Social contagion over adolescent friendship networks

Robert Eyre\textsuperscript{1}, Edward Hill\textsuperscript{1,2}, Frances Griffiths\textsuperscript{3}, Thomas House\textsuperscript{2,4}

\textsuperscript{1} Centre for Complexity Science, University of Warwick
\textsuperscript{2} Warwick Infectious Disease Epidemiology Research (WIDER) Centre, University of Warwick
\textsuperscript{3} Warwick Medical School, University of Warwick
\textsuperscript{4} School of Mathematics, The University of Manchester.

Division of Health Sciences Seminar Series
Why are we interested in social contagion?

The data

Initial work on modelling mood

Further work on modelling mood

Obesity work
Social contagion theory: examining dynamic social networks and human behavior

Nicholas A. Christakis\textsuperscript{a,b} and James H. Fowler\textsuperscript{c,d}
The World Health Organisation estimates there are currently more than **350 million people affected by depression**.

Can the **number and nature of social ties** be used to determine the future emotional state of an individual?

Produced by the Substance Abuse and Mental Health Services Administration.
The Data

The National Longitudinal Study of Adolescent to Adult Health (Add Health)

- Sample of United States adolescents in grades 7 through 12.

Friendship network

- Respondents were asked to nominate either up to 1 male and 1 female friend, or up to 5 male and 5 female friends.

Centre for Epidemiologic Studies Depression Scale (CES-D)
Friendship Network

A → B
The National Longitudinal Study of Adolescent to Adult Health (Add Health)

- Sample of United States adolescents in grades 7 through 12.

Friendship network
- Respondents were asked to nominate either up to 1 male and 1 female friend, or up to 5 male and 5 female friends.

Centre for Epidemiologic Studies Depression Scale (CES-D)
## CES-D Scale

<table>
<thead>
<tr>
<th></th>
<th>Rarely or none of the time (less than 1 day)</th>
<th>Some or a little of the time (1-2 days)</th>
<th>Occasionally or a moderate amount of time (3-4 days)</th>
<th>Most or all of the time (5-7 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 I was bothered by things that usually don’t bother me.</strong></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>2 I did not feel like eating; my appetite was poor.</strong></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>3 I felt that I could not shake off the blues even with help from my family or friends.</strong></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>4 I felt that I was just as good as other people.</strong></td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>5 I had trouble keeping my mind on what I was doing.</strong></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

**References:**
CES-D Scale

- Used to create a binary indicator of state of mood\(^1\).

\[
X_i = \begin{cases} 
N & \text{if score is below cut-off} \\
D & \text{if score is above cut-off}
\end{cases}
\]

- According to the score cut-off associated with a clinical diagnosis of depression.

References:
Inclusion Criteria

For a respondent to be included in our study, for both wave 1 and wave 2 they had to:

- be from a saturated school,
- be allowed to list up to 5 male and 5 female friends,
- provide answers to all the CES-D scale related questions.
Wave 1 and 2 Sampling Flow Chart

Wave 1 study population size: 20745

Inclusion criteria satisfied by: 3085

Inclusion criteria in both waves satisfied by: 2194

“Not depressed” in both waves: 1749

Wave I – “not depressed”, Wave II – “depressive symptoms”: 168

“Depressive symptoms” in both waves: 123

Wave I - “depressive symptoms”, Wave II – “not depressed”: 154

Wave 2 study population size: 14738

Inclusion criteria satisfied by: 2707
Proposed Models

\[ p = \Pr[X_i(t + 1) = D | X_i(t) = N] \]

Initial State | Final State
--- | ---
(1) \(N\) | \(D\) No transmission
(2) \(N\) | \(D\) N transmits
(3) \(D\) | \(D\) D transmits
Proposed Models

\[ q = \Pr[X_i(t + 1) = N | X_i(t) = D] \]

**Initial State** \hspace{1cm} **Final State**

(4) \hspace{1cm} (5) \hspace{1cm} (6)

- D \hspace{1cm} No transmission
- N

Recovery from Depressive Symptoms

- D transmits
- N transmits
- D transmits
Proposed Models

No transmission:

\[ p_k \text{ or } q_k \]

\[ k \]

N transmits/ D transmits:

\[ p_k \text{ or } q_k \]

\[ k \]

- Competing models assessed using standard statistical methods.
Avoiding confounding

- We fit to the probability of moving to a final state given an initial state.
- Homophily cannot confound the results.
D transmits model **not preferred** to no transmission.
N transmits model preferred to no transmission.
Model goodness-of-fit tests

- Simulated our fitted no transmission model and N transmits model
- Compared simulated static network summary statistics to observed data
- Analysed residual errors
Significant differences between the no transmission model and the data.
Summary of findings

For predicting the individuals most at risk of undergoing a change in emotional state:

• The number of depressed friends has no causal effect on the emotional state of the individual.

• Spread of healthy mood can be captured using a non-linear complex contagion model.
Limitations

- Method of classifying emotional state

- Increase or decrease of CES-D raw score based on CES-D raw score of named friends not studied.

- Missing data
\[ X_i = \begin{array}{c} \text{N} \\text{D} \end{array} \]

\[ p = \Pr[X_i(t + 1) = D | X_i(t) = N] \]

\[ q = \Pr[X_i(t + 1) = N | X_i(t) = D] \]

---

\[ X_i = \begin{array}{ccccccccccc} 0 & 1 & 2 & 3 & \ldots & n-3 & n-2 & n-1 & n \end{array} \]

\[ p = \Pr[X_i(t + 1) > X_i(t)] \]

\[ q = \Pr[X_i(t + 1) < X_i(t)] \]
$X_i = \text{ND}$

\[
p = \Pr[X_i(t + 1) = D | X_i(t) = N]
\]

\[
q = \Pr[X_i(t + 1) = N | X_i(t) = D]
\]

\[
p = \Pr[X_i(t + 1) > X_i(t)]
\]

\[
q = \Pr[X_i(t + 1) < X_i(t)]
\]
$k = \text{Number higher scoring friends}$
$k = \text{Number lower scoring friends}$
Competing models assessed using standard statistical methods.
Total CES-D Score

![Graph showing the probability of worsening and improving as a function of the number of worse-off friends.](image-url)
Component symptoms

References:
Helplessness

Similar – anhedonia, concentration, dysphoria, tiredness, worthlessness.
Helplessness

Similar – anhedonia, concentration, dysphoria, tiredness, worthlessness.
Figure 1: Trends in obesity among children and adolescents aged 2–19 years, by sex: United States, 1971–1974 through 2009–2010


References:
\[ \text{BMI} = \frac{\text{weight [lb]}}{(\text{height [in]})^2} \times 703 \]

\[ X_i = \text{BMI}_z \]

References:
Threshold

\[ X_i = \begin{cases} \text{Lower} & \text{if } X_i(t+1) - X_i(t) < 0 \\ \text{Higher} & \text{if } X_i(t+1) - X_i(t) > 0 \end{cases} \]

(1) No threshold \[ |X_i(t+1) - X_i(t)| > 0 \]

(2) 0.2 threshold \[ |X_i(t+1) - X_i(t)| \geq 0.2 \]

References:
The Data

The National Longitudinal Study of Adolescent to Adult Health (Add Health)

Friendship network
- Allowed to list up to 5 male and 5 female friends.

Weight, height, age, and gender
- Complete for both waves 1 and 2.

N = 2161
Weight - no threshold

![Graph showing the probability of increasing BMI values with the number of higher BMI friends.](image)

![Graph showing the probability of decreasing BMI values with the number of higher BMI friends.](image)
Weight – no threshold

![Graph showing the probability of increasing BMIz, p_k, and decreasing BMIz, q_k, against the number of lower BMIz friends, k.]
Weight – 0.2 threshold

Probability of increasing BMIz, $p_k$

Probability of decreasing BMIz, $q_k$

Number of higher BMIz friends, $k$
Further work

- Threshold
- Goodness-of-fit
- Further development of model
- Pregnancy “contagion”