Spreading of healthy mood in adolescent social networks

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1. The Problem

Depression and other mood disorders are major and growing contributors to mortality and morbidity worldwide. The World Health Organisation estimates there are currently more than **350 million people affected by depression**[1]. An improved understanding of the social processes that drive the epidemiology of depression therefore has the potential to bring **highly significant public health benefits**.

2. Research Question

"Given the current emotional state of an individual, can you predict if they are at risk of changing emotional state (in the near future, we look at within a year) based on the number of friends they currently have of a given emotional state?"

3. The Data

The National Longitudinal Study of Adolescent to Adult Health (Add Health)[2]
- Sample of United States adolescents in grades 7 through 12.
- Data from two time points: **wave 1 (1994-95), wave 2 (1996)**.
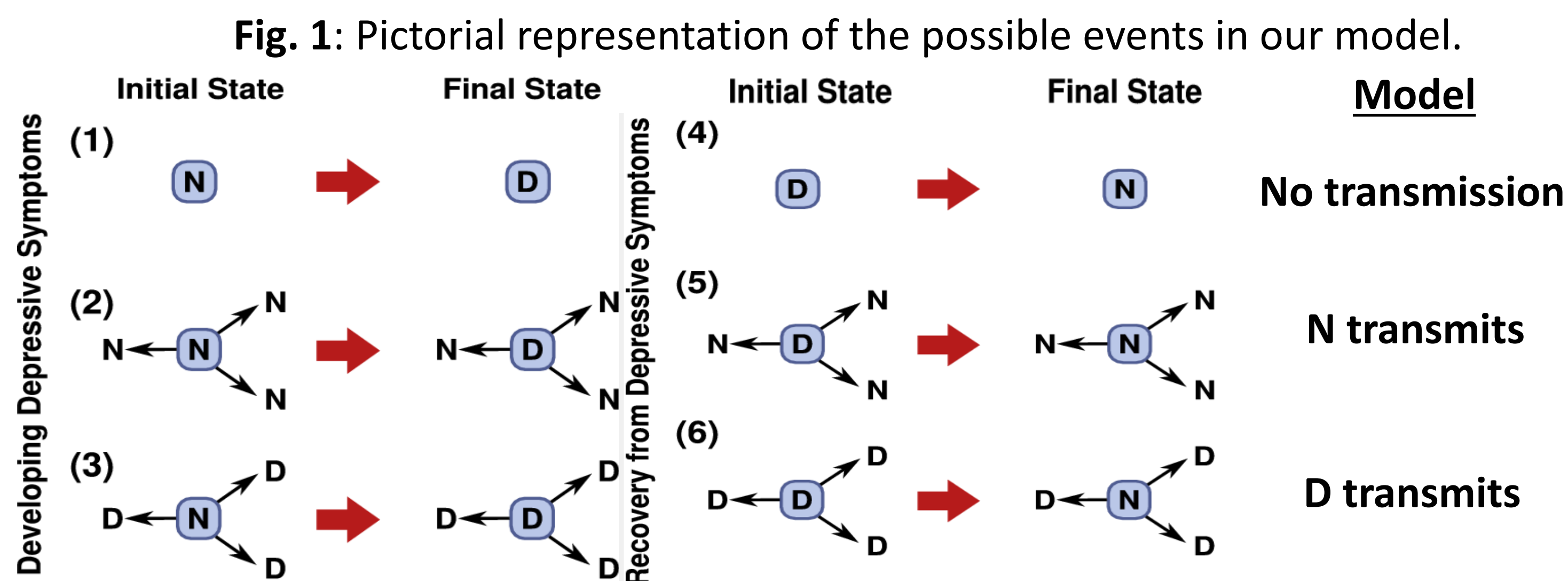
In-school friendship network

Respondents in our study sample were asked to nominate up to five male and five female friends.

Centre for Epidemiologic Studies Depression scale (CES-D)[3]
Used to create **binary indicator** of state of mood[4]
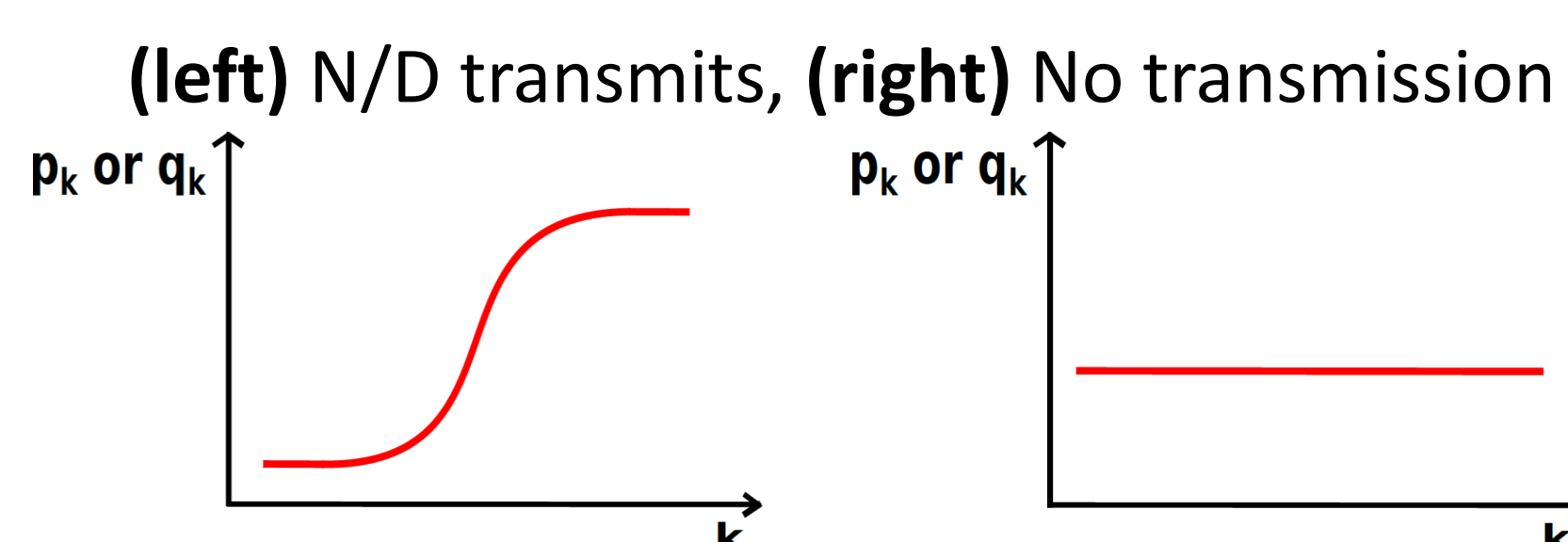N – Not depressed; D – Depressive symptoms
$X_i = $ **N D**

4. Model Formulation

- Model mood status as a **discrete-time Markov chain**, where each individual i at time t has state $X_i(t)$, taking the value D or N.
- To address the research question, we developed a **model framework** that:
  i. Is flexible by making **no prior assumption** as to whether it is low mood or healthy mood that spreads.
  ii. Uses the **dynamical behaviour** of mood over time to determine directly evidence for transmission or no transmission of mood.
- Change in mood status specified by two probabilities:
  Developing depressive symptoms: $p = \Pr[X_i(t+1) = D | X_i(t) = N]$
  Recovery from depressive symptoms: $q = \Pr[X_i(t+1) = N | X_i(t) = D]$
- Fit **three models** to the Add Health data moving from wave 1 to wave 2 (Fig. 1).

Fig. 1: Pictorial representation of the possible events in our model.

Initial State	Final State	Initial State	Final State	Model
(1) N	D	(4) D	N	**No transmission**
(2)		(5)		**N transmits**
(3)		(6)		**D transmits**

Developing or recovering from depressive symptoms; in the absence of friends (no transmission), with friends with healthy mood (N transmits), or with friends with depressive symptoms (D transmits).

- N transmits/D transmits models - dependence on number of N/D friends took the form of an **S-shaped function** (Fig. 2).
- Model parameters – inferred from data using **maximum likelihood estimation**.

Fig. 2: Model probability dependencies on k, the number of friends with mood N/D.
(left) N/D transmits, **(right)** No transmission
p_k or q_k ... p_k or q_k ... k ... k

5. Results

Model selection

Models compared using **Akaike Information Criterion (AIC)**.

Computed **ΔAIC values** by subtracting the no transmission model AIC value from the relevant transmission model (D transmits or N transmits) AIC value.
- D transmits model **not preferred** to no transmission (Fig. 3).
- N transmits model **preferred** to no transmission (Fig. 4).

Fig. 3: Dynamical behaviour of depression status as a function of D friends
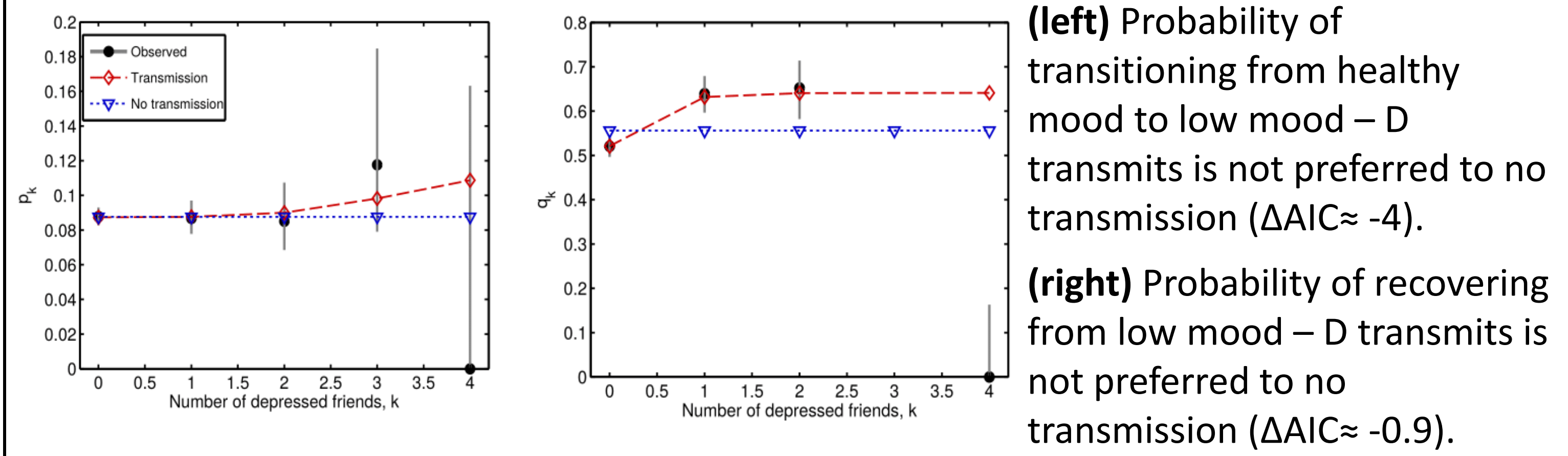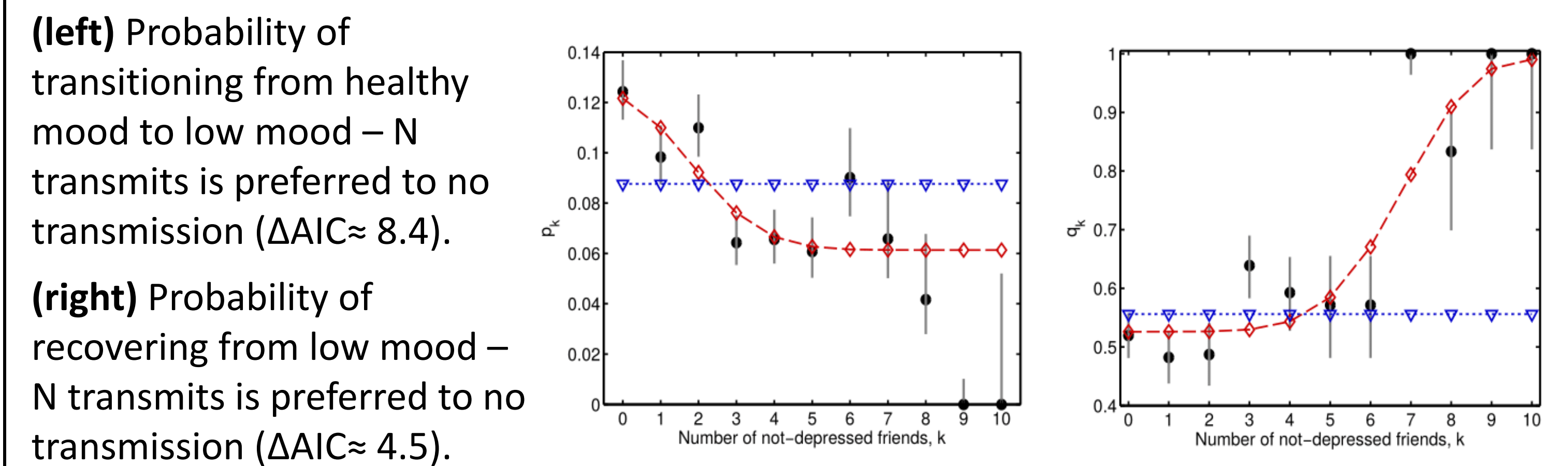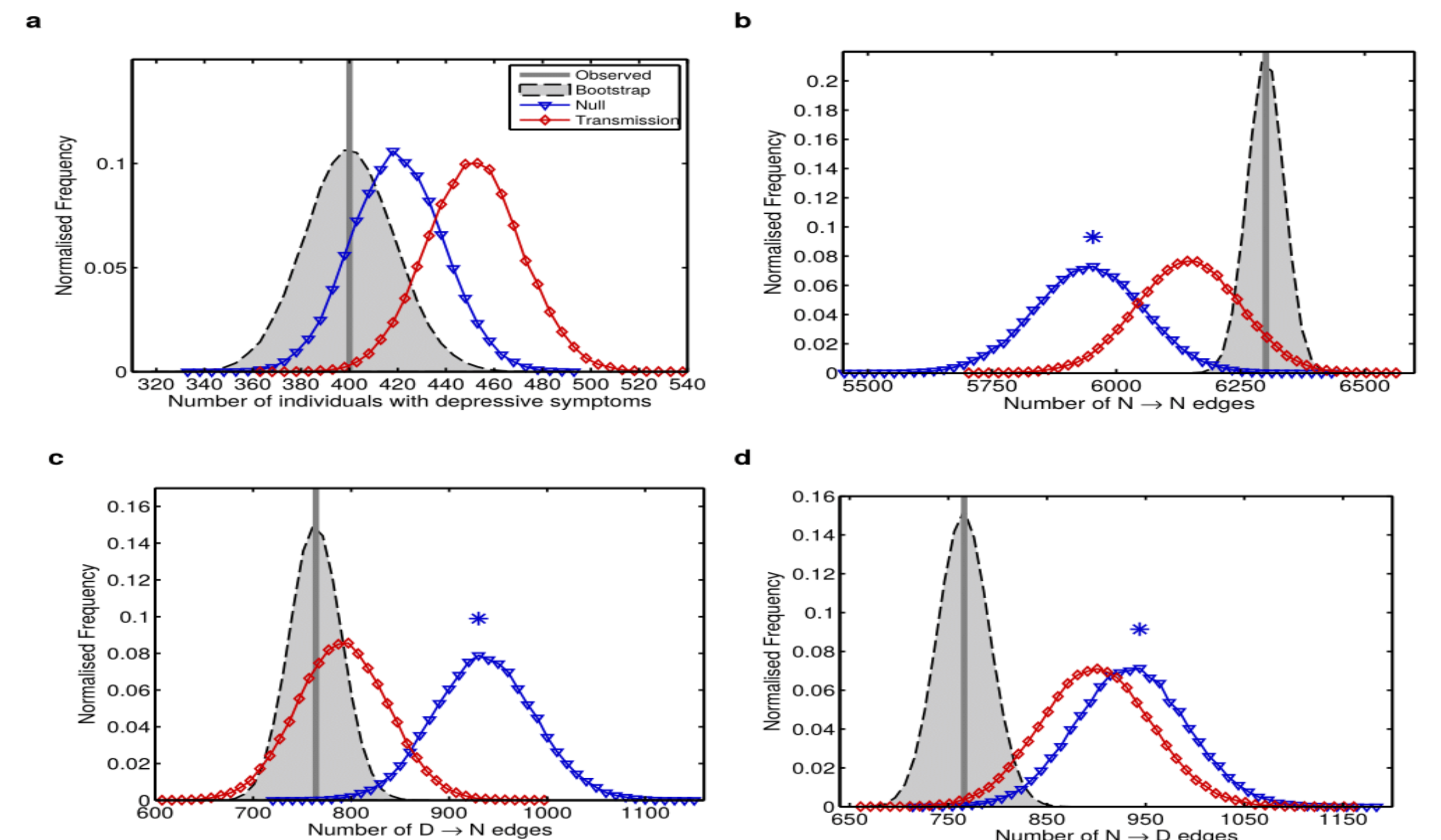
(left) Probability of transitioning from healthy mood to low mood – D transmits is not preferred to no transmission (ΔAIC≈ -4).

(right) Probability of recovering from low mood – D transmits is not preferred to no transmission (ΔAIC≈ -0.9).

Fig. 4: Dynamical behaviour of depression status as a function of N friends

(left) Probability of transitioning from healthy mood to low mood – N transmits is preferred to no transmission (ΔAIC≈ 8.4).

(right) Probability of recovering from low mood – N transmits is preferred to no transmission (ΔAIC≈ 4.5).

Goodness-of-fit tests

- Simulated our fitted no transmission model and N transmits model.
- Compared simulated static network summary statistics to observed data.
- **Significant differences** between the no transmission model and the data (Fig. 5).

Fig. 5: Model verification – static network summary statistics

Asterisks above a plot denote a significant statistical difference at the 5% level, corresponding to p<0.01 using the Bonferroni method to account for multiple testing.
a, prevalence of individuals with depressive symptoms; **b,** number of N→N edges; **c,** number of D→N edges; **d,** number of N→D edges.

6. Conclusions

- The **number of depressed friends has no causal effect** on the emotional state of the individual.
- Healthy mood amongst friends is associated with **significantly reduced risk of developing** and **increased chance of recovering** from depression.
- **Spread of healthy mood** can be captured using a non-linear complex contagion model.
- These results suggest that promotion of friendship between adolescents can reduce both incidence and prevalence of depression.

[1] World Health Organisation. Depression - Fact Sheet No. 369. 2014. URL: http://www.who.int/mediacentre/factsheets/fs369/en/.
[2] E. Whitsel, J. Hussey, J. Tabor, P. Entzel, K. Harris, C. Halpern, and J. Udry. The National Longitudinal Study of Adolescent Health: Research Design. 2009. URL: http://www.cpc.unc.edu/projects/addhealth/design.
[3] L. S. Radloff. (1977) The CES-D scale a self-report depression scale for research in the general population. *Appl. Psych. Meas.* **1**: 385-401.
[4] R.E. Roberts, P.M. Lewinsohn and J.R. Seeley. (1991) Screening for adolescent depression: A comparison of depression scales. *J. Am. Acad. Child Psy.* **30**: 58-66.