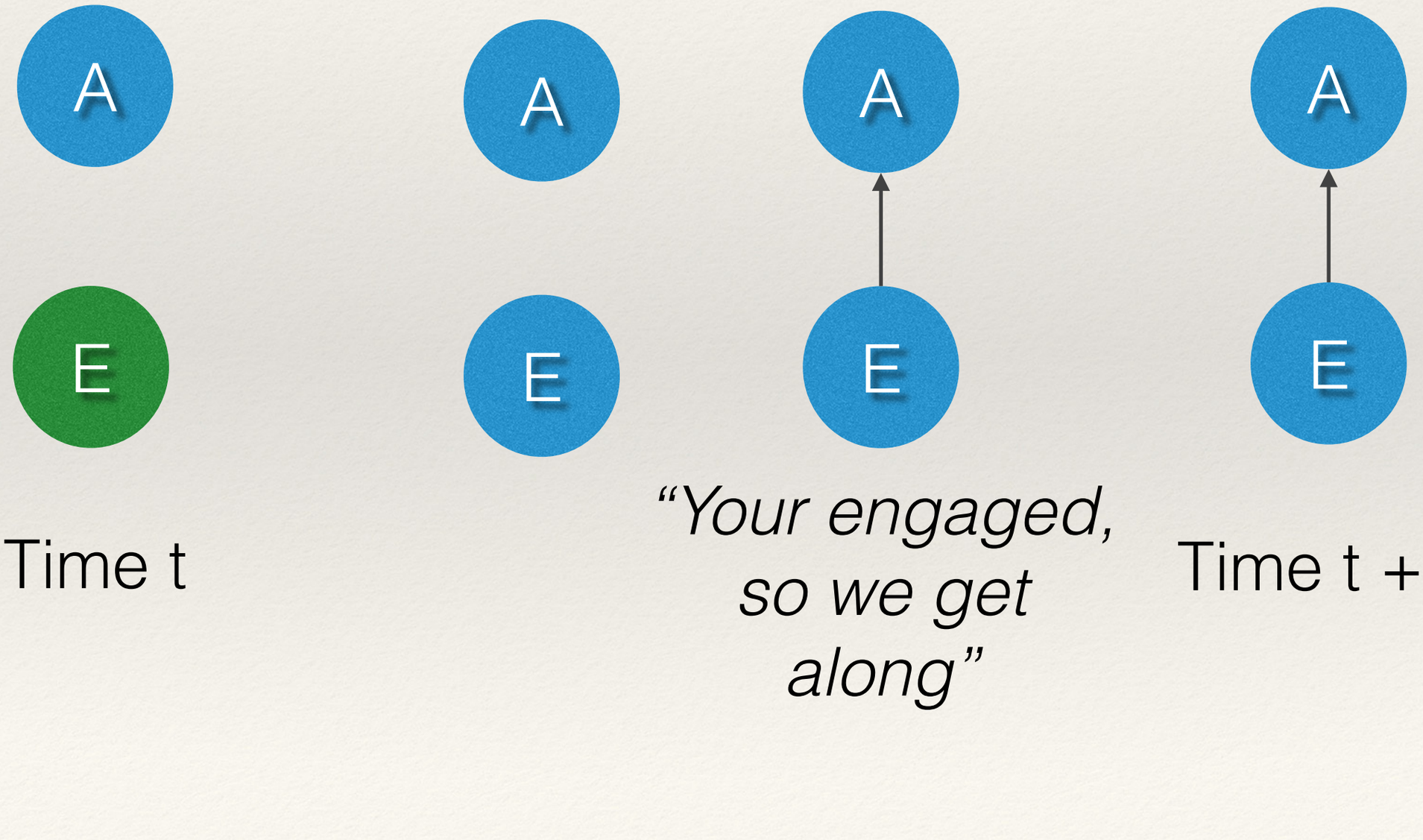
Motivating Example

Social influence



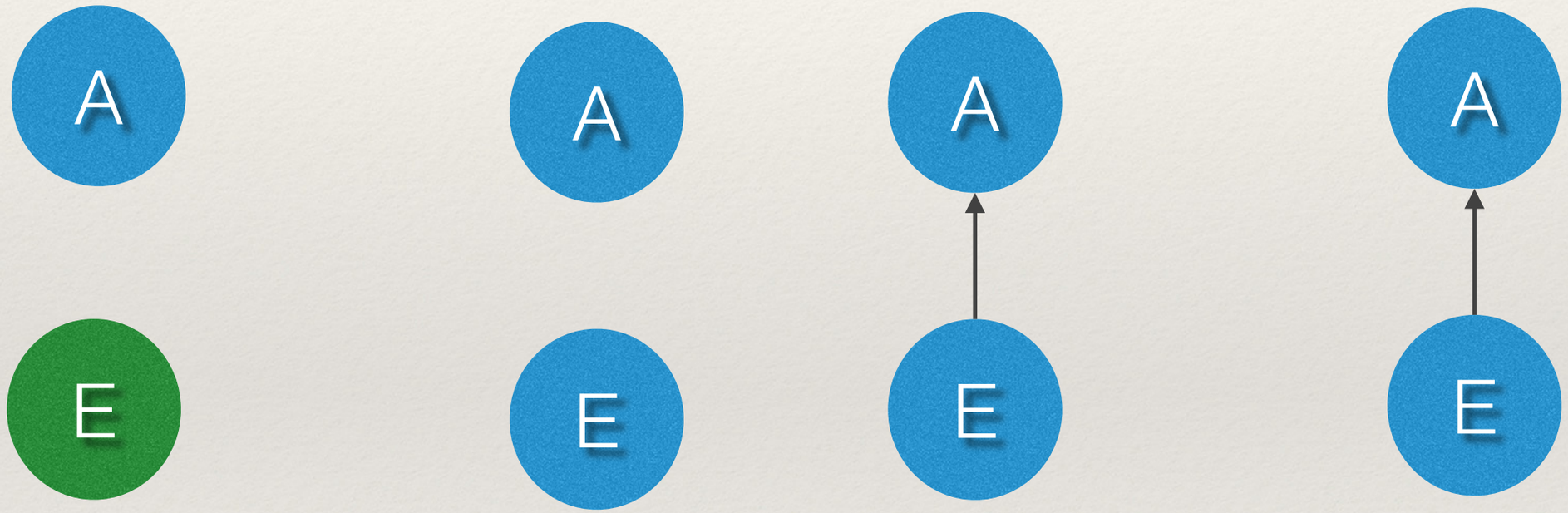
Motivating Example

Selection



Motivating Example

Cross-Dimensional selection



Time t

"Your also a circle, we get along"

Time t + 1

Motivating Example

- What do the authors find?

Table 1
Stochastic Actor-Oriented Models of Social Ties in a Prison Therapuetic Community.

	M1			M2			M3			M4		
Network Selection Function	b		(se)	b		(se)	b		(se)	b		(se)
Rate (period 1)	16.95	***	(1.38)	16.06	***	(1.28)	17.26	***	(1.19)	14.49	***	(1.07)
Rate (period 2)	10.46	***	(0.76)	10.26	***	(0.86)	10.58	***	(0.77)	9.63	***	(0.74)
Rate (period 3)	9.28	***	(0.81)	9.34	***	(0.91)	9.38	***	(0.82)	8.56	***	(0.74)
Rate (period 4)	13.02	***	(1.12)	13.59	***	(1.41)	14.37	***	(1.18)	12.99	***	(1.13)
Rate (period 5)	15.60	***	(1.15)	15.89	***	(1.37)	16.65	***	(1.18)	14.64	***	(1.04)
Rate (period 6)	12.79	***	(0.96)	12.73	***	(1.01)	14.45	***	(1.07)	13.07	***	(1.06)
Rate (period 7)	12.88	***	(0.90)	13.18	***	(1.16)	14.11	***	(1.12)	13.12	***	(1.03)
Rate (period 8)	14.89	***	(1.09)	15.38	***	(1.24)	16.65	***	(1.30)	15.12	***	(1.17)
Rate (period 9)	12.66	***	(1.14)	12.59	***	(1.09)	13.70	***	(1.10)	12.66	***	(1.07)
Outdegree (density)	−.80	***	(0.03)	−1.43	***	(0.03)	−1.15	***	(0.05)	−1.67	***	(0.05)
Reciprocity				1.67	***	(0.09)				1.58	***	(0.09)
Transitive Triplets				.25	***	(0.02)				.29	***	(0.02)
Transitive Reciprocal Triplets				−.31	***	(0.05)				−.31	***	(0.05)
Same Race							.67	***	(0.05)	.53	***	(0.05)
Alter Age							−.009	***	(0.002)	−.007	***	(0.002)
Ego Age							.009	**	(0.004)	.009	***	(0.003)
Age Similarity							.87	***	(0.12)	.75	***	(0.11)
Alter Offense Gravity Score							.01		(0.01)	.01	†	(0.01)
Ego Offense Gravity Score							.03	*	(0.01)	.02	*	(0.01)
Offense Gravity Score Similarity							.14		(0.16)	.06		(0.15)
Alter TABE Score							.002	*	(0.001)	.001		(0.001)
Ego TABE Score							−.001		(0.001)	−.001		(0.001)
TABE Similarity							.24	***	(0.09)	.22	***	(0.09)
Alter TCU Score							.03		(0.02)	.01		(0.02)
Ego TCU Score							.08	*	(0.03)	.04		(0.03)
TCU Score similarity							.25	†	(0.14)	.16		(0.13)
Alter Time on Unit							−.001		(0.001)	−.005	***	(0.001)
Ego Time on Unit							−.008	***	(0.001)	−.010	***	(0.001)
Time on Unit Similarity							1.83	***	(0.11)	1.19	***	(0.12)
Alter Treatment Engagement	−.01		(0.03)	−.07	**	(0.03)	.07	*	(0.03)	−.001		(0.03)
Ego Treatment Engagement	.15	***	(0.03)	.09	***	(0.03)	.24	***	(0.04)	.16	***	(0.03)
Trtmt. Engagement Similarity	.46	***	(0.16)	.32	*	(0.14)	.22		(0.16)	.07		(0.16)
Engagement Function												
Rate (period 1)	.70	*	(0.34)	.68	**	(0.28)	.71	***	(0.25)	.71	***	(0.24)
Rate (period 2)	.74	**	(0.29)	.76	***	(0.29)	.76	**	(0.32)	.77	**	(0.30)
Rate (period 3)	.96	†	(0.51)	.97	**	(0.38)	.98	*	(0.44)	.98	**	(0.39)
Rate (period 4)	.63	*	(0.31)	.64	**	(0.26)	.65	***	(0.24)	.65	**	(0.25)
Rate (period 5)	1.14	**	(0.48)	1.14	**	(0.48)	1.15	*	(0.54)	1.16	***	(0.42)
Rate (period 6)	.52	**	(0.21)	.50	***	(0.19)	.52	**	(0.22)	.51	***	(0.20)
Rate (period 7)	.68	***	(0.26)	.69	***	(0.25)	.69	***	(0.27)	.69	***	(0.23)
Rate (period 8)	.50	**	(0.19)	.50	**	(0.21)	.50	**	(0.20)	.50	**	(0.21)
Rate (period 9)	.50	**	(0.21)	.49	***	(0.19)	.51	**	(0.21)	.51	*	(0.23)
Linear Shape	−.41		(0.88)	−.41		(0.67)	−.42		(0.85)	−.33		(0.64)
Quadratic Shape	−.31		(0.38)	−.31		(0.27)	−.30		(0.27)	−.29		(0.23)
Indegree	−.03		(0.09)	−.03		(0.08)	−.02		(0.07)	−.02		(0.07)
Outdegree	.02		(0.07)	.03		(0.07)	.03		(0.07)	.02		(0.07)
Total Alter (Peer Influence)	−.08		(0.29)	−.10		(0.23)	−.07		(0.18)	−.07		(0.20)
Total Alter X Alter Role Model	1.17		(2.52)	1.18		(1.78)	1.03		(1.55)	1.00		(1.49)
Black Race	.52		(0.75)	.55		(0.63)	.51		(0.58)	.49		(0.54)
Hispanic Race	1.19		(1.55)	1.16		(1.05)	1.16		(1.14)	1.10		(0.99)
Age	.04		(0.05)	.04		(0.04)	.03		(0.03)	.03		(0.03)
Offense Gravity Score	.02		(0.06)	.02		(0.06)	.01		(0.06)	.01		(0.06)
TABE Score	.004		(0.008)	.004		(0.007)	.004		(0.007)	.004		(0.006)
TCU Score	−.08		(0.16)	−.08		(0.15)	−.08		(0.14)	−.08		(0.14)
Time on Unit	.005		(0.009)	.005		(0.009)	.005		(0.008)	.006		(0.007)

Note: Standard errors in parentheses. †p < .10; *p < .05; **p < .01; ***p < .001 (two-tailed tests).

Motivating Example

- How do they do it?
  - Coevolution models!

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Rate (period 5)	15.60	***	(1.15)	15.89	***	(1.37)	16.65	***	(1.18)	14.64	***	(1.04)
Rate (period 6)	12.79	***	(0.96)	12.73	***	(1.01)	14.45	***	(1.07)	13.07	***	(1.06)
Rate (period 7)	12.88	***	(0.90)	13.18	***	(1.16)	14.11	***	(1.12)	13.12	***	(1.03)
Rate (period 8)	14.89	***	(1.09)	15.38	***	(1.24)	16.65	***	(1.30)	15.12	***	(1.17)
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Rate (period 2)	.74	**	(0.29)	.76	***	(0.29)	.76	**	(0.32)	.77	**	(0.30)
Rate (period 3)	.96	†	(0.51)	.97	**	(0.38)	.98	*	(0.44)	.98	**	(0.39)
Rate (period 4)	.63	*	(0.31)	.64	**	(0.26)	.65	***	(0.24)	.65	**	(0.25)
Rate (period 5)	1.14	**	(0.48)	1.14	**	(0.48)	1.15	*	(0.54)	1.16	***	(0.42)
Rate (period 6)	.52	**	(0.21)	.50	***	(0.19)	.52	**	(0.22)	.51	***	(0.20)
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Linear Shape	−.41		(0.88)	−.41		(0.67)	−.42		(0.85)	−.33		(0.64)
Quadratic Shape	−.31		(0.38)	−.31		(0.27)	−.30		(0.27)	−.29		(0.23)
Indegree	−.03		(0.09)	−.03		(0.08)	−.02		(0.07)	−.02		(0.07)
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Hispanic Race	1.19		(1.55)	1.16		(1.05)	1.16		(1.14)	1.10		(0.99)
Age	.04		(0.05)	.04		(0.04)	.03		(0.03)	.03		(0.03)
Offense Gravity Score	.02		(0.06)	.02		(0.06)	.01		(0.06)	.01		(0.06)
TABE Score	.004		(0.008)	.004		(0.007)	.004		(0.007)	.004		(0.006)
TCU Score	−.08		(0.16)	−.08		(0.15)	−.08		(0.14)	−.08		(0.14)
Time on Unit	.005		(0.009)	.005		(0.009)	.005		(0.008)	.006		(0.007)

Note: Standard errors in parentheses. †p < .10; *p < .05; **p < .01; ***p < .001 (two-tailed tests).

Statistical Analysis of Networks

Coevolution of Networks and Behavior

Learning Goals

- By the end of this lecture, you should be able to answer these questions:
  - What is the basic logic of the coevolution model?
  - Why use the coevolution model?
  - What are **network** and **behavior** configurations?

Learning Goals

- Understand the logic of the coevolution model.
- Reasons for using coevolution model.
- Understand **network** and **behavior** configurations.

Introduction

- Last week: How do networks change? (network dynamics)
- This week: a new question…
  - *How do networks* **and** *behavior coevolve?*

Interdependence

- As we have seen, tie formation (i.e. network dynamics) can depend on behavior.
- Examples:
  - Homophily (Ego has a preference for being tied to alters with similar/same attribute values)
  - Receiver & Sender Effects (Ego has a preference for sending ties to those with a particular attribute)

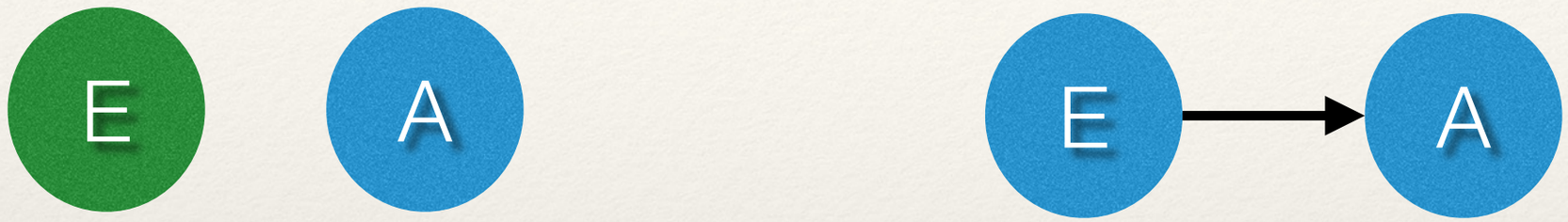
Interdependence

- However, *behavior* can depend on network properties.
  - Examples:
    - Assimilation/Contagion (adopting attitudes of those around you)
    - Isolation (those with no friends may become depressed)

Separating Mechanisms

- As a consequence, we are trying to separate the mechanisms that generate the networks we observe.
  - Example:
    - Delinquent individuals **select** delinquent friends.
    - *Or,* individuals engage in delinquency if their friends do.
      - In the cross-section, we cannot determine which mechanism is correct (could be either or both).

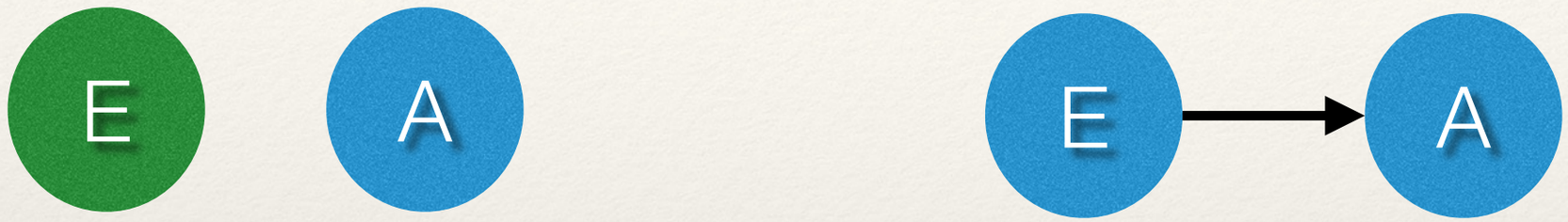
Say we observe these two cross-sections



t

$t + 1$

Say we observe these two cross-sections

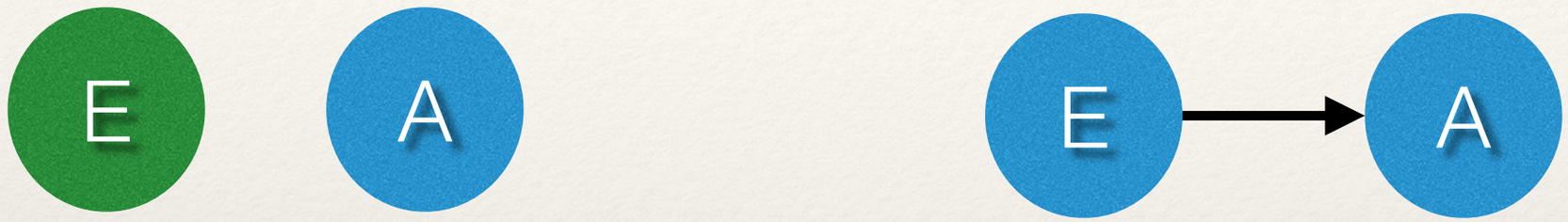


t

t + 1

At time *t*, **ego** is a different "type" or attribute value than **alter** and is not connected to **alter**.

Say we observe these two cross-sections

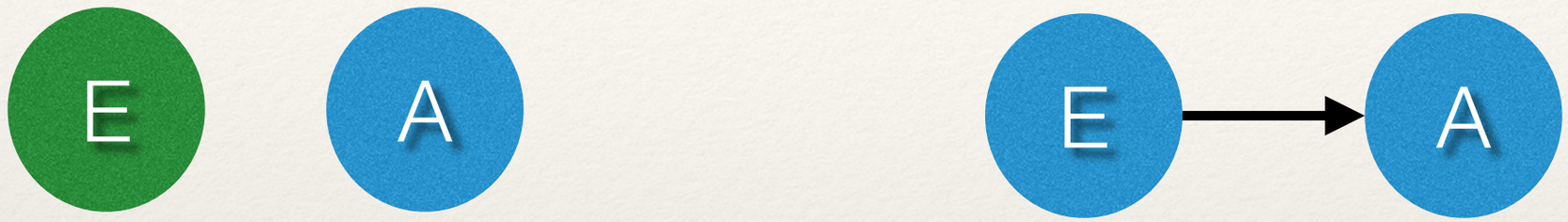


t

t + 1

At time *t + 1*, **ego** is the same “type” or attribute value as **alter** and is connected to **alter**.

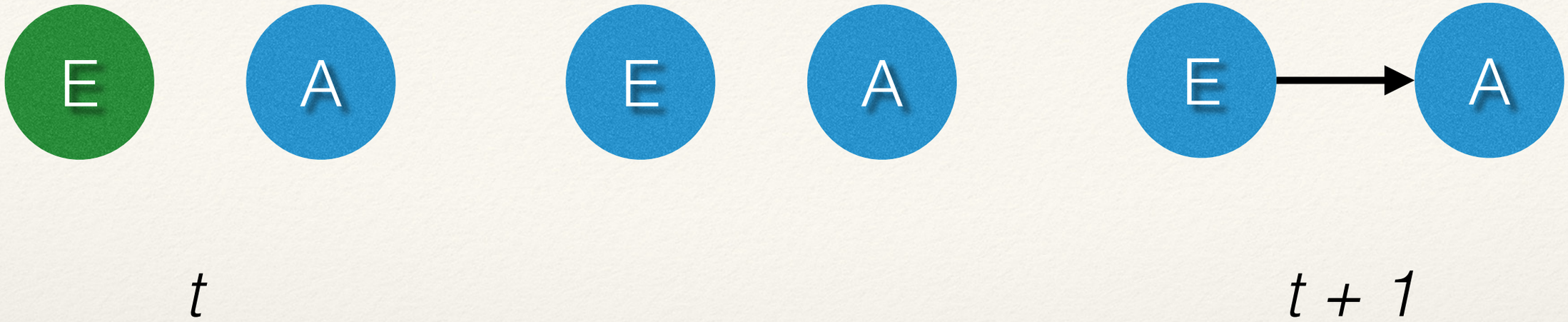
Say we observe these two cross-sections



t

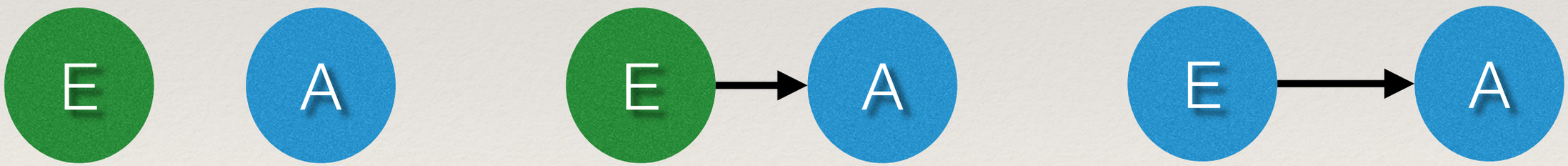
t + 1

Let’s think about the ways that this could have occurred (i.e. micro-steps).



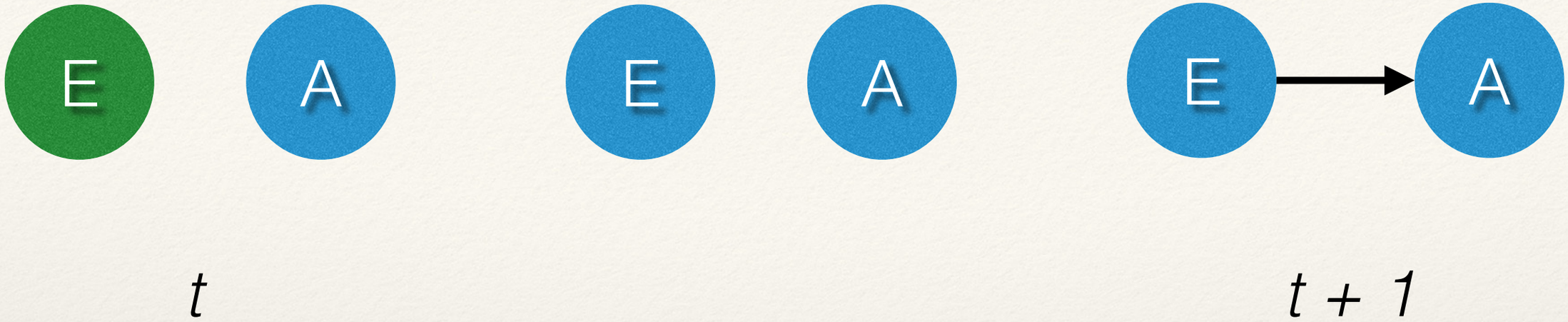
Ego changes his behavior, **then** befriends alter.

Ego befriends alter, **then** changes his behavior.

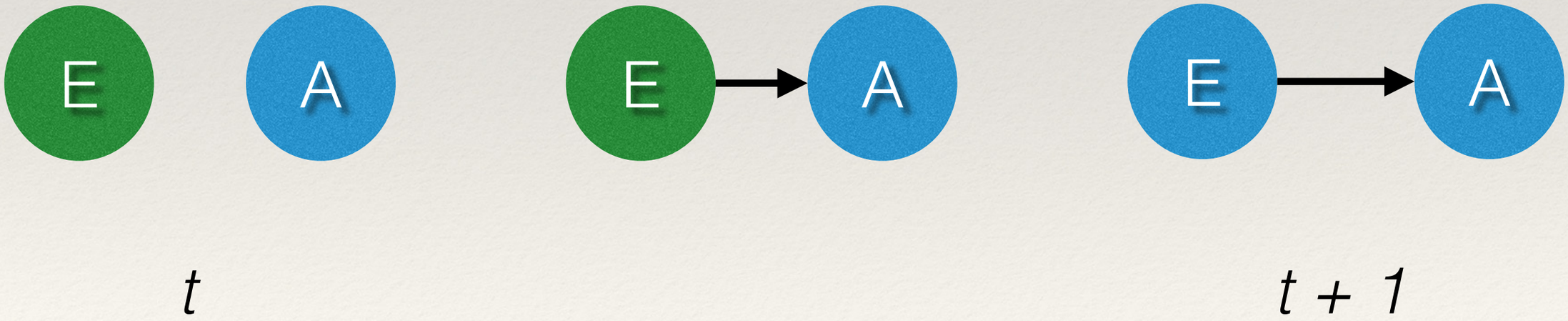


t

t + 1



We would like a model that shows the coevolution of both the network and behavior.



Separating Mechanisms

- The basic problem is trying to determine whether the observed network is a consequence of:
  - The network leading to behavioral alignment
  - Actors' behavior leading to network alignment
    - Coevolution models aim to construct a model that can tease these apart.

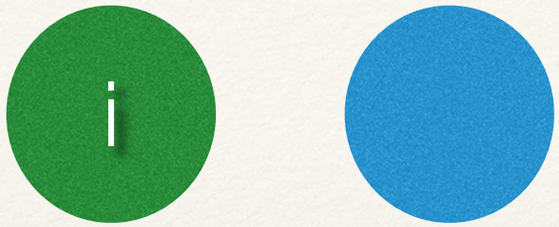
Stochastic Actor-Based Models

- We can extend the SABM logic to a behavioral domain.
- Now, actors control:
  - Their ties
  - Their behavior

Stochastic Actor-Based Models

- We simply extend the functions to include behavior:
  - **Rate** functions for the network *and* for behavior.
    - How frequently are individuals changing ties? Their behavior?
  - **Objective** functions for the network and behavior.
    - What are actors' preferences for their ties? Their behavior?

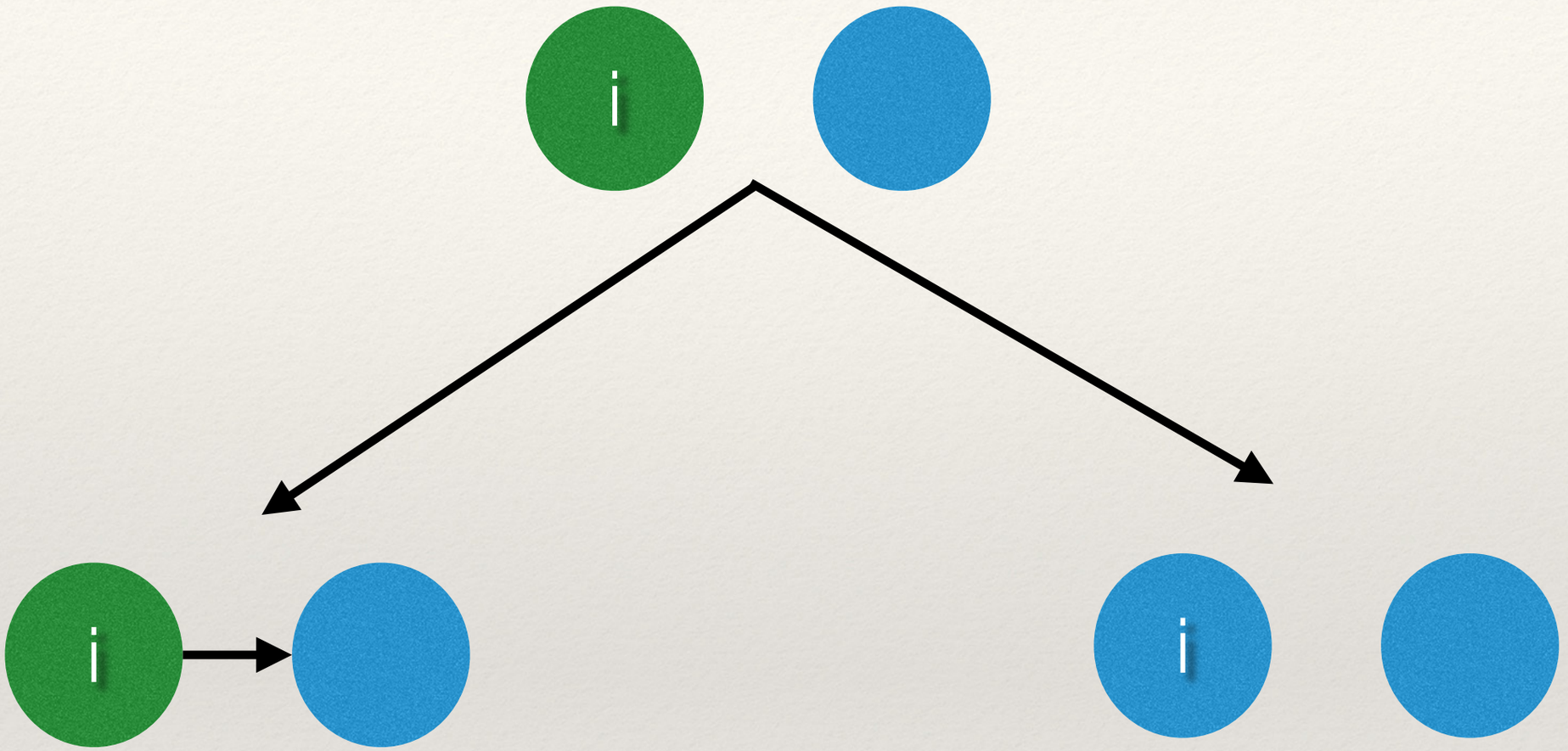
What can *i* do?



What can *i* do?

Change network
(*network objective function*)

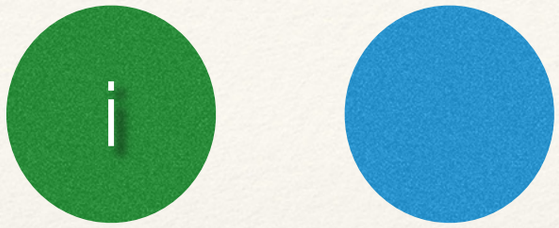
What can *i* do?



Change network
(*network objective function*)

Change behavior
(*behavior objective function*)

What can *i* do?



Not making any changes

(*behavior and network rate functions*)

is still an option as well

Objective Function

- As before, we want to specify the configurations.
- But, what is different is that in addition to **network** configurations, we are going to specify **behavioral** configurations.

Basic Effects

Basic Effects

t	*t+1*	Effect (RSiena term)	Preference
Ego		Ego →	for ties to similar alters

Basic Effects

t	*t+1*	Effect (RSiena term)	Preference
Ego		Similarity (sameX or simX)	for ties to similar alters
Ego			

Basic Effects

t	*t+1*	Effect (RSiena term)	Preference
		Similarity (sameX or simX)	for ties to similar alters
			to change to behavior of friends

Basic Effects

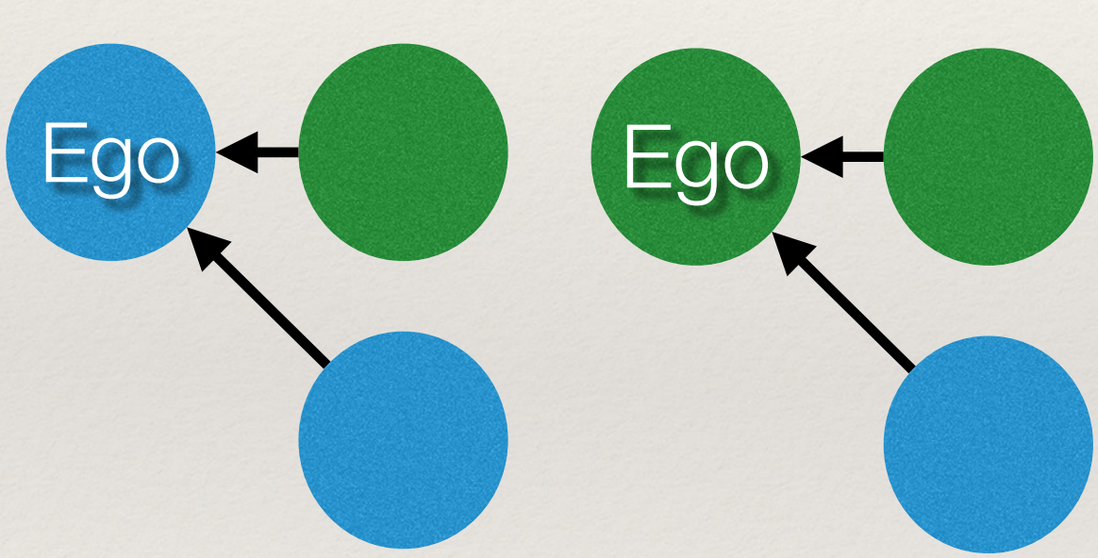
t	*t+1*	Effect (RSiena term)	Preference
		Similarity (sameX or simX)	for ties to similar alters
		Similarity (avSim or totSim)	to change to behavior of friends

Interactions w/ Covariates

Interactions w/ Covariates

t

t+1

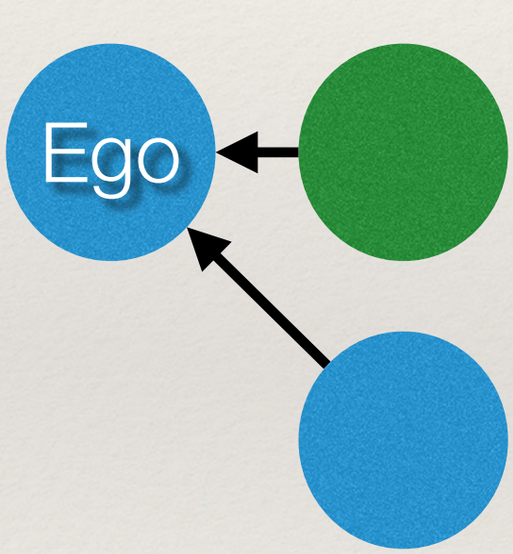
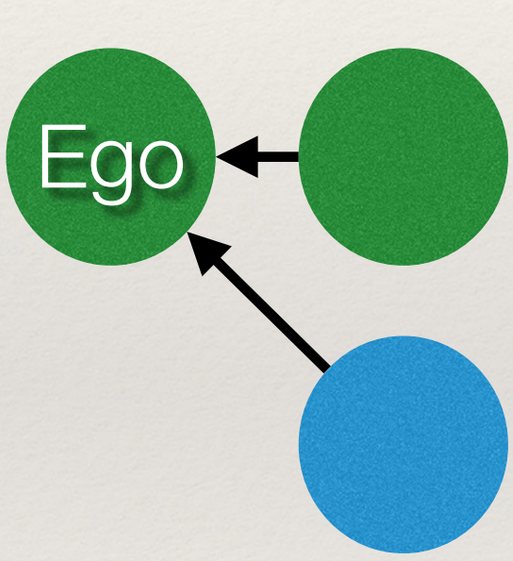


Effect
(RSiena term)

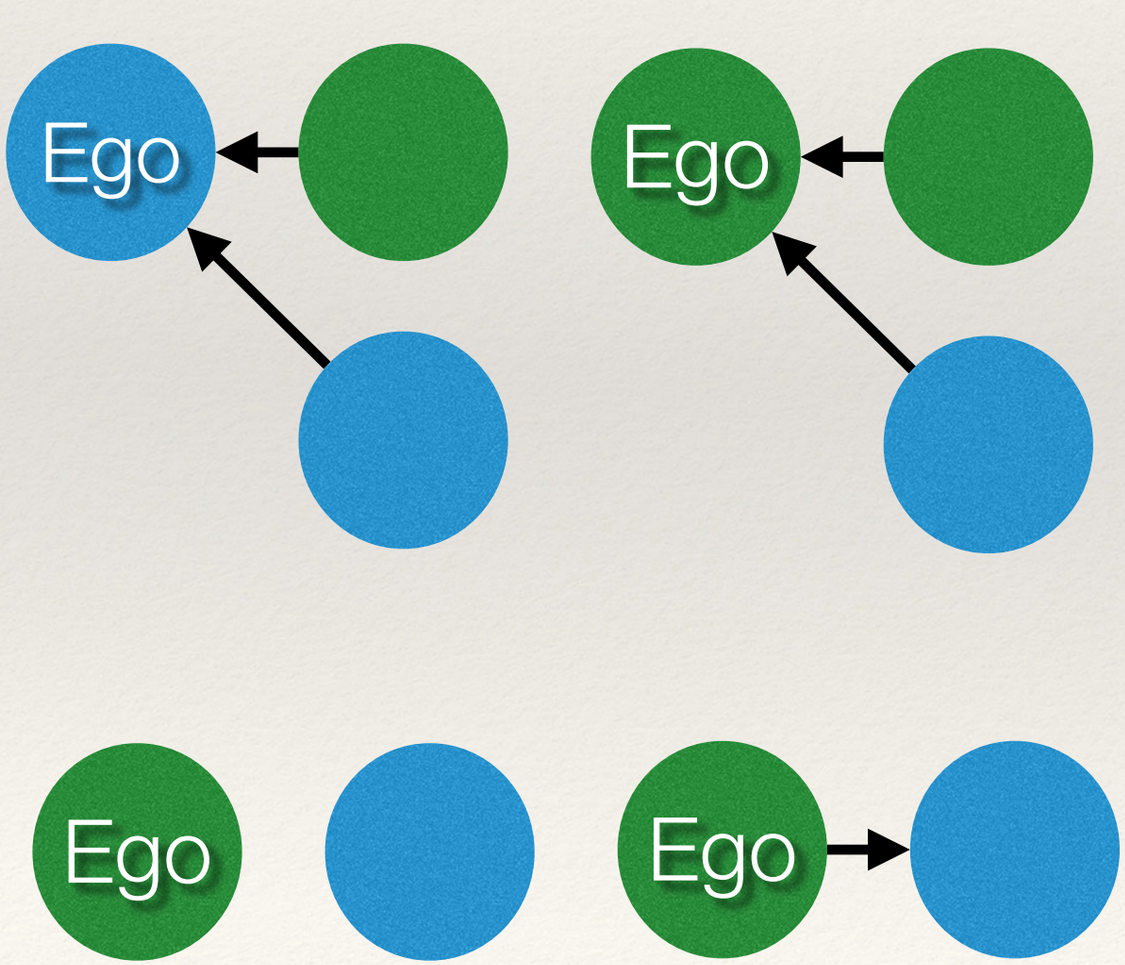
Preference

effect of popularity on behavior

Interactions w/ Covariates

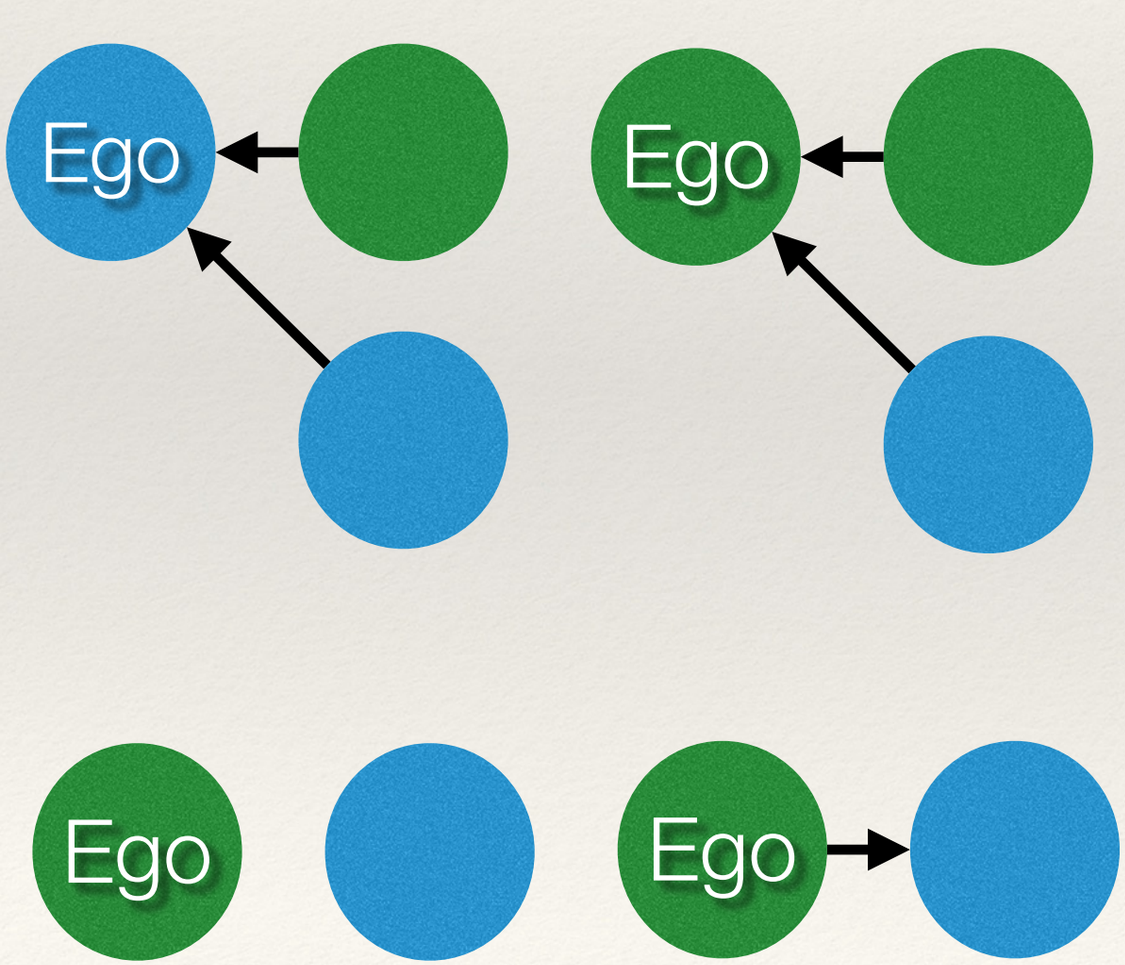
t	*t+1*	Effect (RSiena term)	Preference
		Indegree (indeg)	effect of popularity on behavior

Interactions w/ Covariates



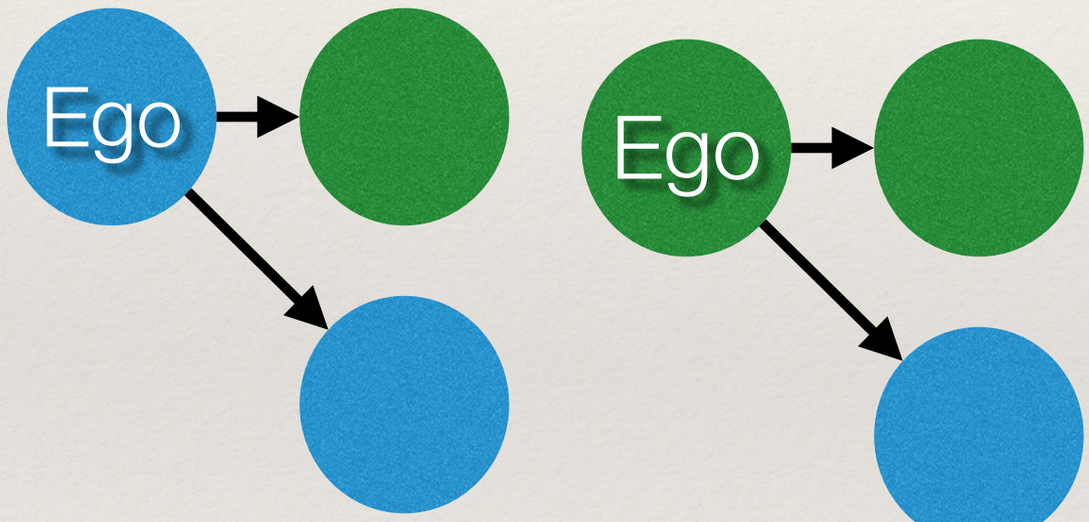
t	*t+1*	Effect (RSiena term)	Preference
		Indegree (indeg)	effect of popularity on behavior
			alter's covariate effect on preference

Interactions w/ Covariates

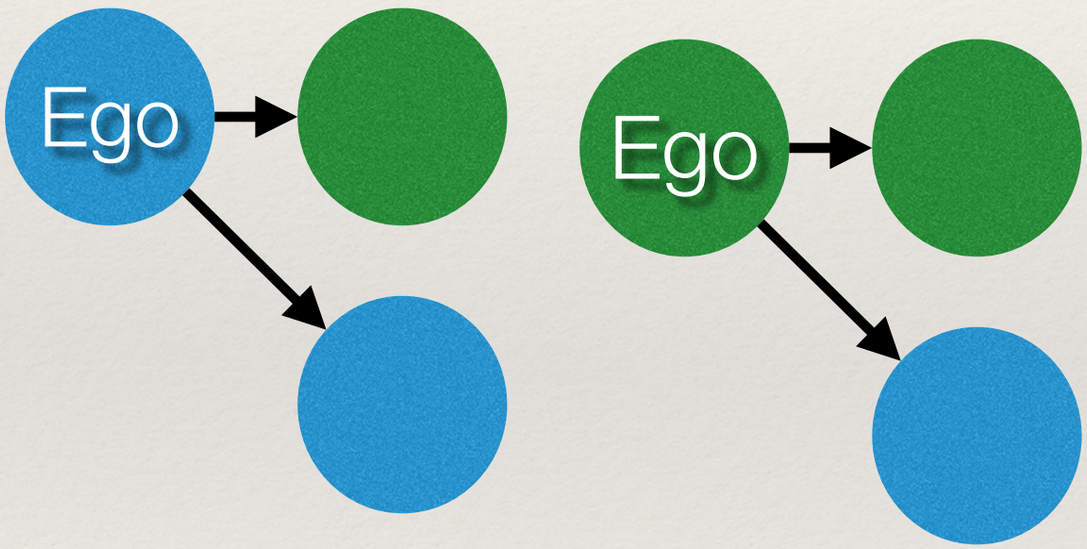


Effect (RSiena term)	Preference
Indegree (indeg)	effect of popularity on behavior
Behavior Alter (AlterX)	alter's covariate effect on preference

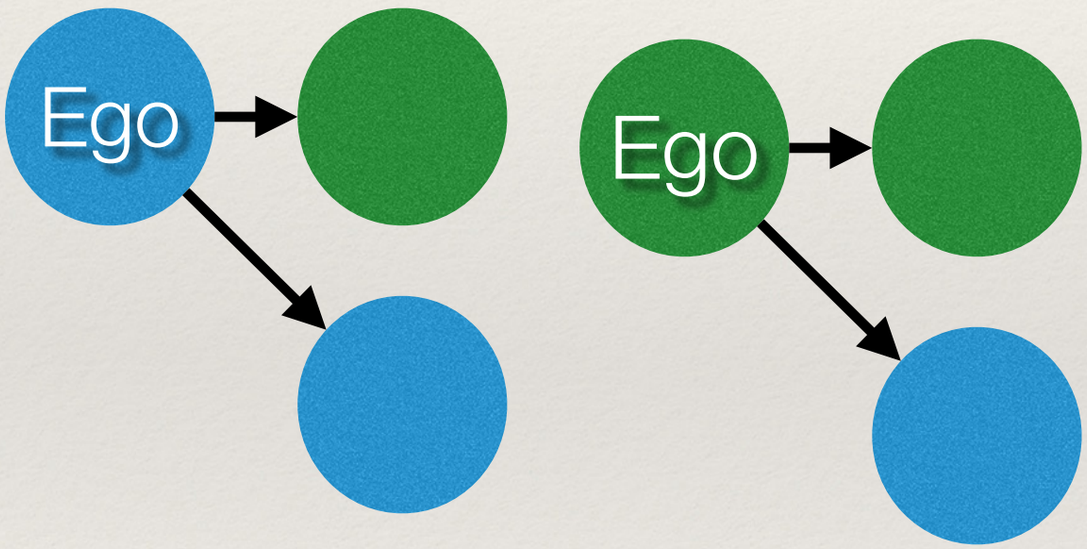
Interactions w/ Covariates

t	*t+1*	Effect (RSiena term)	Preference
			effect of activity on behavior

Interactions w/ Covariates

t	*t+1*	Effect (RSiena term)	Preference
		Outdegree (outdeg)	effect of activity on behavior

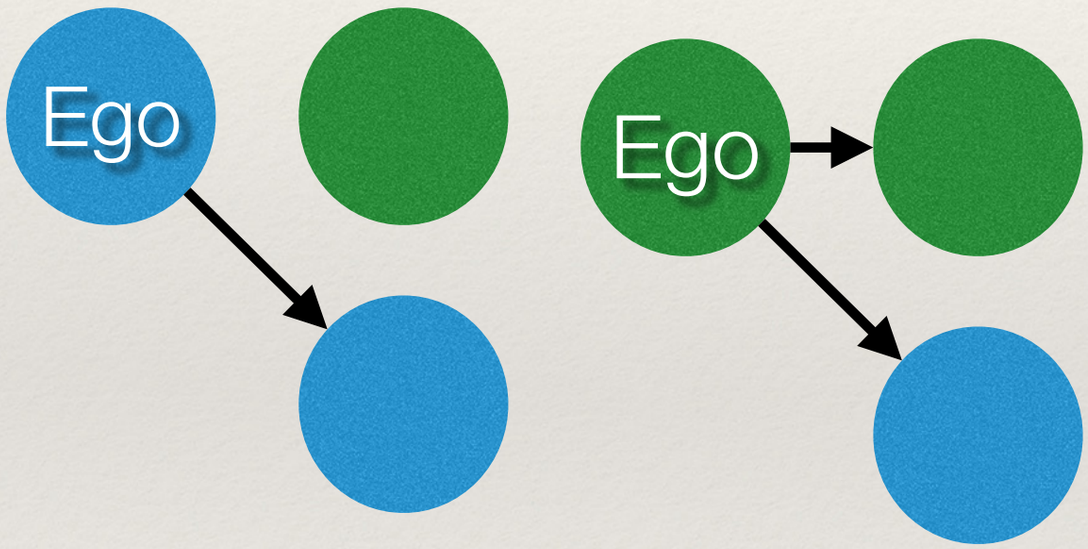
Interactions w/ Covariates

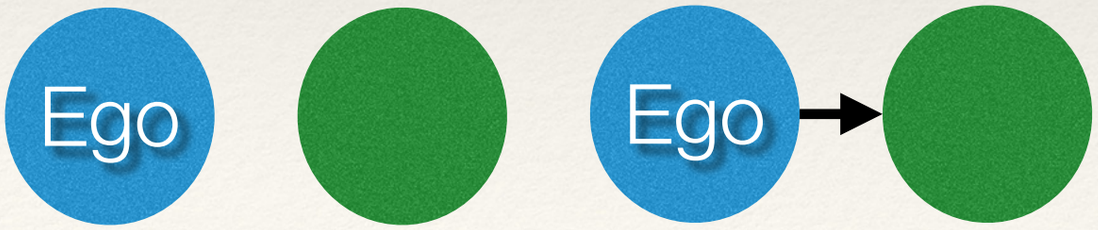


t	*t+1*	Effect (RSiena term)	Preference
		Outdegree (outdeg)	effect of activity on behavior

Note the difference from EgoX

Interactions w/ Covariates





Effect (RSiena term)	Preference
Outdegree (outdeg)	effect of activity on behavior
Behavior Ego (EgoX)	ego's covariate effect on preference

Motivating Example

- What do the authors find?

Table 1
Stochastic Actor-Oriented Models of Social Ties in a Prison Therapuetic Community.

	M1			M2			M3			M4		
Network Selection Function	b		(se)	b		(se)	b		(se)	b		(se)
Rate (period 1)	16.95	***	(1.38)	16.06	***	(1.28)	17.26	***	(1.19)	14.49	***	(1.07)
Rate (period 2)	10.46	***	(0.76)	10.26	***	(0.86)	10.58	***	(0.77)	9.63	***	(0.74)
Rate (period 3)	9.28	***	(0.81)	9.34	***	(0.91)	9.38	***	(0.82)	8.56	***	(0.74)
Rate (period 4)	13.02	***	(1.12)	13.59	***	(1.41)	14.37	***	(1.18)	12.99	***	(1.13)
Rate (period 5)	15.60	***	(1.15)	15.89	***	(1.37)	16.65	***	(1.18)	14.64	***	(1.04)
Rate (period 6)	12.79	***	(0.96)	12.73	***	(1.01)	14.45	***	(1.07)	13.07	***	(1.06)
Rate (period 7)	12.88	***	(0.90)	13.18	***	(1.16)	14.11	***	(1.12)	13.12	***	(1.03)
Rate (period 8)	14.89	***	(1.09)	15.38	***	(1.24)	16.65	***	(1.30)	15.12	***	(1.17)
Rate (period 9)	12.66	***	(1.14)	12.59	***	(1.09)	13.70	***	(1.10)	12.66	***	(1.07)
Outdegree (density)	−.80	***	(0.03)	−1.43	***	(0.03)	−1.15	***	(0.05)	−1.67	***	(0.05)
Reciprocity				1.67	***	(0.09)				1.58	***	(0.09)
Transitive Triplets				.25	***	(0.02)				.29	***	(0.02)
Transitive Reciprocal Triplets				−.31	***	(0.05)				−.31	***	(0.05)
Same Race							.67	***	(0.05)	.53	***	(0.05)
Alter Age							−.009	***	(0.002)	−.007	***	(0.002)
Ego Age							.009	**	(0.004)	.009	***	(0.003)
Age Similarity							.87	***	(0.12)	.75	***	(0.11)
Alter Offense Gravity Score							.01		(0.01)	.01	†	(0.01)
Ego Offense Gravity Score							.03	*	(0.01)	.02	*	(0.01)
Offense Gravity Score Similarity							.14		(0.16)	.06		(0.15)
Alter TABE Score							.002	*	(0.001)	.001		(0.001)
Ego TABE Score							−.001		(0.001)	−.001		(0.001)
TABE Similarity							.24	***	(0.09)	.22	***	(0.09)
Alter TCU Score							.03		(0.02)	.01		(0.02)
Ego TCU Score							.08	*	(0.03)	.04		(0.03)
TCU Score similarity							.25	†	(0.14)	.16		(0.13)
Alter Time on Unit							−.001		(0.001)	−.005	***	(0.001)
Ego Time on Unit							−.008	***	(0.001)	−.010	***	(0.001)
Time on Unit Similarity							1.83	***	(0.11)	1.19	***	(0.12)
Alter Treatment Engagement	−.01		(0.03)	−.07	**	(0.03)	.07	*	(0.03)	−.001		(0.03)
Ego Treatment Engagement	.15	***	(0.03)	.09	***	(0.03)	.24	***	(0.04)	.16	***	(0.03)
Trtmt. Engagement Similarity	.46	***	(0.16)	.32	*	(0.14)	.22		(0.16)	.07		(0.16)
Engagement Function												
Rate (period 1)	.70	*	(0.34)	.68	**	(0.28)	.71	***	(0.25)	.71	***	(0.24)
Rate (period 2)	.74	**	(0.29)	.76	***	(0.29)	.76	**	(0.32)	.77	**	(0.30)
Rate (period 3)	.96	†	(0.51)	.97	**	(0.38)	.98	*	(0.44)	.98	**	(0.39)
Rate (period 4)	.63	*	(0.31)	.64	**	(0.26)	.65	***	(0.24)	.65	**	(0.25)
Rate (period 5)	1.14	**	(0.48)	1.14	**	(0.48)	1.15	*	(0.54)	1.16	***	(0.42)
Rate (period 6)	.52	**	(0.21)	.50	***	(0.19)	.52	**	(0.22)	.51	***	(0.20)
Rate (period 7)	.68	***	(0.26)	.69	***	(0.25)	.69	***	(0.27)	.69	***	(0.23)
Rate (period 8)	.50	**	(0.19)	.50	**	(0.21)	.50	**	(0.20)	.50	**	(0.21)
Rate (period 9)	.50	**	(0.21)	.49	***	(0.19)	.51	**	(0.21)	.51	*	(0.23)
Linear Shape	−.41		(0.88)	−.41		(0.67)	−.42		(0.85)	−.33		(0.64)
Quadratic Shape	−.31		(0.38)	−.31		(0.27)	−.30		(0.27)	−.29		(0.23)
Indegree	−.03		(0.09)	−.03		(0.08)	−.02		(0.07)	−.02		(0.07)
Outdegree	.02		(0.07)	.03		(0.07)	.03		(0.07)	.02		(0.07)
Total Alter (Peer Influence)	−.08		(0.29)	−.10		(0.23)	−.07		(0.18)	−.07		(0.20)
Total Alter X Alter Role Model	1.17		(2.52)	1.18		(1.78)	1.03		(1.55)	1.00		(1.49)
Black Race	.52		(0.75)	.55		(0.63)	.51		(0.58)	.49		(0.54)
Hispanic Race	1.19		(1.55)	1.16		(1.05)	1.16		(1.14)	1.10		(0.99)
Age	.04		(0.05)	.04		(0.04)	.03		(0.03)	.03		(0.03)
Offense Gravity Score	.02		(0.06)	.02		(0.06)	.01		(0.06)	.01		(0.06)
TABE Score	.004		(0.008)	.004		(0.007)	.004		(0.007)	.004		(0.006)
TCU Score	−.08		(0.16)	−.08		(0.15)	−.08		(0.14)	−.08		(0.14)
Time on Unit	.005		(0.009)	.005		(0.009)	.005		(0.008)	.006		(0.007)

Note: Standard errors in parentheses. †p < .10; *p < .05; **p < .01; ***p < .001 (two-tailed tests).

Motivating Example

- Peer influence?

Total Alter (Peer Influence)	−.07		(0.20)
Total Alter X Alter Role Model	1.00		(1.49)

- Selection?

Alter Treatment Engagement	−.001		(0.03)
Ego Treatment Engagement	.16	***	(0.03)
Trtmt. Engagement Similarity	.07		(0.16)

- Cross-dimensional selection?

Learning Goals

- By the end of this lecture, you should be able to answer these questions:
  - What is the basic logic of the coevolution model?
  - Why use the coevolution model?
  - What are **network** and **behavior** configurations?

Questions?