Inequalities in social networks

Joint work with:

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Minorities in social networks: Importance

Ranking of minorities

Perception biases

The same underlying social mechanisms can help explain both phenomena
Social networks

Two „universal“* laws governing social networks:

1) Preferential Attachment (Yule 1925, Simon 1955, Price 1976)
The tendency of nodes to preferentially attach to nodes of high degree
→ yielding scale-free networks

2) Homophily: Lazarsfeld and Merton (1954)
The tendency of similar nodes to attach to each other
→ yielding communities
What is Homophily

Paul F. Lazarsfeld and Robert K. Merton (1954)
Friendship as Social Process; A Substantive and Methodological Analysis
FREEDOM AND CONTROL IN MODERN SOCIETY

Oddly enough, the English language lacks a word to signify…

“a tendency for friendships to form between those who are alike in some designated respect”

useful, to speak of “degrees of homophily,” as measured by indices of positive correlation between the attributes of friends

\[ h = \frac{f_o - f_e}{f_e} \times 100 \]

\( f_o \) ... observed freq. of friendships
\( f_e \) ... expected freq. of friendships

friendship networks based on race (Moody 2001)
Inequalities in social networks

Overview of this talk:

• **Part I: Ranking of minorities in social networks**
  Does homophily influence ranking of minorities?

• **Part II: Perception of minorities in social networks**
  Does homophily influence perception of minorities?

• **Part III: Conclusions**
Part I: Ranking of minorities in social networks

Does homophily influence ranking of minorities?

Example: LinkedIn

Ranking of people in online social networks

1. **Carsten**  
   Chief Sales and Marketing Officer, Member of the Executive Board at E.M.P. Merchandising Group  
   Cologne Area, Germany

2. **Oliver**  
   Founder & Chief Executive Officer at Rocket Internet SE - Managing Partner at Global Founders Capital  
   Munich Area, Germany

3. **Alexander**  
   Artificial Intelligence Research & Solutions  
   Austria area

4. **Martina**  
   Chief Executive Officer (CEO) YourKit GmbH  
   Cologne Area, Germany

<table>
<thead>
<tr>
<th>Rank</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>m</td>
</tr>
<tr>
<td>2.</td>
<td>m</td>
</tr>
<tr>
<td>3.</td>
<td>m</td>
</tr>
<tr>
<td>4.</td>
<td>f</td>
</tr>
</tbody>
</table>

¼ (25%) women in the top 4 results
Minorities in social networks

How visible are minorities in rankings?

Example: rank share of a 25% minority

Potential disadvantage

Where does this potential disadvantage come from? Algorithmic or social?

Expected rank share of a 25% minority

Actual rank share the 25% minority
Minorities in social networks

Main take-away

SOCIAL MECHANISMS LIKE HOMOPHILY AND PREF. ATTACHMENT ALONE can create disadvantages for minorities in social networks.
Combining Preferential Attachment and Homophily

via an adapted Barabasi-Albert network generation model

Arrival nodes connect to existing nodes based on

- preferential attachment \((k)\)
- homophily \((h)\)

Simplest case with 2 groups

- minority / majority

Visual demo: https://maxohn.github.io/networkgeneration/
Homophily and preferential attachment in social networks

How does homophily influence degree distributions of minorities?

- Barabasi-Albert model with a homophily parameter

![Networks with different homophily parameters](image)

- Degree distribution with increasing homophily parameter $h$.
Ranking of minorities in social networks

Visibility of minority in top d%

![Graph showing the visibility of minority in top d%](image)

- Minority size $f_a = 0.2$
- Heterophilic network
- Expectation

fraction of minorities in top d% vs. top d% degree rank
Ranking of minorities in social networks

Visibility of minority in top d%
Ranking of minorities in social networks

Visibility of minority in top d%

$h = 0.5$ and $h = 1.0$

Minority advantage

Minority disadvantage
Ranking of minorities in social networks

Fraction of minorities total degree vs. homophily

20% minority captures much more than 20% of total degree

20% minority captures less than 20% of total degree
Ranking of minorities in social networks

What about empirical datasets?

Heterophilic networks

- **A) Sexual contacts**
  - Minority: Sex workers
  - Analysis: $h_{aa} = 0; h_{bb} = 0$
  - Dataset: Online prostitution

- **B) POK**
  - Minority: Women
  - Analysis: $h_{aa} = 0.21; h_{bb} = 0.17$
  - Dataset: Online dating

Homophilic networks

- **C) Scientific collaboration**
  - Minority: Women
  - Analysis: $h_{aa} = 0.57; h_{bb} = 0.56$
  - Dataset: Co-author network
    - Comp. Science

- **D) Scientific citation**
  - Minority: Scientific subfield
  - Analysis: $h_{aa} = 0.87; h_{bb} = 1.0$
  - Dataset: Scientific citation
    - Academic literature
Ranking of minorities in social networks

Practical implications: Sampling (sampling size 10%, k=100)

nCGR: normalized Cumulative Group Relevance
(a measure to quantify over/underrepresentation of groups)

Part II: Perception of minorities in social networks

Does homophily influence perception of minorities?

Perception of minorities

Muslim population
% of total, 2010
- above 7.0
- 5.1-7.0
- 3.1-5.0
- 1.1-3.0
- 1.0 & below

Public estimates of Muslim population
%, 2014

Public’s answer
Actual population
Perception of minorities in social networks

Individual and group-level perception

(a) Homophilic network
(True Consensus)

(b) Heterophilic network
(True Uniqueness)

\[ P_{\text{indiv}}(i) = \frac{1}{6} \approx 16\% \]
(0.5 fold underestimation)

\[ P_{\text{indiv}}(i) = \frac{4}{6} \approx 67\% \]
(2 fold overestimation)
Perception of minorities in social networks

Perception bias vs. homophily and minority size

Estimates of the size of the minority

- Minority overestimation (filter bubble)
- Minority underestimation
- Majority overestimation (majority illusion)

Minority size overestimated
Minority size underestimated
## Perception of minorities in social networks

### Empirical datasets

<table>
<thead>
<tr>
<th>Data</th>
<th>Nodes</th>
<th>Minority</th>
<th>Majority</th>
<th>Symmetric h</th>
<th>Asymmetric h (minority, majority)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>16,730</td>
<td>sex-workers 6,624 (40%)</td>
<td>sex-buyers 10,106</td>
<td>0</td>
<td>0, 0</td>
</tr>
<tr>
<td>POK</td>
<td>29,341</td>
<td>minority 12,868 (44%)</td>
<td>majority 16,473</td>
<td>0.15</td>
<td>0.2, 0.17</td>
</tr>
<tr>
<td>USF51</td>
<td>6,253</td>
<td>male 2626(42%)</td>
<td>female 3,627</td>
<td>0.47</td>
<td>0.48, 0.47</td>
</tr>
<tr>
<td>DBLP</td>
<td>280,200</td>
<td>female 63,356(22%)</td>
<td>male 216,844</td>
<td>0.56</td>
<td>0.57, 0.57</td>
</tr>
<tr>
<td>Github</td>
<td>127,668</td>
<td>female 7,330 (6%)</td>
<td>male 120,338</td>
<td>0.6</td>
<td>0.69, 0.54</td>
</tr>
<tr>
<td>APS</td>
<td>1,853</td>
<td>CSM 695(37%)</td>
<td>QSM 1,158</td>
<td>0.74</td>
<td>0.88, 1.0</td>
</tr>
</tbody>
</table>
Perception of minorities in social networks

Perception bias vs. homophily in empirical datasets

Estimates of the size of the minority

- Minority size overestimated
- Minority size underestimated

(a) Minority

(b) Majority

Graph showing estimates of the size of the minority in different social networks.
Perception of minorities on a population level

Can we observe similar perception biases on a national level?

International survey programs including the **US, Germany** and **South Korea**:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Question text</th>
<th>Original source of the question text the data for the general population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Not having money for food</td>
<td>Have there been times in the past 12 months when you did not have enough money to buy food you or your family needed? Yes–No</td>
<td>Gallup World Poll (2010)</td>
</tr>
<tr>
<td>3. Experiencing theft</td>
<td>Within the past 12 months, have you had money or property stolen from you or another household member? Yes–No</td>
<td>Gallup World Poll (2010)</td>
</tr>
</tbody>
</table>
Perception of minorities on a population level

Can we observe similar perception biases on a national level?

Examples of different minority / majority issues:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>US(%)</th>
<th>Germany(%)</th>
<th>Korea(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1. Not having money for food</td>
<td>19</td>
<td>81</td>
<td>5</td>
</tr>
<tr>
<td>2. Donating to charity</td>
<td>57</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>3. Experiencing theft</td>
<td>12</td>
<td>88</td>
<td>9</td>
</tr>
<tr>
<td>4. Religion importance</td>
<td>70</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>5. Worship attendance</td>
<td>53</td>
<td>47</td>
<td>33</td>
</tr>
<tr>
<td>6. God and morality</td>
<td>47</td>
<td>53</td>
<td>33</td>
</tr>
<tr>
<td>7. Belief in a god</td>
<td>64</td>
<td>36</td>
<td>38</td>
</tr>
<tr>
<td>8. Smoking</td>
<td>15.2</td>
<td>85</td>
<td>21.9</td>
</tr>
<tr>
<td>9. Military force</td>
<td>76.5</td>
<td>24</td>
<td>50</td>
</tr>
<tr>
<td>10. Homosexuality</td>
<td>35.5</td>
<td>64</td>
<td>12.1</td>
</tr>
</tbody>
</table>

Table S2. The object ratio of population for US, Germany, and Korea with the survey questions.

+ a crowdworker survey (n=300) asking:
1. Do you have characteristic x?
2. How frequent is characteristic x in your personal network?
3. How frequent is characteristic x in the population of your country?
Perception of minorities on a population level

Can we observe similar perception biases on a national level?

Results for minority/majority estimates from the US (results similar for Germany):

- Minority size overestimated
- Minority size underestimated
Perception of minorities in social networks

Can we mitigate perception biases in social networks?

Asking friends:
Part III: Conclusions
Inequalities in social networks

Conclusions

1.) Homophily influences ranking of minorities
   Minorities are more affected by homophilic interactions and their group size than majorities

2.) Homophily can impact perception of groups
   Evidence for perception biases on social network and population levels, can be (partially) mitigated
Inequalities in social networks

Implications for Computational Social Science

1.) Confluence of separate streams of research integrating models, theory, behavioral data and survey data

2.) Attention shifts from theory to models and data (for now) new opportunities to evaluate the rich historic body of theories and hypotheses

3.) Emergence of entirely new computational social systems where social interactions are influenced and/or shaped by algorithmic systems, requiring new theories and models
Thank you!

Markus Strohmaier

References:


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