Social Psychology Meets Social Computing: State of the Art and Future Direction

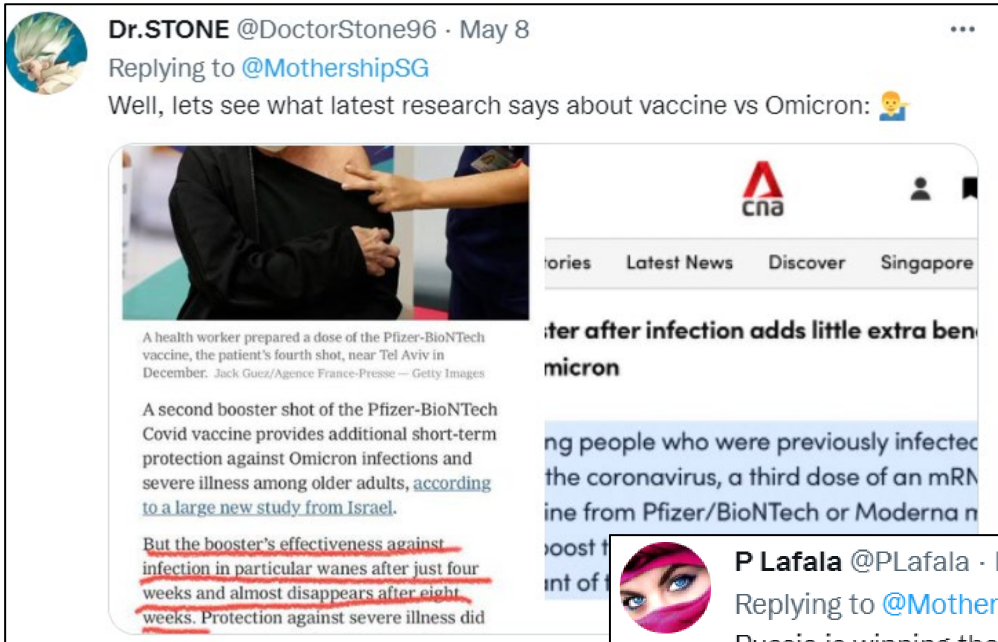
Sourav S Bhowmick, NTU Singapore
Hui Li, Xidian University, China
S H Annabel Chen, NTU Singapore
Yining Zhao, NTU Singapore

Data in Social Computing

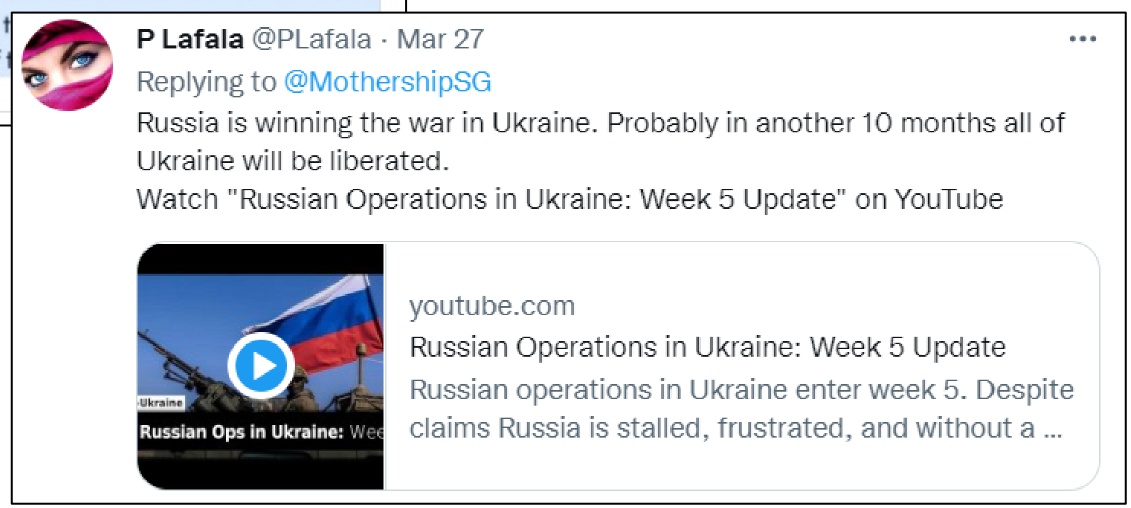
Nature of Data

- Many data in social computing is related to humans or produced by humans.
- Many of these solutions are also directly consumed by humans.

Social Data



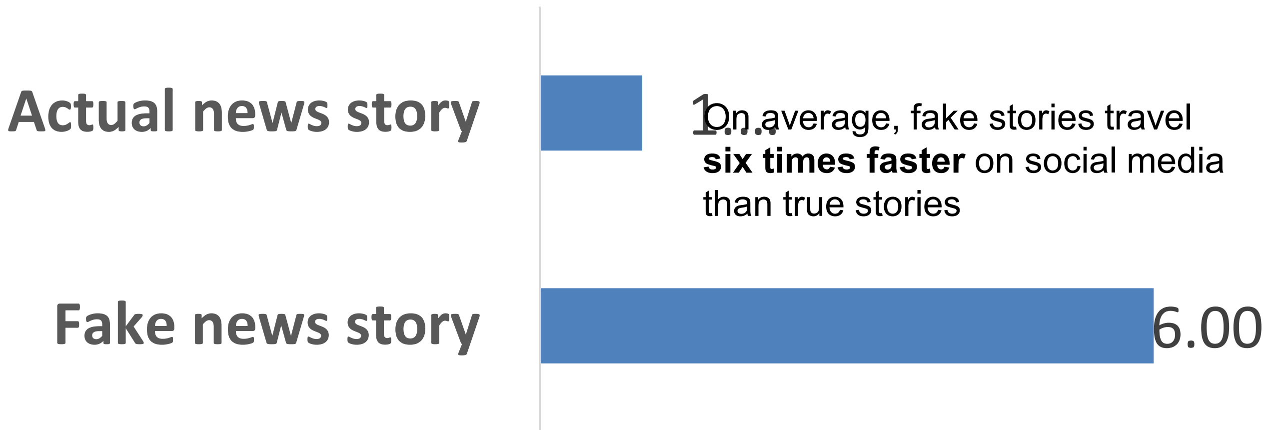
Dr.STONE @DoctorStone96 · May 8
Replying to @MothershipSG
Well, lets see what latest research says about vaccine vs Omicron:
cna
tories
Latest News
Discover
Singapore
A health worker prepared a dose of the Pfizer-BioNTech vaccine, the patient's fourth shot, near Tel Aviv in December. Jack Guez/Agence France-Presse — Getty Images
A second booster shot of the Pfizer-BioNTech Covid vaccine provides additional short-term protection against Omicron infections and severe illness among older adults, according to a large new study from Israel.
But the booster's effectiveness against infection in particular wanes after just four weeks and almost disappears after eight weeks. Protection against severe illness did
ter after infection adds little extra ben
micron
ng people who were previously infectec
the coronavirus, a third dose of an mRN
ine from Pfizer/BioNTech or Moderna m



P Lafala @PLafala · Mar 27
Replying to @MothershipSG
Russia is winning the war in Ukraine. Probably in another 10 months all of Ukraine will be liberated.
Watch "Russian Operations in Ukraine: Week 5 Update" on YouTube
Ukraine
Russian Ops in Ukraine:
youtube.com
Russian Operations in Ukraine: Week 5 Update
Russian operations in Ukraine enter week 5. Despite claims Russia is stalled, frustrated, and without a ...

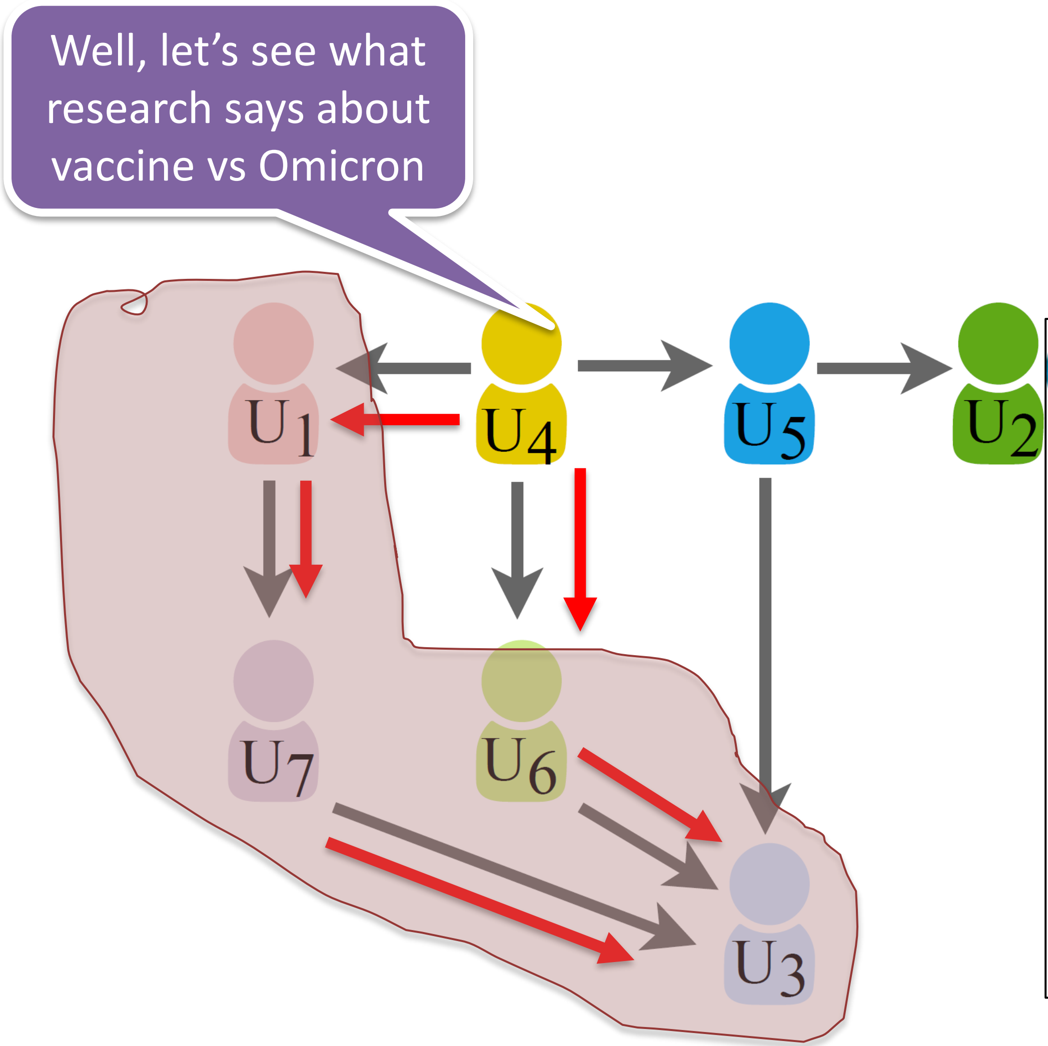
The Power of Fake to Attract Our Attention

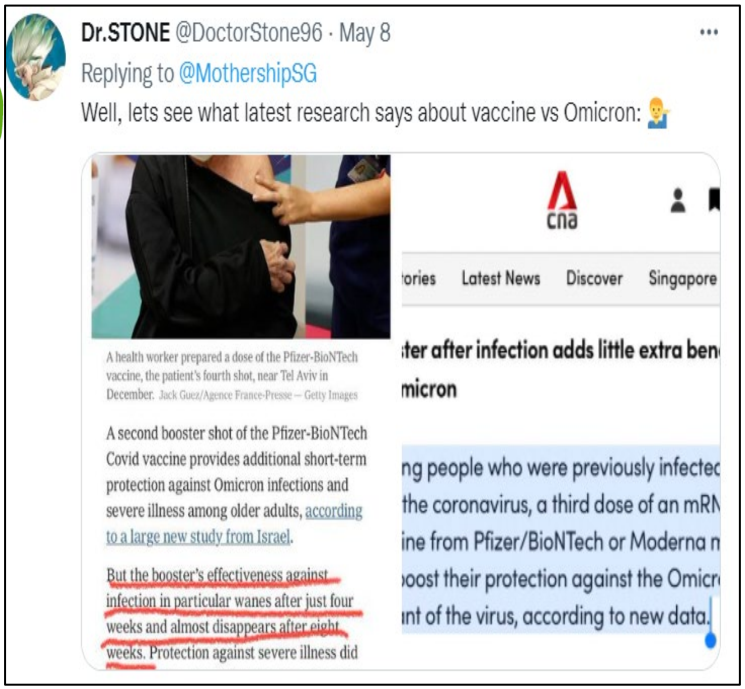
relative speed with which a story "travels" on social media.



Source: Soroush Vosoughi, Deb Roy, and Sinan Aral, "The spread of true and false news online," *Science* 369 (2018): 1146-1151.

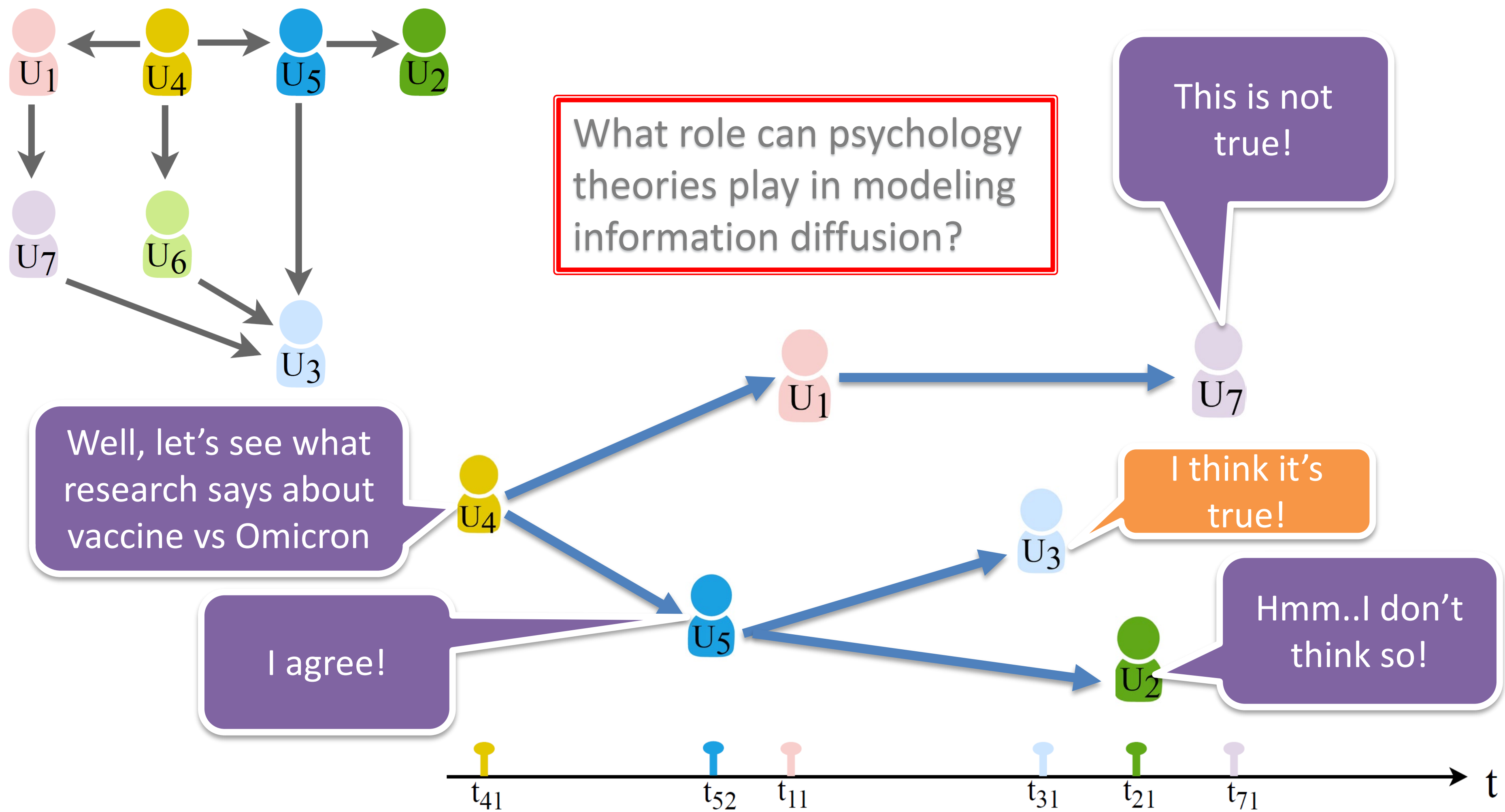
Spread of (Fake) Information





Online Information Diffusion

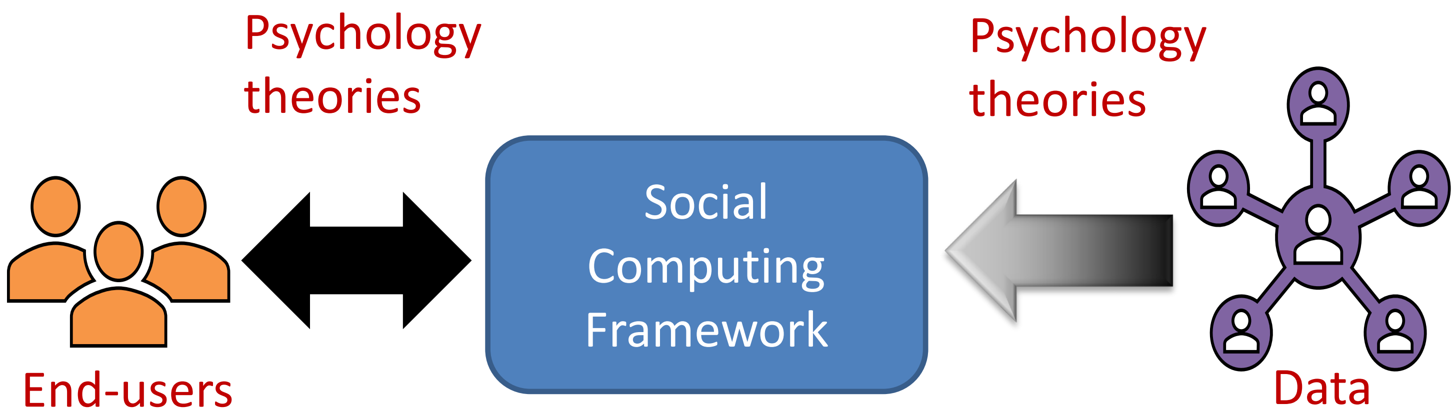
What role can psychology theories play in modeling information diffusion?



Goal of the Tutorial

Psychology Theory-informed Design

- Design social computing solutions that are informed by theories from social psychology.
- Focus on social influence.



Overview of the Tutorial

- Psychology theory-informed design
- Background on psychology theories
- Psychology theory-informed design of diffusion models
- Psychology theory-informed design of social influence
- Future directions

Role of Theory

Theory

- A scientific theory is a testable explanation for a broad set of facts or observations.
- Different from the way people customarily use the term (wild speculation, mere hunch).

Attributes of theory

- The power to explain the facts.
- The ability to be tested.

Problems of Pure CS Theory-based Social Computing Solutions

Issues

- Classical CS-based solutions focuses on computing resource cost but not on cognitive and social bias in humans
- Conformity may promote or block the influence spread
- Impacts prediction accuracy of the system

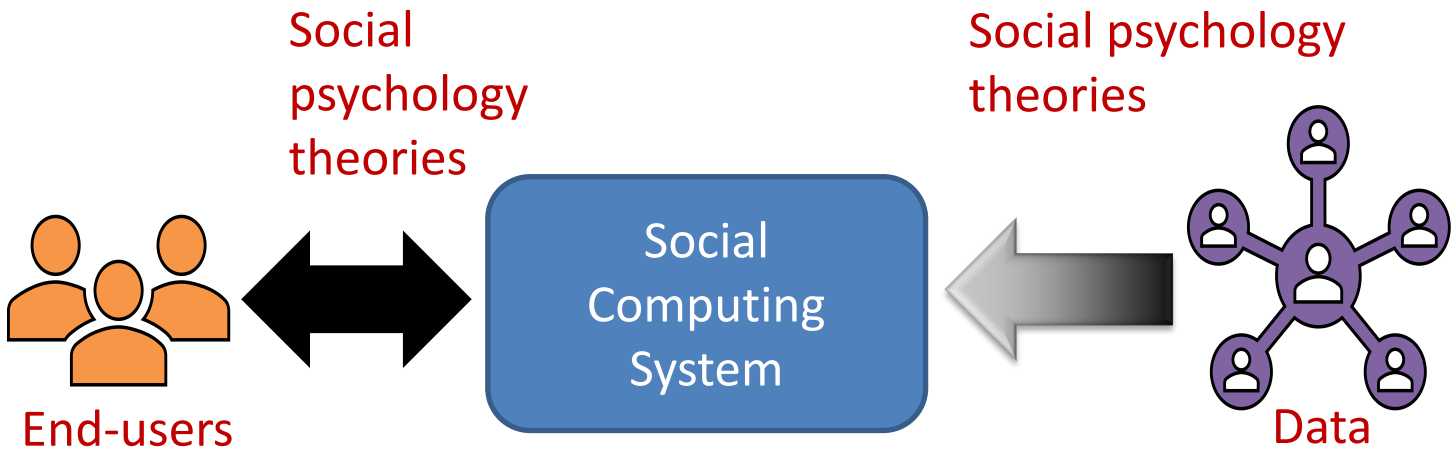
Psychology theory-informed Solution

- Make the modeling of social computing problems and solutions human behavior-sensitive

What Can Psychology Theories Do To Social Computing?

Theory-informed Design

- Design social computing solutions that are informed by theories from psychology (in addition to theories from CS).
- Many social computing framework deals with data related to humans or are consumed by humans.



Focus on Social Psychology

Human Behavior

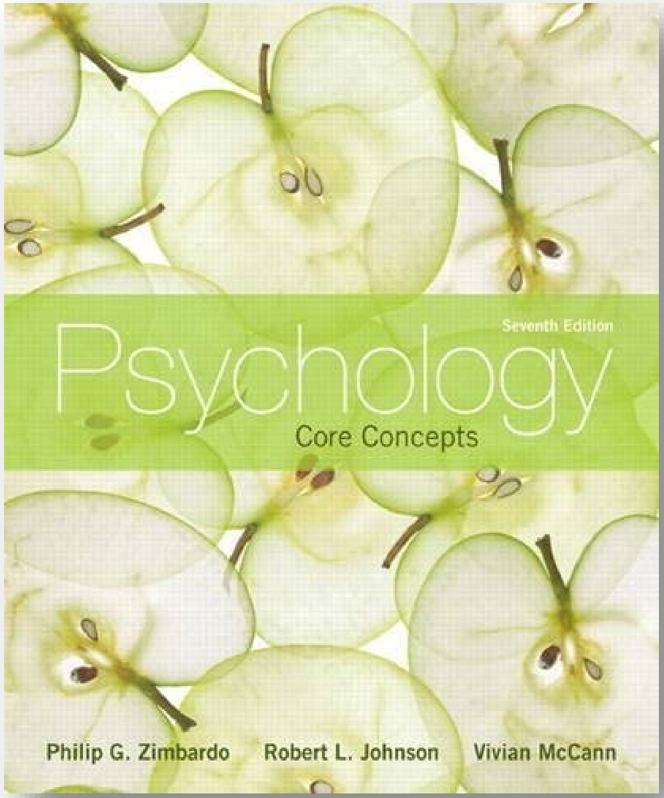
- Adapt our behavior to the demands of the social situation.
- In new or ambiguous situations, we take our cues from the behavior of others in that setting.
- Social psychology studies the behavior of individuals or groups in the context of particular situations.

Social Computing and Social Psychology

- Human-related data implicitly or explicitly contain cues of human behavior
- Any social computing framework that do not consider it may be ineffective in practice.

Next..

- Psychology theory-informed design
- Background on psychology theories
- Psychology theory-informed design of diffusion models
- Psychology theory-informed design of social influence
- Future directions



What is Psychology?

As a Field

- A broad field with many specialties.
- Science of behavior and mental processes (brain).
- The science of psychology is based on objective, verifiable evidence – not just the opinions of experts and authorities.

Note

- Includes not only mental processes but also behaviors.
- Covers internal mental processes that we observe only indirectly (thinking, feeling, desiring).
- External (observable behaviors) such as talking, smiling, and running.

Three Ways of Doing Psychology

Experimental Psychologists

- They perform most of the research that creates new psychological knowledge.

Educators of Psychology

- Focus more exclusively on teaching but some may conduct limited amount of research as well.

Applied Psychologists

- Use the knowledge developed by experimental psychologists to tackle human problems of all kinds.

Psychology Is Not Psychiatry

Psychiatry

- Psychiatry is a medical specialty, not part of psychology at all.
- Almost all psychiatrists treat mental disorders.
- Psychiatrists hold MD (Doctor of Medicine) degrees and have specialized training in the treatment of mental and behavioral problems (typically with drugs).

Psychology

- Much broader field – from brain function to social interaction and from mental well-being to mental disorder.
- Training is not usually medical training.

Six Perspectives Of Psychology

Motivation

- Each perspective offers its own unique explanation for human behavior.

A Tool to Understand Human Behavior

- Each perspective is an important tool in your “psychological toolbox” for understanding human behavior.

Biological

Cognitive

Behavioral

Developmental

Sociocultural

Whole-person

Six Perspectives of Psychology

The six perspectives all play key roles in developing a holistic understanding of human behavior

Many perspectives can reasonably apply to any single behavior – rarely just one perspective sufficient to adequately explain the behavior

Need multiple perspectives to fully understand the causes of human behavior

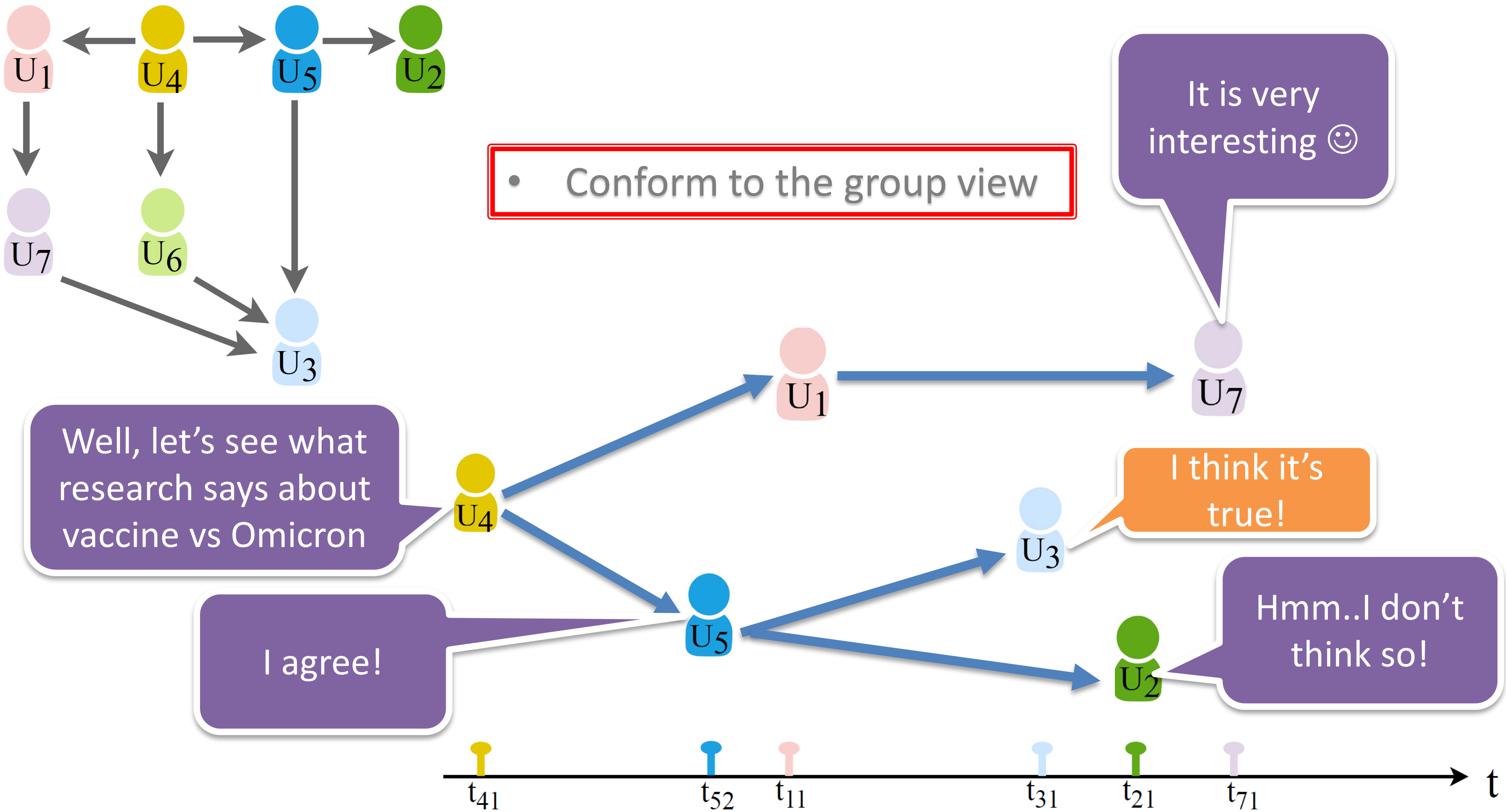
Sociocultural Perspective

Current View
• Who could deny that people exert powerful influences on each other? • Sociocultural perspective places the idea of social influence center stage.

The social and cultural situation in which the person is embedded can sometimes overpower all other factors that influence behavior.

Spread of (Fake) Information

- Conform to the group view



Power of the System

System Power

- Power that creates and maintains specific situations
- Many studies in social psychology show that the power of the situation can pressure ordinary people to commit horrible acts.

Understanding Human Behavior

- Three level analysis
- The individual’s dispositions
- The power of the situation
- The power of the system

Understanding Human Behavior

Individual

- Individual’s dispositions.

Power of the Situation

- The environment that creates situations that influence behaviors.

Power of the System

- Systems shape situations which in turn affects behavior.

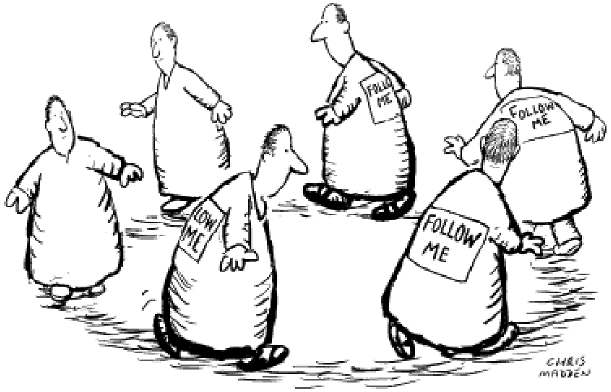
Relevant Social Psychology Theories

- Conformity Theory
- Confirmation Bias Theory
- Attenuation Theory
- Interference Theory

Theory of Conformity

Conformity

- Refers to the inclination to align our attitudes and behaviors with those around us.
- Long stream of research in social psychology that shows existence of conformity in social interactions.
- Asch effect – the powerful influence that a group exerts on the objective judgments of an individual




Attaaaaaaack!
Ivan! You're out!
Simon says... Attaaaaaaack!

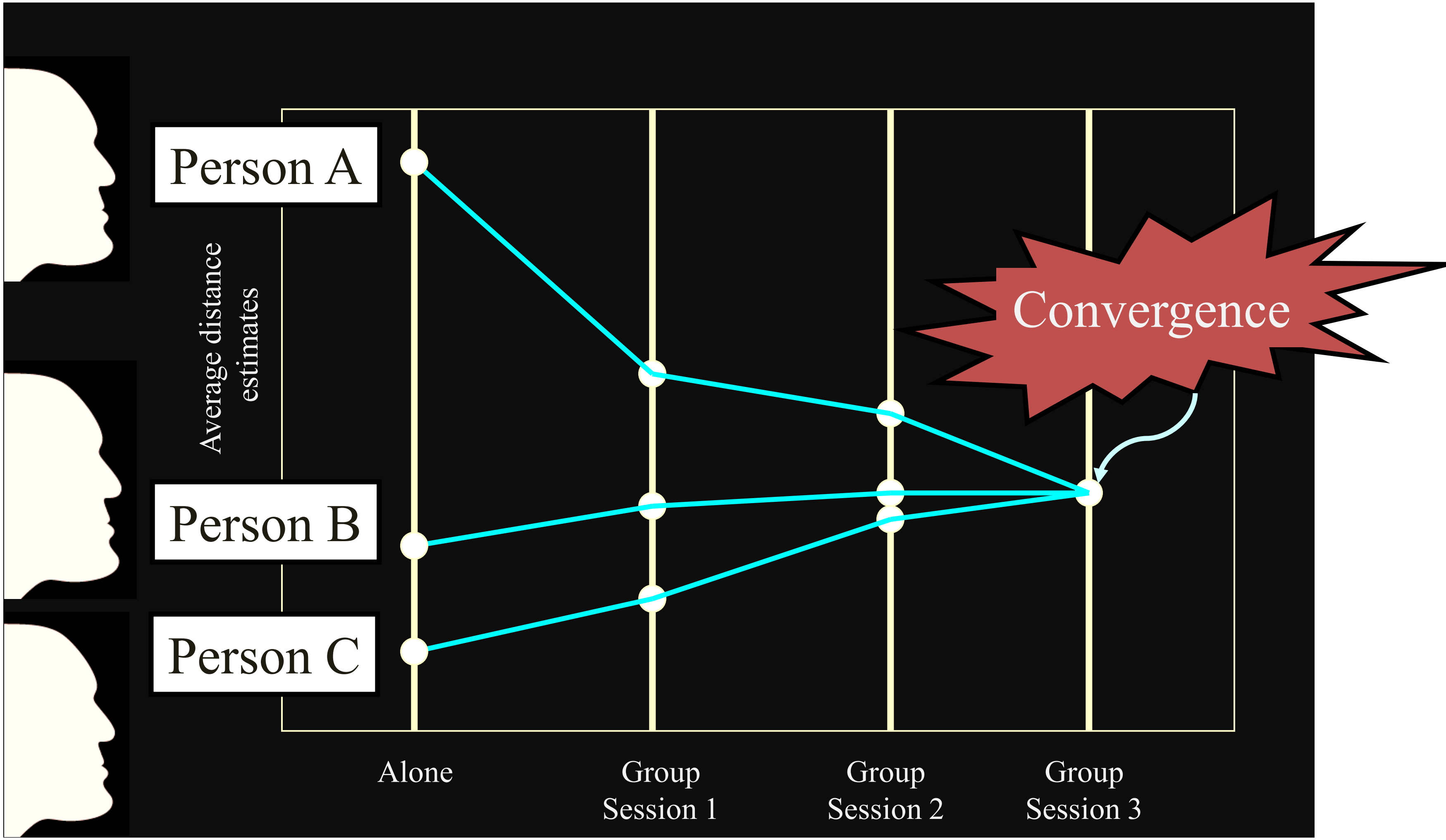
Why Do We Conform To the Group?

Informational Conformity

- People conform to peer views in an attempt to reach appropriate behaviours and attitudes due to lack of knowledge.

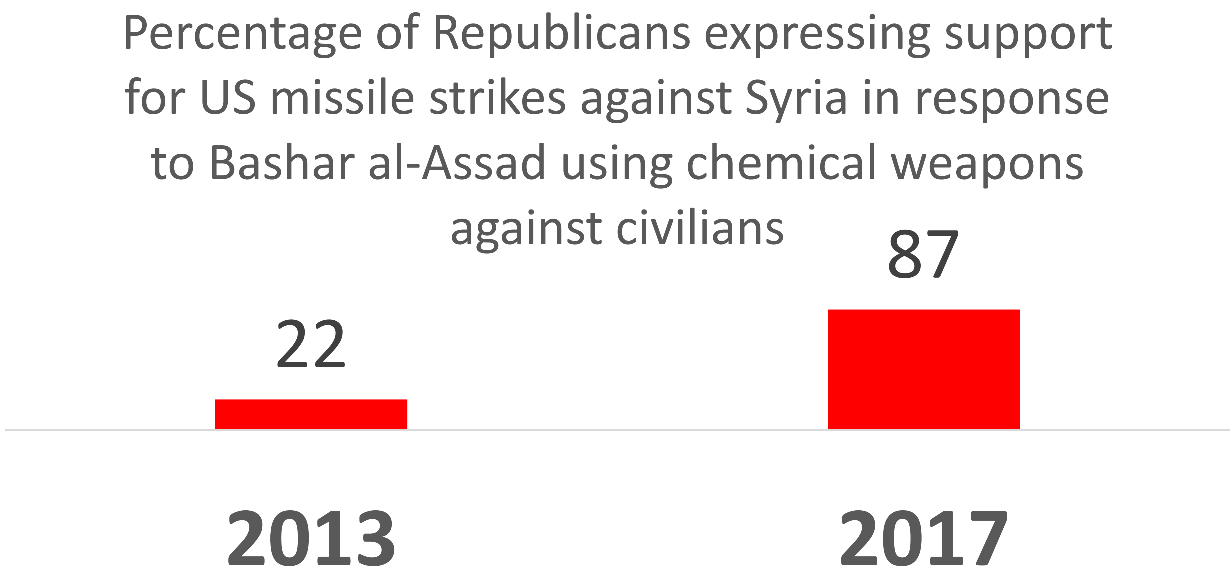
Normative Conformity

- Desire to be accepted or that keep us from being isolated or rejected by others.



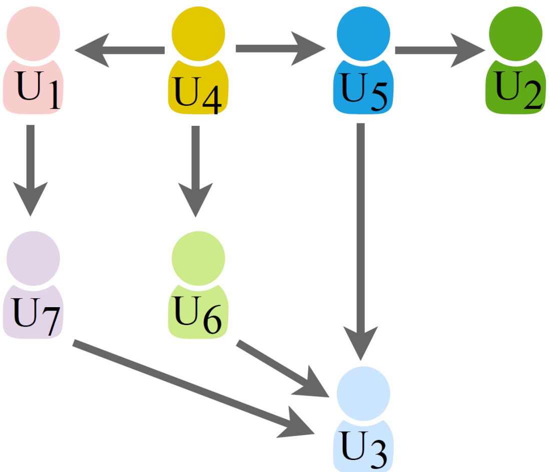
Initially, they differ; but over trials, they converge

Conformity to claims made by party leaders and by like-minded media sources

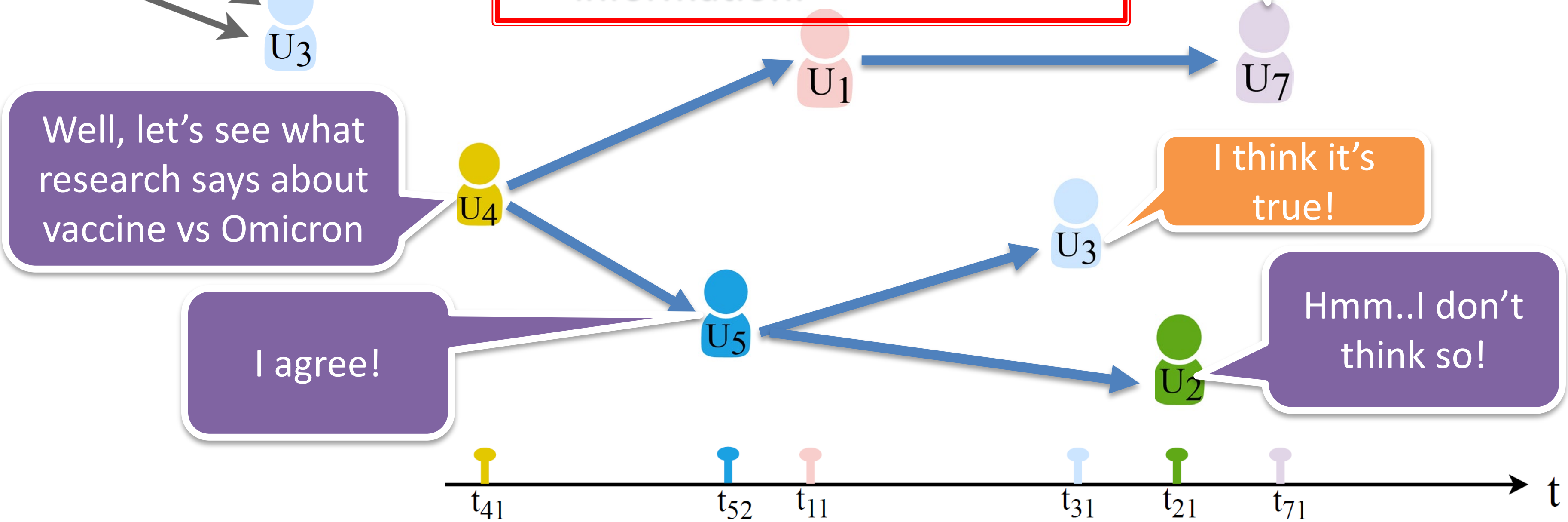


Source: Washington Post/ABC News polls, 2013 and 2017.

Spread of (Fake) Information



- U3 may demonstrate high conformity.
- U2 may be showing high non-conformity.
- U2 may block spread of information.



What Conditions Encourage Conformity?

Unanimity of the majority

- If everyone in the group agrees, they exert a powerful social pressure
- If one person defects from the majority, conformity can go down drastically

Size of the group

- Conformity pressure increases when confronting a group of 3 or more.

What Conditions Encourage Conformity?

Making a public commitment

- If you believe others in the group will not hear your responses, you are less likely to go along with them when you think they are incorrect

Ambiguity

- When peoples are more to self-doubt, they yield to group conformity

What Conditions Encourage Conformity?

Self-esteem

- People who place a low value on themselves are more likely to conform.

Makeup of the majority

- More conformity occurs when the group has high status

Resisting Conformity

Illusion of personal invulnerability

- NOT ME syndrome
- Others may but not me!
- More susceptible to influence agents because their guard is done and they do not engage in mindful, critical analysis of situational forces acting on them.

Can Groups Themselves be Pressured to Conform?

Groupthink

- Encourages conformity in the thinking and decision making of individuals when they are in groups (e.g., committees).
- Members of the group attempt to conform their opinions to what each believes to be the consensus of the group.
- Can lead the group to take actions each member might normally consider to be unwise.

When Groupthink Likely to Happen?

Conditions Promoting Groupthink
• Directive leadership, a dominant leader • High group cohesiveness, with absence of dissenting views • Lack of norms requiring methodical procedures for evidence collection/evaluation • Homogeneity of members' social background and ideology • High stress from external threats combined with low hope of a better solution than that of the group leader

Confirmation Bias Theory

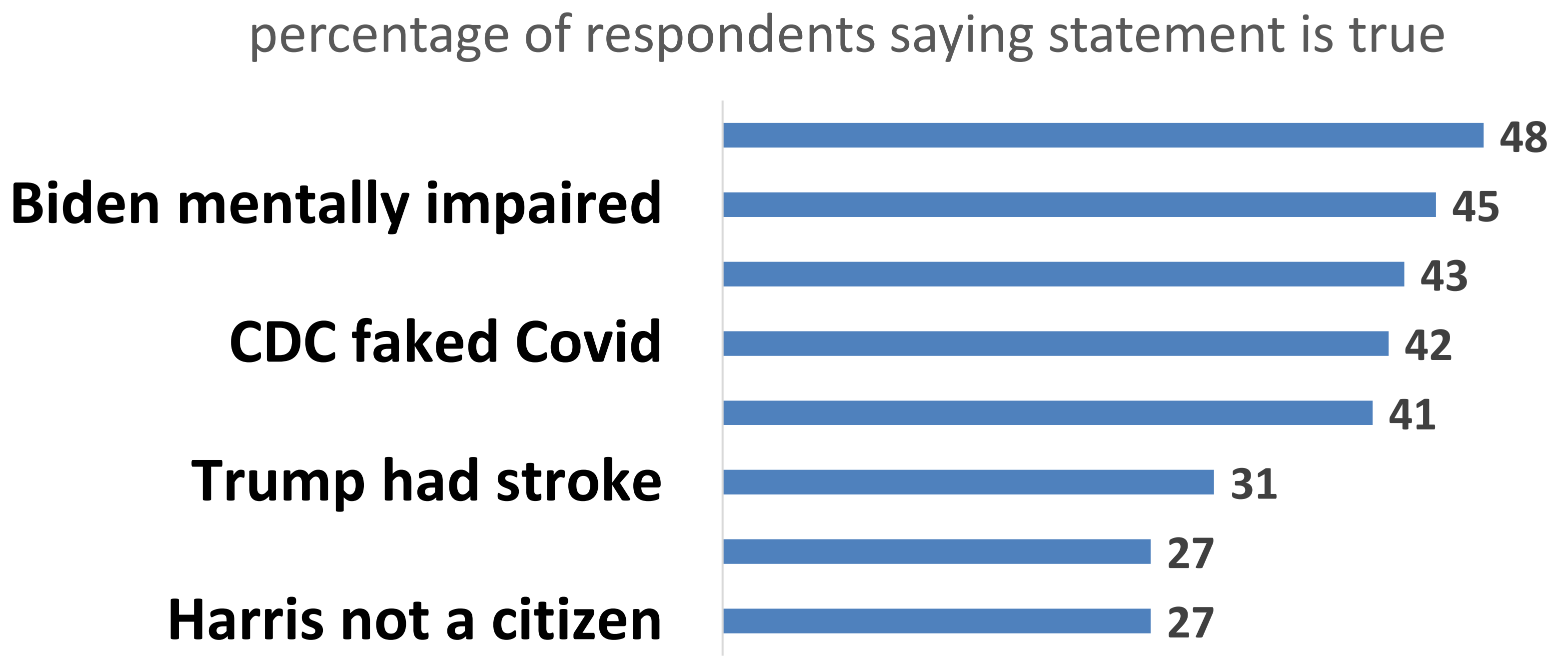
Confirmation Bias

- Remember events that confirm our beliefs and ignore or forget contradictory evidence.
- A powerful and all-too-human tendency.

It's a bias!

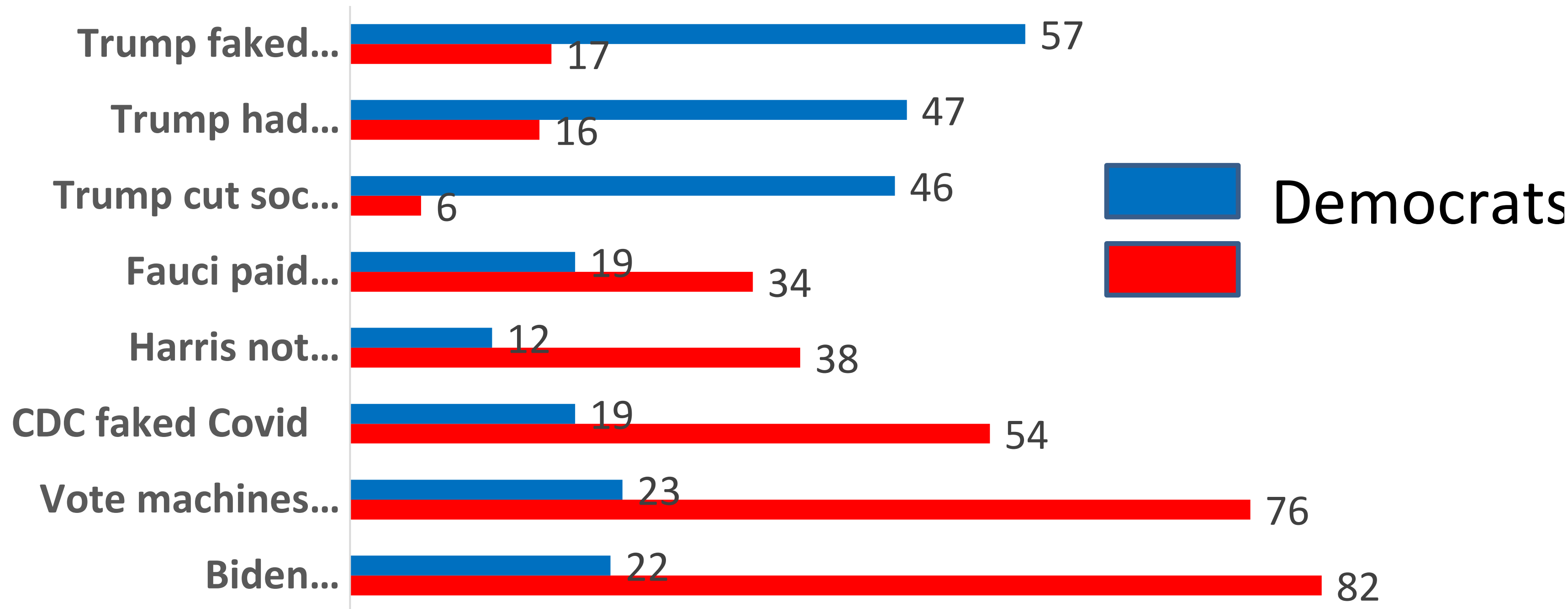
- Unconscious or unintentional.
- It does not mean that individuals are incapable of providing perspectives that counter their own beliefs.
- Unmotivated to do so.

None are true, but each is believed by tens of millions of Americans



Source: Indiana University's Observatory on Social Media survey, November 2020

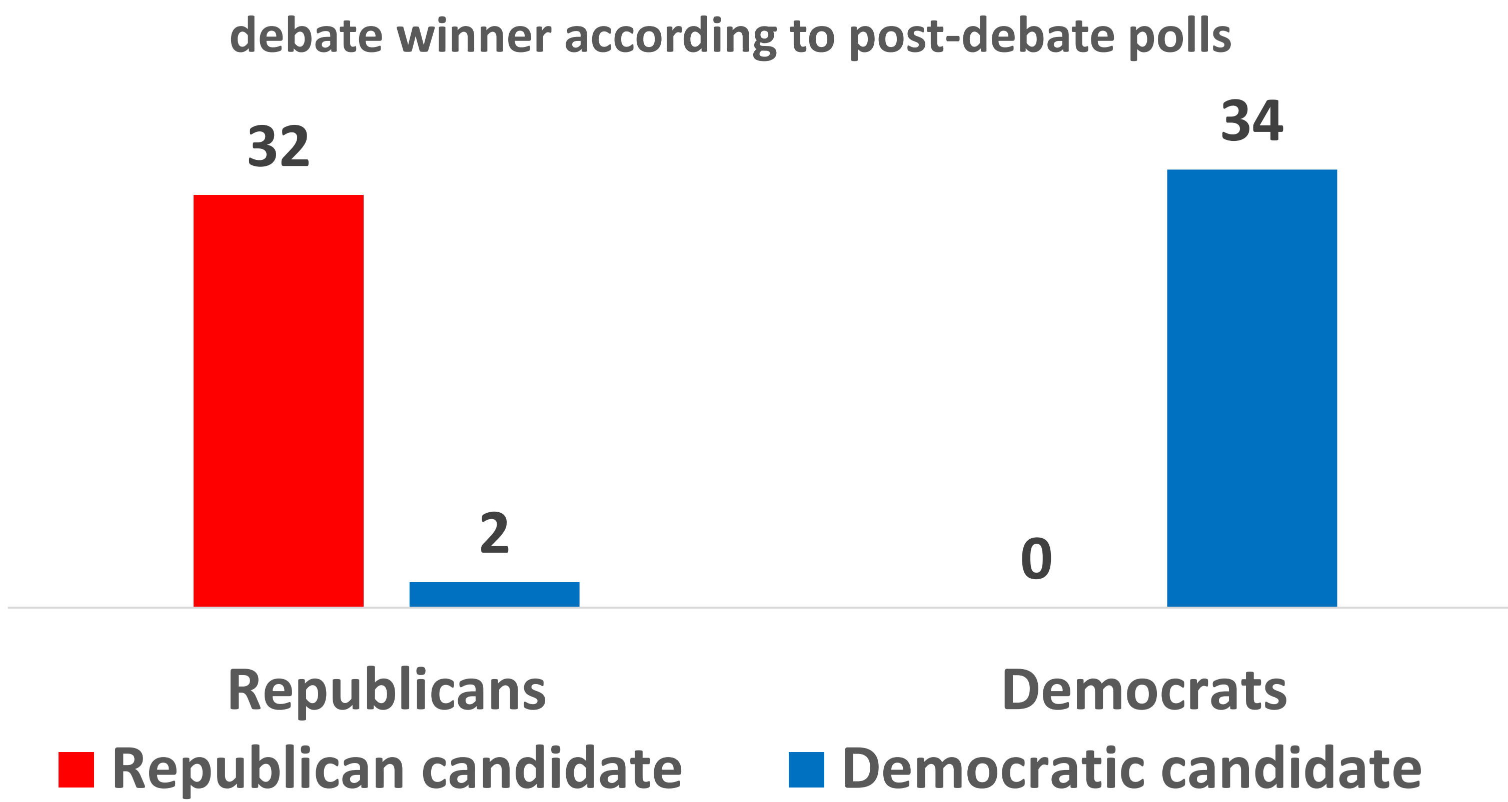
Confirmation Bias affects Republicans & Democrats alike - accepting false claims that align with one's partisanship



Source: Indiana University's Observatory on Social Media survey, November 2020

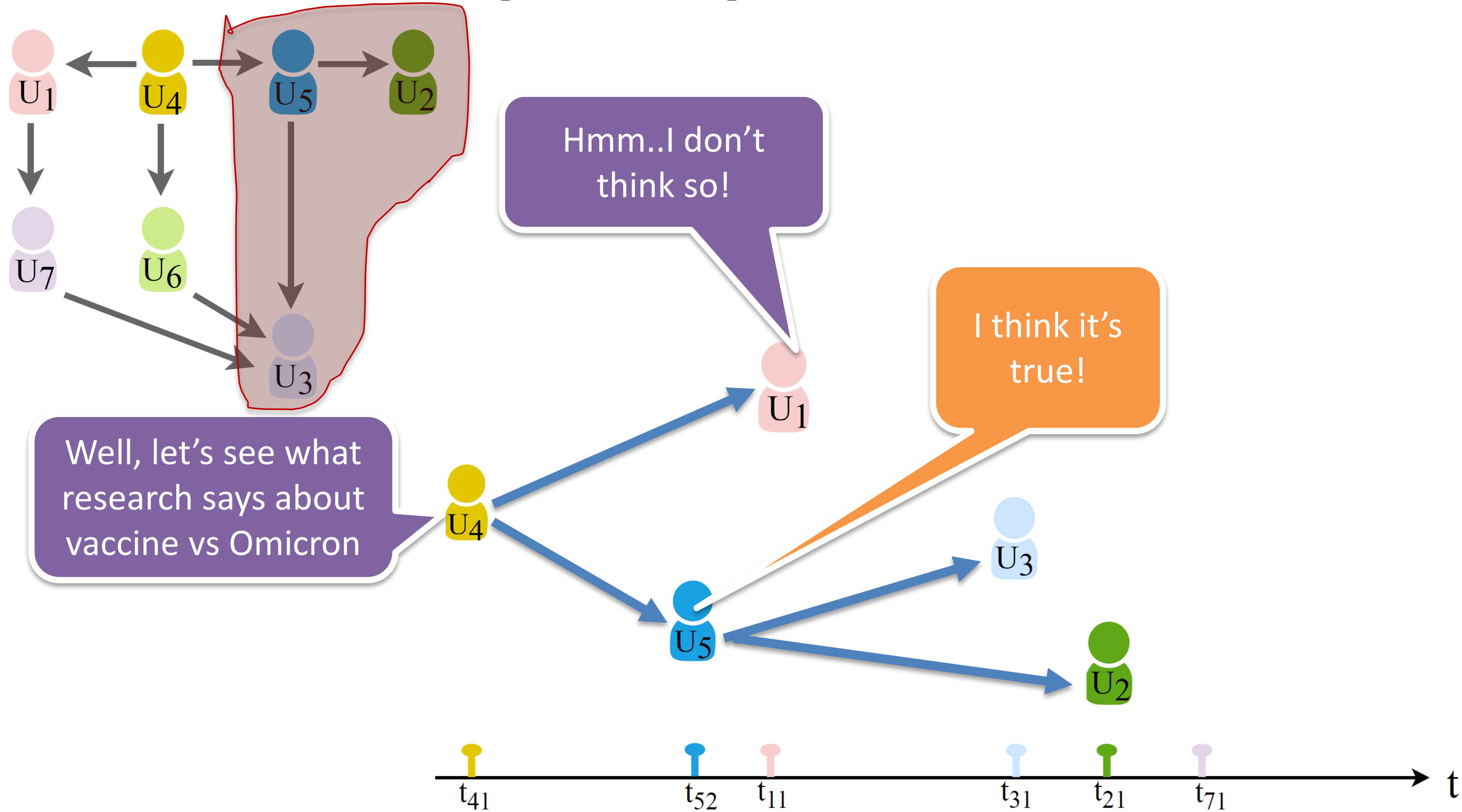
Confirmation Bias example

Of the 34 election presidential debates . . .



Source: Multiple polls, estimated for some on incomplete data

Spread of (Fake) Information



Theory of Attention

Attention

- A form of mental activity or energy that can be distributed to different tasks.

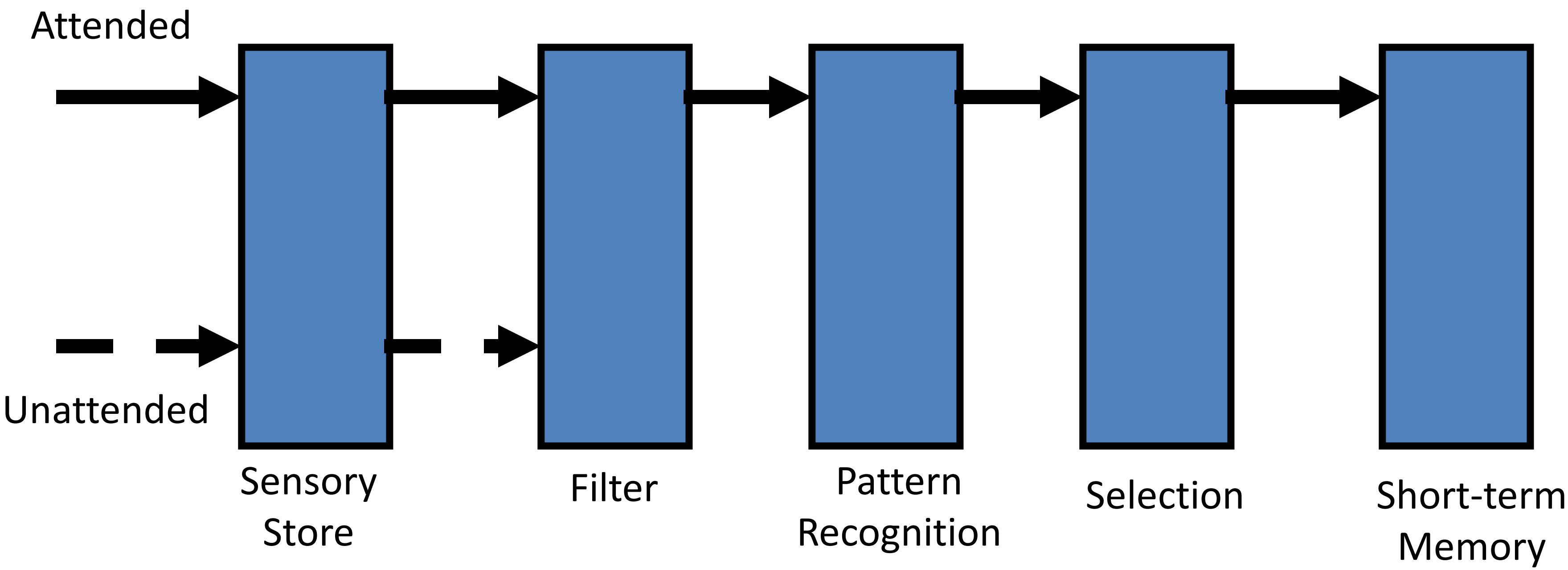
Attention is

1. Selective
2. Divisible
3. Shiftable
4. Sustainable

The Filter Model

Broadbent's Filter Model of Attention
•Information is selected on the basis of physical characteristics. •The selected information is allowed to pass to later stages where it undergoes further processing. •Unselected information is blocked completely. •An example of an *early selection model*.

The Broadbent Model of Selective Attention

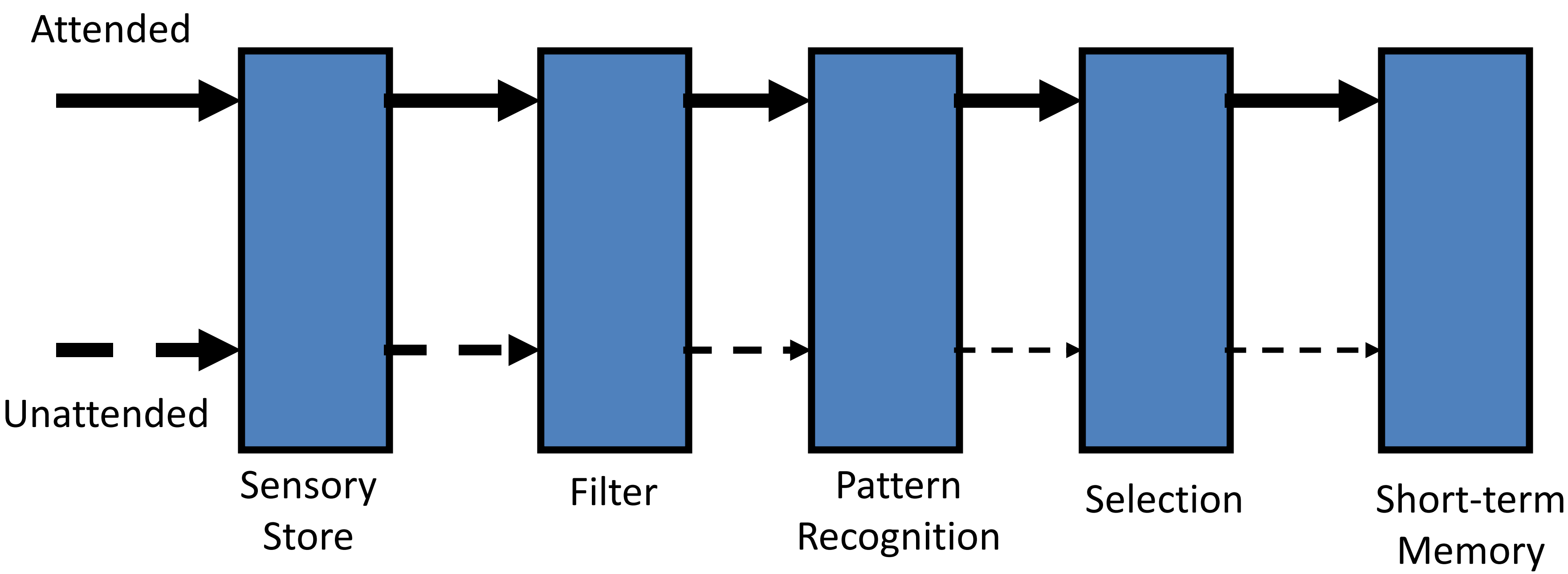


The Attenuation Model

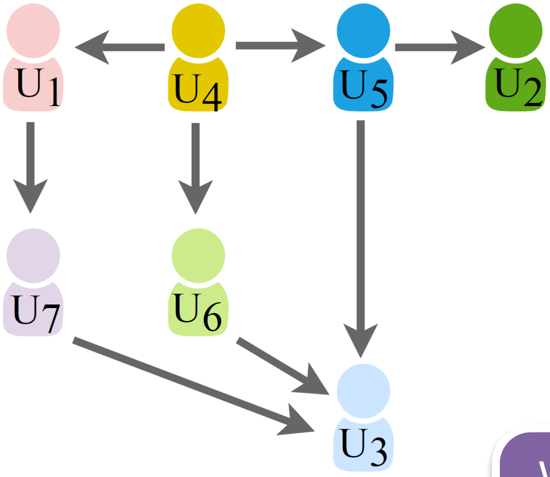
Treisman's Model

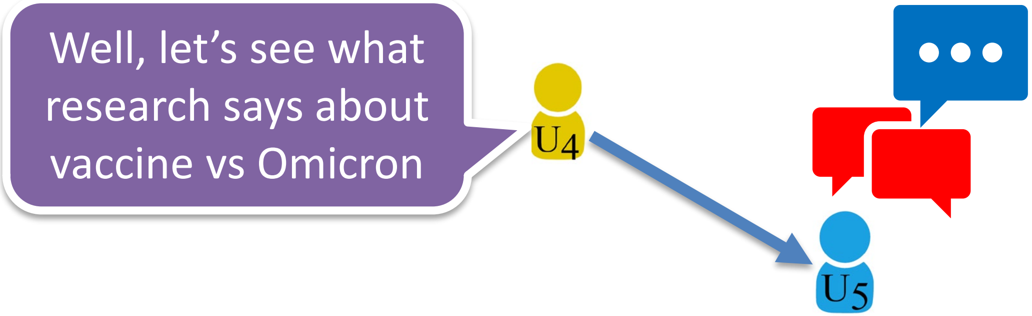
- Formulated by Treisman (1964).
- This theory aims to explain why and how individuals tend to process only certain parts of the world surrounding them, while ignoring others.
- Unattended message is attenuated (i.e., weakly processed information) but not entirely blocked from further processing and entry into memory.
- The likelihood of information getting through is determined by its *threshold*.
- Weakly processed information have different thresholds of recognition depending on their relevance and significance to the individual.

Treisman Model of Selective Attention



Spread of (Fake) Information





Why Do We Forget?

Five Key Theories

- Decay
- Interference
- Motivated Forgetting
- Encoding Failure
- Retrieval Failure

Decay Theory

- Memory degrades with time.

Interference Theory

- All forgetting cannot simply be explained by decay.
- One memory competes (*interferes*) with another.

Interference Theory

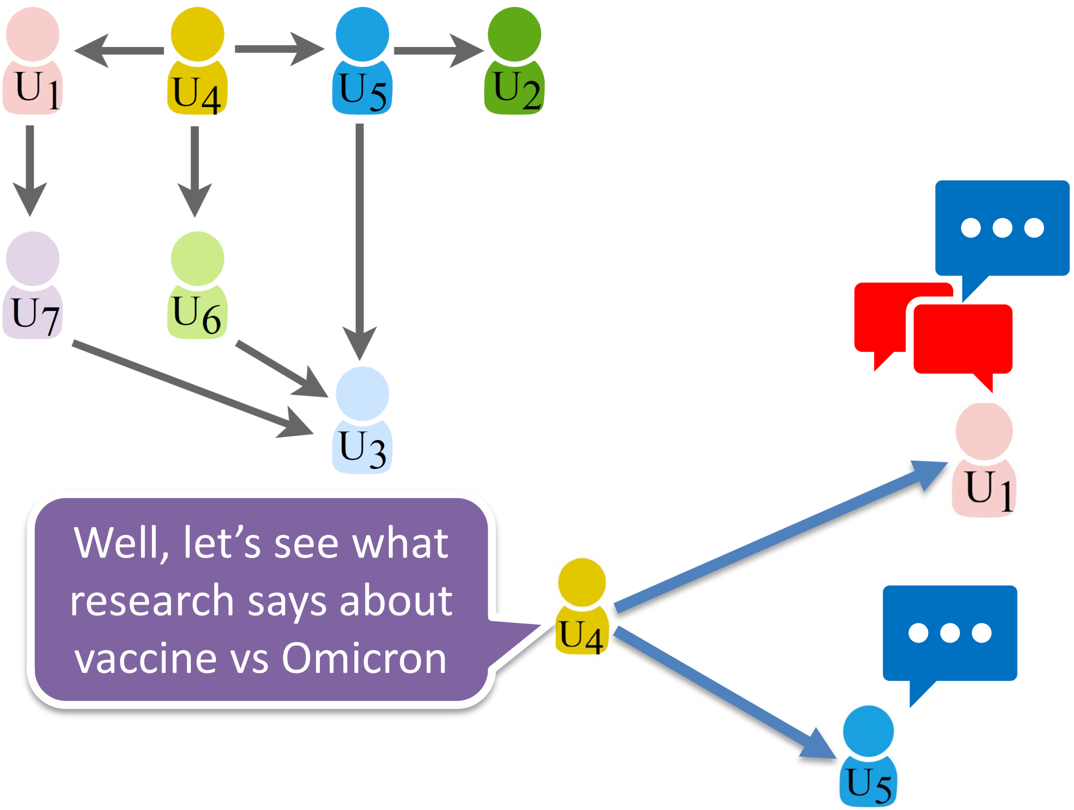
Retroactive Interference

- New information *interferes* with recall of old.

Proactive Interference

- Old information *interferes* with recall of new.
- When learning SQL your knowledge of Python interferes.

Spread of information in the presence of retroactive interference



Testing an Idea Scientifically in Psychology

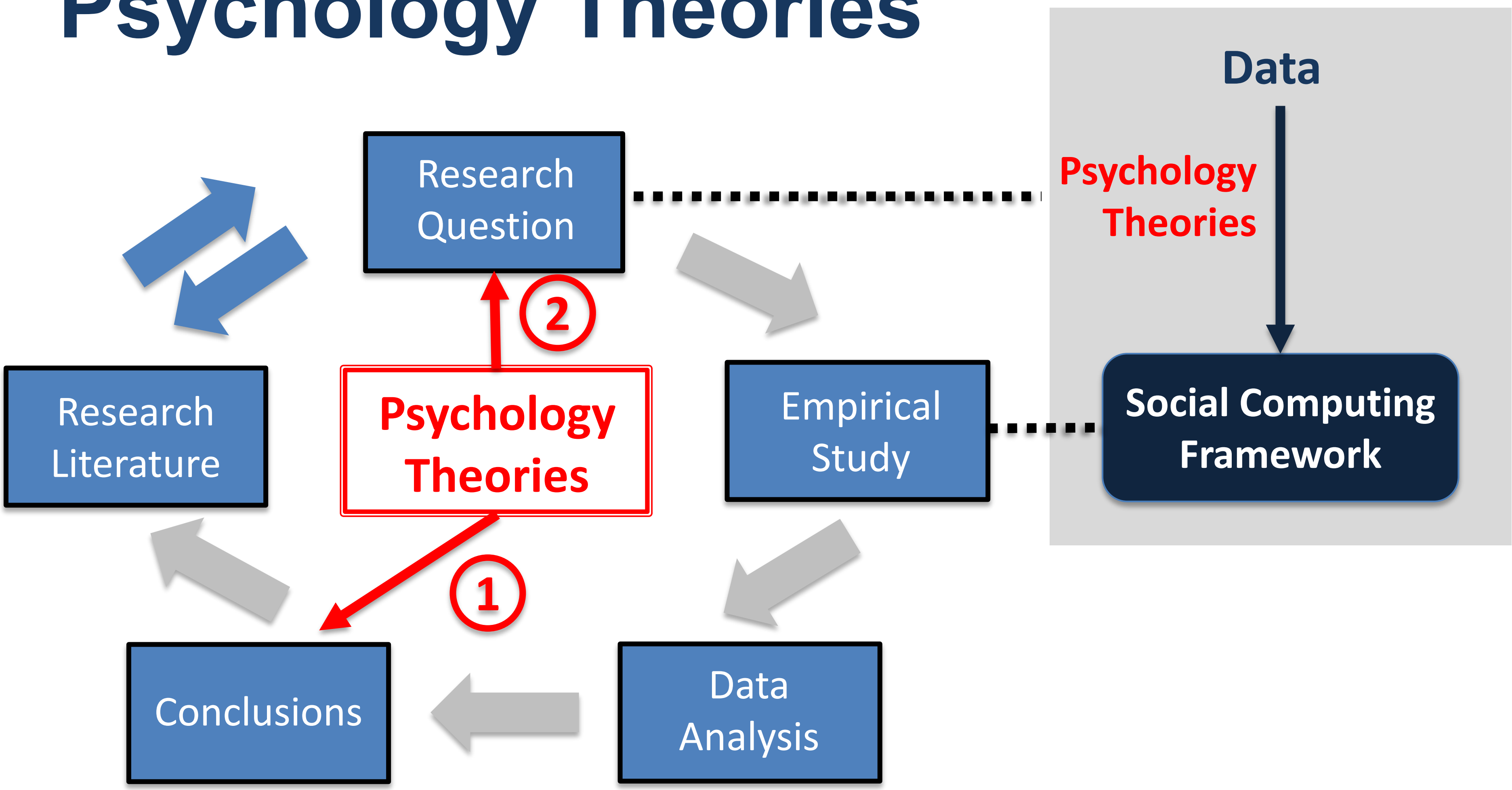
Four Steps

- Develop a hypothesis (a specific testable idea or prediction)
- Gathering objective data
- Analyzing the results
- Publishing, criticizing, and replicating the results

Gathering objective data

- Start of empirical investigation.
- Investigating a question empirically means collecting evidence (data) carefully and systematically using a set of methods.
- These methods are designed to avoid false conclusions caused by our expectations, biases, and prejudices.

Framework Used to Investigate Psychology Theories



Shaughnessy, John J., Eugene B. Zechmeister, and Jeanne S. Zechmeister. *Research methods in psychology*. McGraw-Hill, 2000.

Psychology-informed Design

- Detect
- Model
- Analyze

Next..

- Psychology theory-informed design
- Background on psychology theories
- Psychology theory-informed design of diffusion models
- Psychology theory-informed design of social influence
- Future directions

Online Information Diffusion

Information Diffusion

A process by which information spreads over a network

- Which pieces of information diffuse the most?
- How and why information is diffusing and will be diffused in the future?
- Which network members play crucial roles?

Diffusion Models

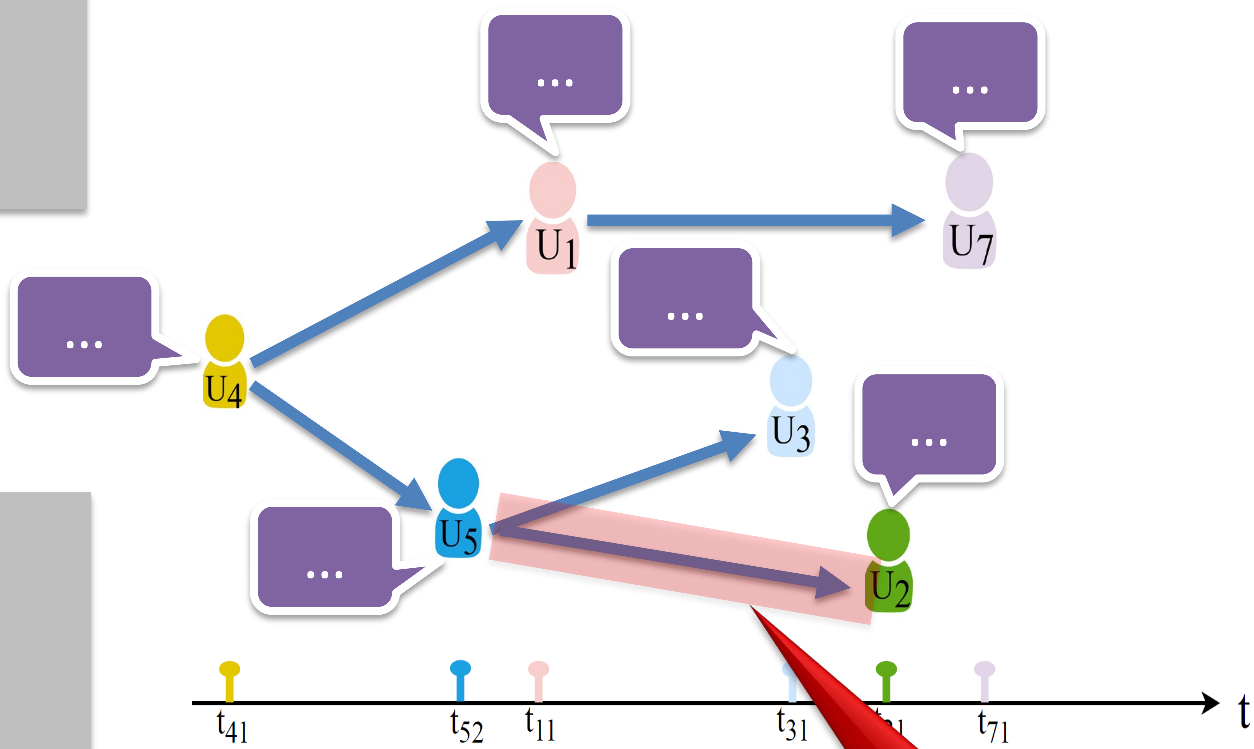
$$\underbrace{\text{Viral marketing} \quad \text{Rumor detection, fake news propagation} \quad \text{User behavior prediction} \quad \ldots}_{\text{Applications}}$$

Online Information Diffusion

Diffusion Process
- Structure
- Temporal dynamics

Explain ↑ Predict

Diffusion Models
- Graph based
- Non-graph based



Underlying psychological elements

Psychology-informed design of diffusion models

Diffusion Models

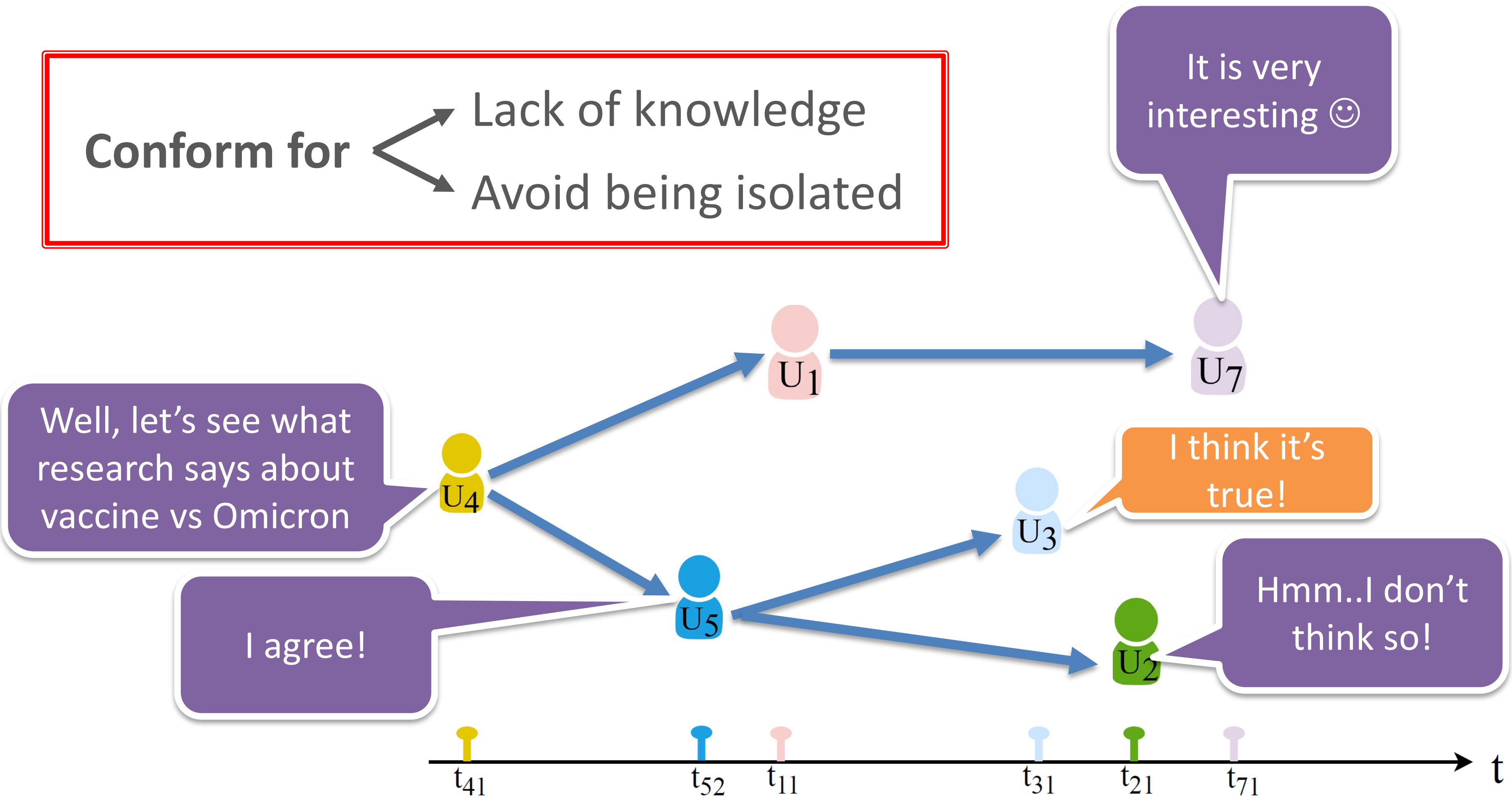
Psychology Theory

- Conformity theory
- Attention attenuation and interference theories
- Confirmation bias theory

Overview of Modeling Psychology Theories

Conformity	• Decompose *interpersonal influence strength* into *two additive parts* • Quantify *informative and normative conformity* within these parts
Attenuation& Interference	• Locate the *static activation threshold* that contrary to psychological mechanisms • Replace the static threshold with *a personalized nonlinear growth function*
Confirmation Bias	• Characterize the *influence weight* of news agencies over individuals as *state-dependent* (i.e., heavily depends on individuals' current opinions)

Diffusion Models and Conformity Theory



Li, Hui, Hui Li, and Sourav S. Bhowmick. "Chassis: Conformity meets online information diffusion." Proceedings of the 2020 ACM SIGMOD International Conference on Management of Data. 2020.

Challenges: Diffusion Models & Conformity Theory

- The private beliefs of individuals may not be exposed explicitly in social activities.
- Conformity of an individual is context-sensitive.
- The knowledge of the topology of a social network is insufficient to model conformity.

Diffusion Models and Conformity Theory

Aim: to better characterize online information diffusion

Classical Diffusion model (Hawkes Processes)

Extend

a. Conformity-aware Information Diffusion Model (CHASSIS)

Informational and normative conformity

Learn

Observed data

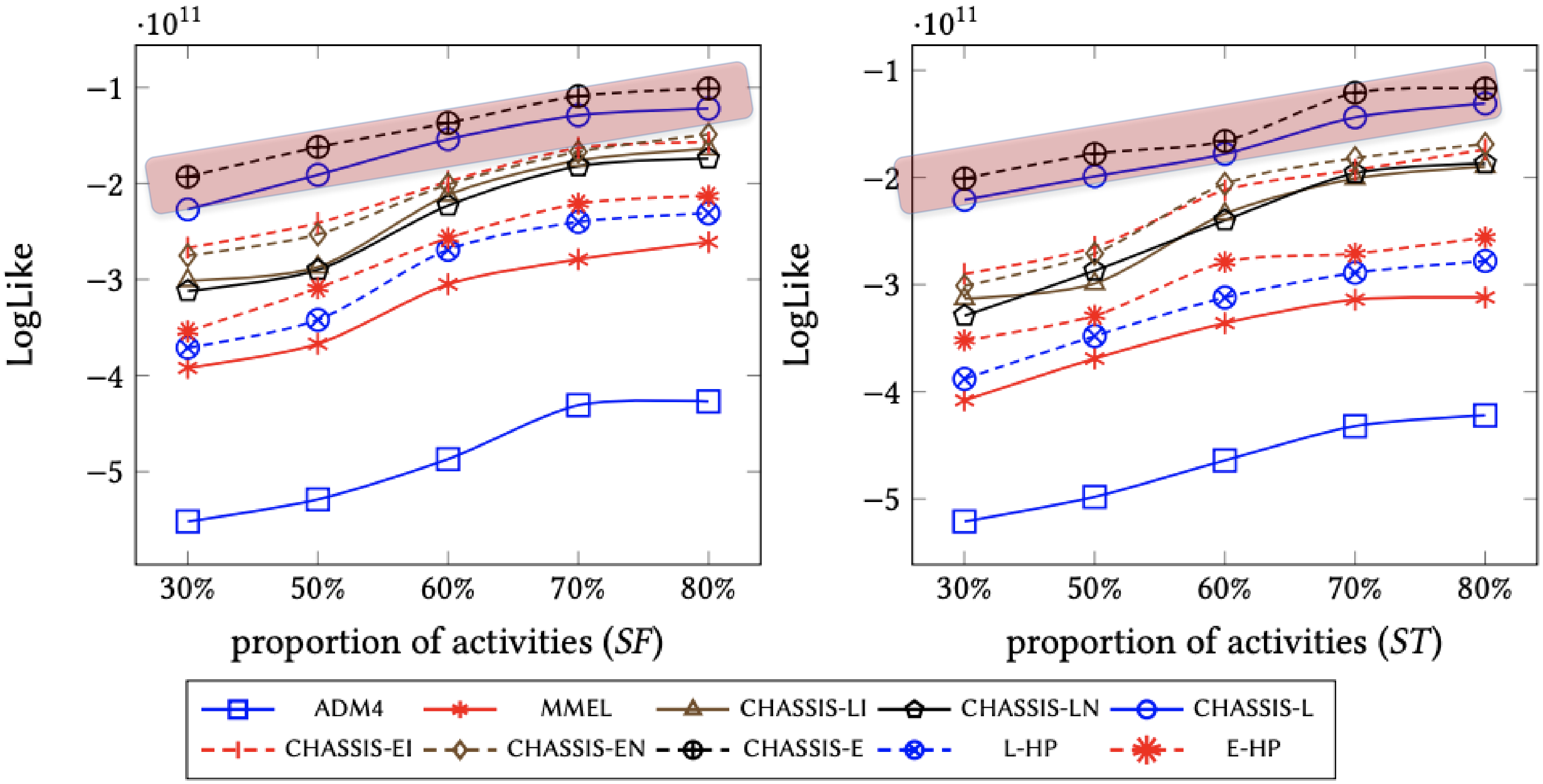
Quantify

c. Semi-parametric inference approach

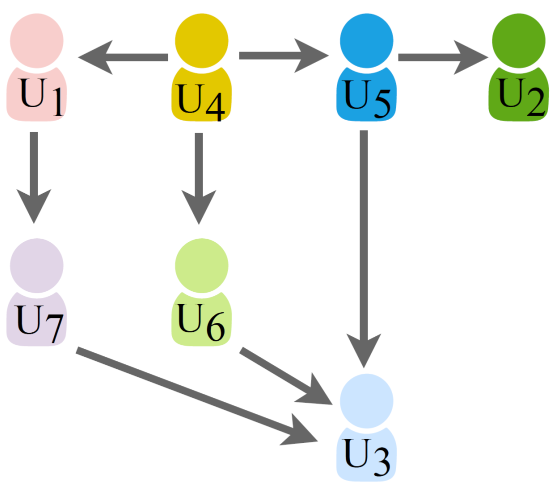
b. Diffusion Tree Inference Techniques

Li, Hui, Hui Li, and Sourav S. Bhowmick. "Chassis: Conformity meets online information diffusion." Proceedings of the 2020 ACM SIGMOD International Conference on Management of Data. 2020.

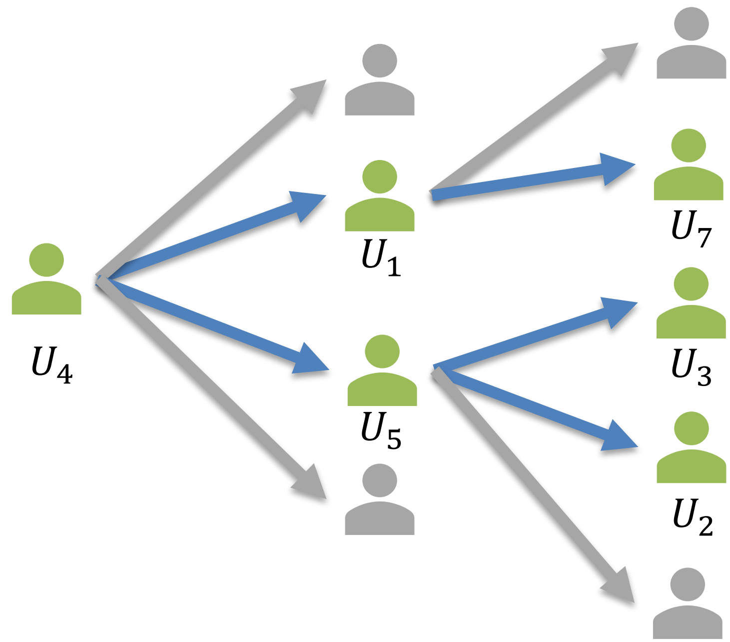
Diffusion Models and Conformity Theory



Diffusion Models and Attention Attenuation and Interference Theories



Activities on Social Networks

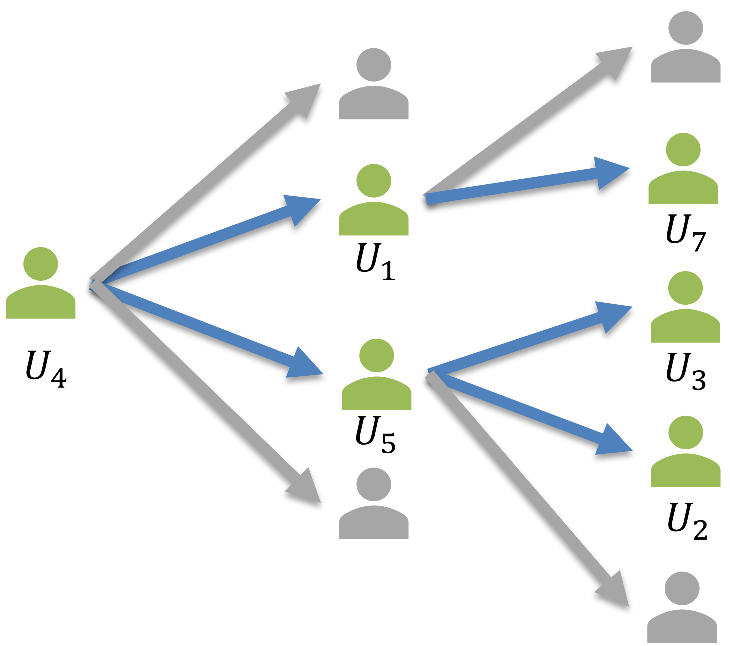


A Sample Cascade

Luo, Tianyi, et al. "A dissemination model based on psychological theories in complex social networks." IEEE Transactions on Cognitive and Developmental Systems 14.2 (2021): 519-531.

Diffusion Models and Attention Attenuation and Interference Theories

People forward and disseminate online information based on interest and attention.



Attention attenuation theory

The attention people give to the obtained information will decrease and shift over time.

Interference theory

New information increases people's resistance, hindering its spread.

Empirical Evidence

The spread of online information becomes more difficult as cascade depth increases.

Diffusion Models and Attention Attenuation and Interference Theories

LT model (Linear Threshold): each node has an **activation threshold** indicating how easily it be affected.

Inactive: influence $< \theta$

Active: influence $\geq \theta$

Constant!

X

Psychological Theories and Empirical Evidence

- The activation threshold of nodes **grows nonlinearly over time** and eventually converges to 1.
- The growth function can be **personalized**.

Diffusion Models and Attention Attenuation and Interference Theories

Resistant Linear Threshold (RLT) Dissemination Model

- Extend the classical linear threshold (LT) model
- Based on psychological theories and empirical findings

RLT Model Validation on three types of networks

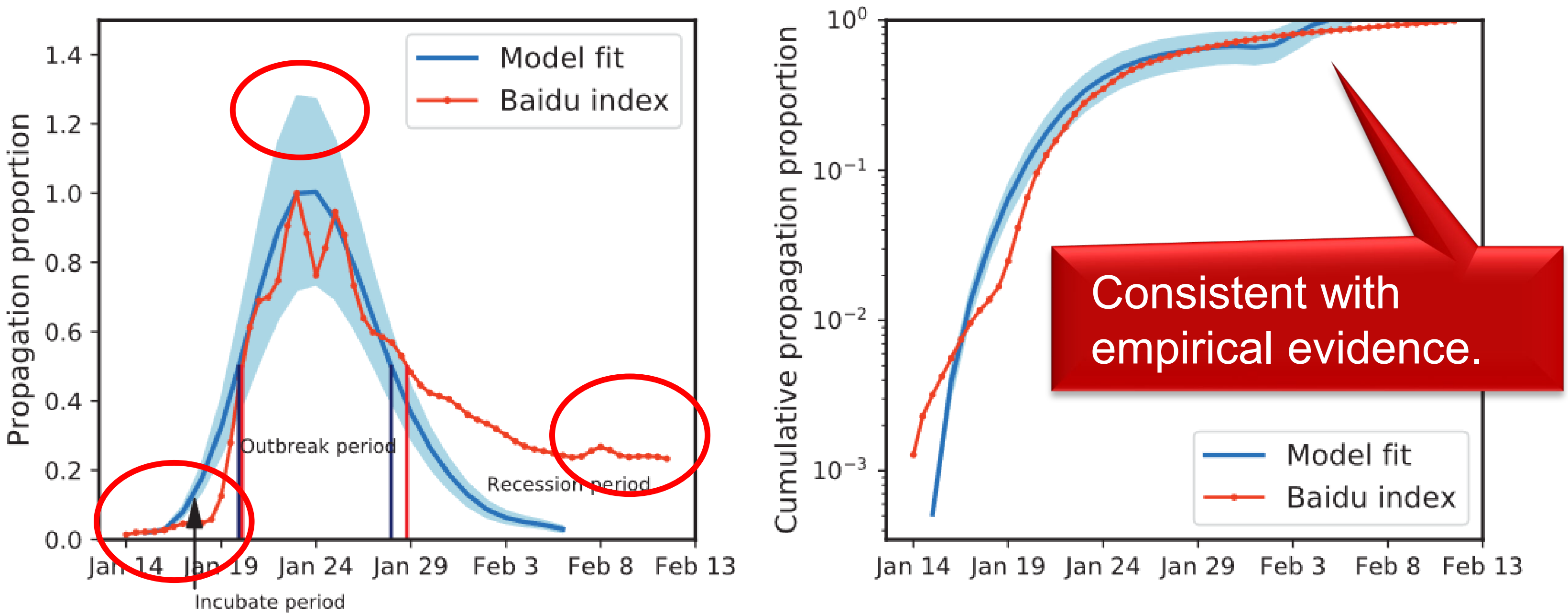
- Quantify and compare the dissemination characteristics of the simulation results with those from the empirical results

Sensitivity Analysis and Case Studies

- Explore the effect of network structure and model parameters on information dissemination
- Perform two case studies to demonstrate the effectiveness and applications of the model

Diffusion Models and Attention Attenuation and Interference Theories

Dissemination of Online Information About COVID-19



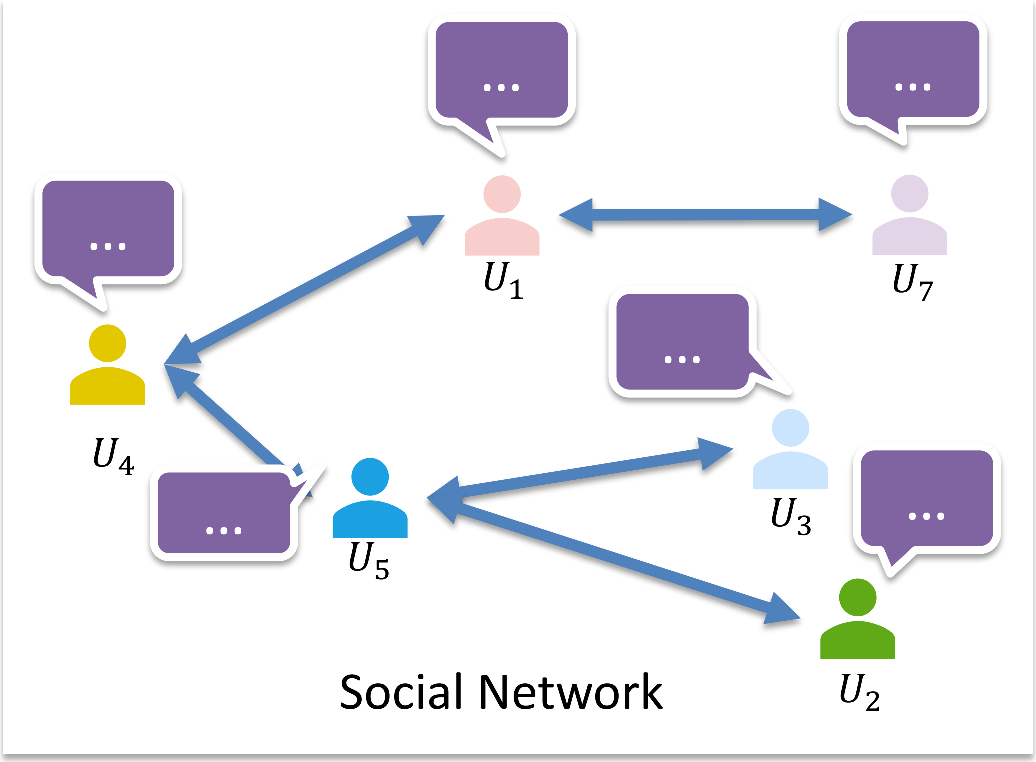
(a) (b)

Diffusion Models and Confirmation Bias

In online social networks, individuals form opinions based on three factors:

- Innate opinions
- Information from other individuals
- Information from the news sources/followed thought leaders

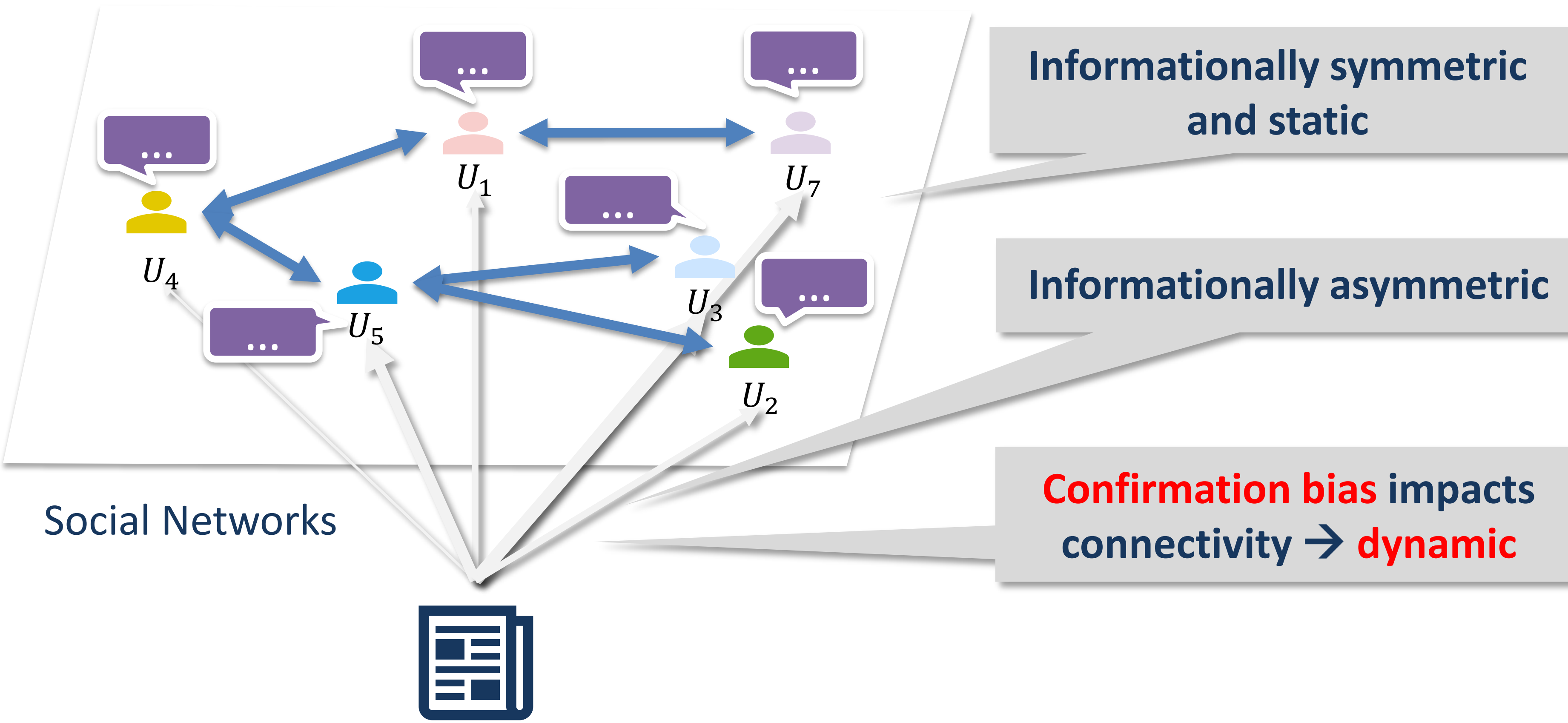
Confirmation bias



Mao, Yanbing, Sadegh Bolouki, and Emrah Akyol. "Spread of information with confirmation bias in cyber-social networks." IEEE Transactions on Network Science and Engineering 7.2 (2018): 688-700.

Diffusion Models and Confirmation Bias

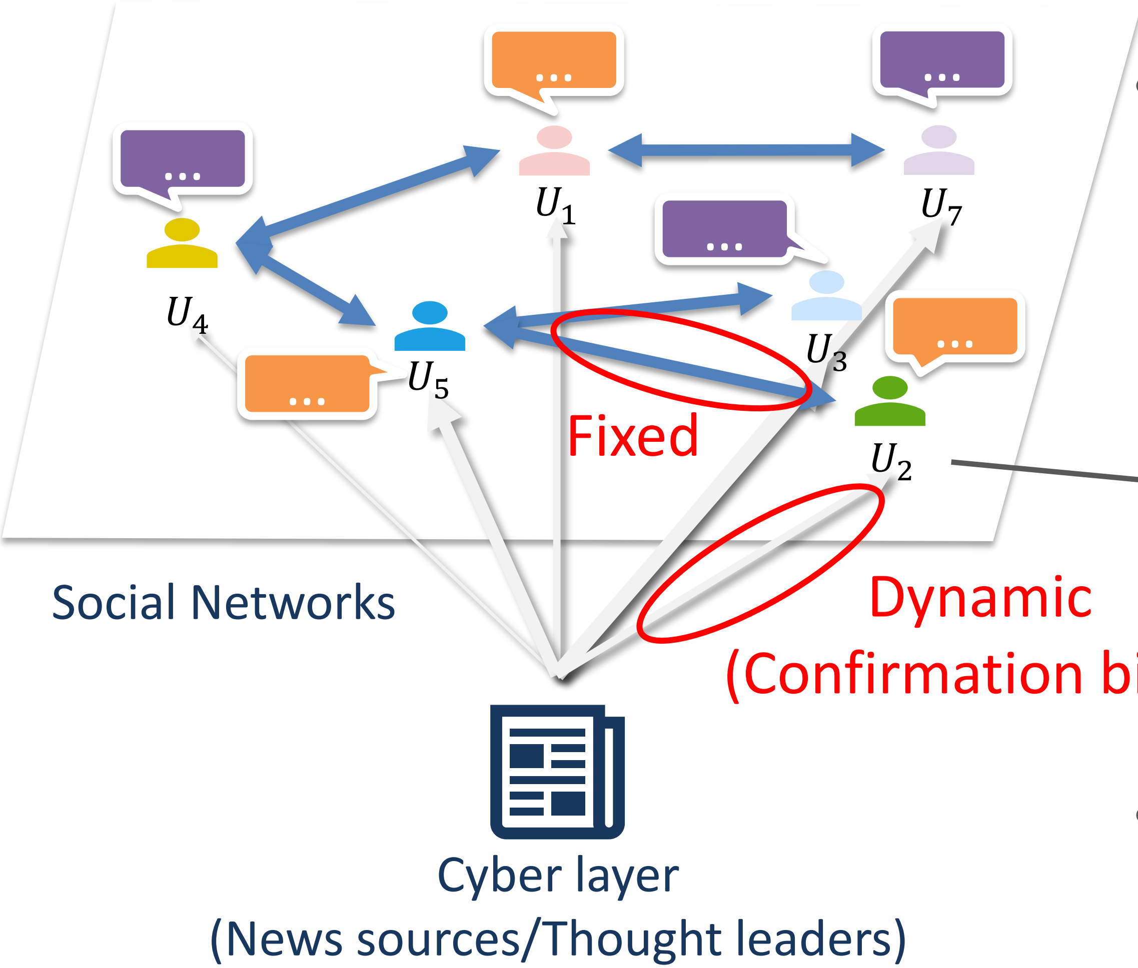
A Dynamics of Cyber-social Networks



Cyber layer
(News sources/Thought leaders)

Diffusion Models and Confirmation Bias

Features of the New Opinion Dynamics Model



- All agents converge to the consensus (same state)

  Steady-state (equilibrium)

- Individual's opinion update mechanism

- The weight of influences

Diffusion Models and Confirmation Bias

Propose a Dynamics of Cyber-social Networks

Individual's opinion update mechanism is a convex combination of three factors

Compute the Equilibrium Point of Proposed Dynamics

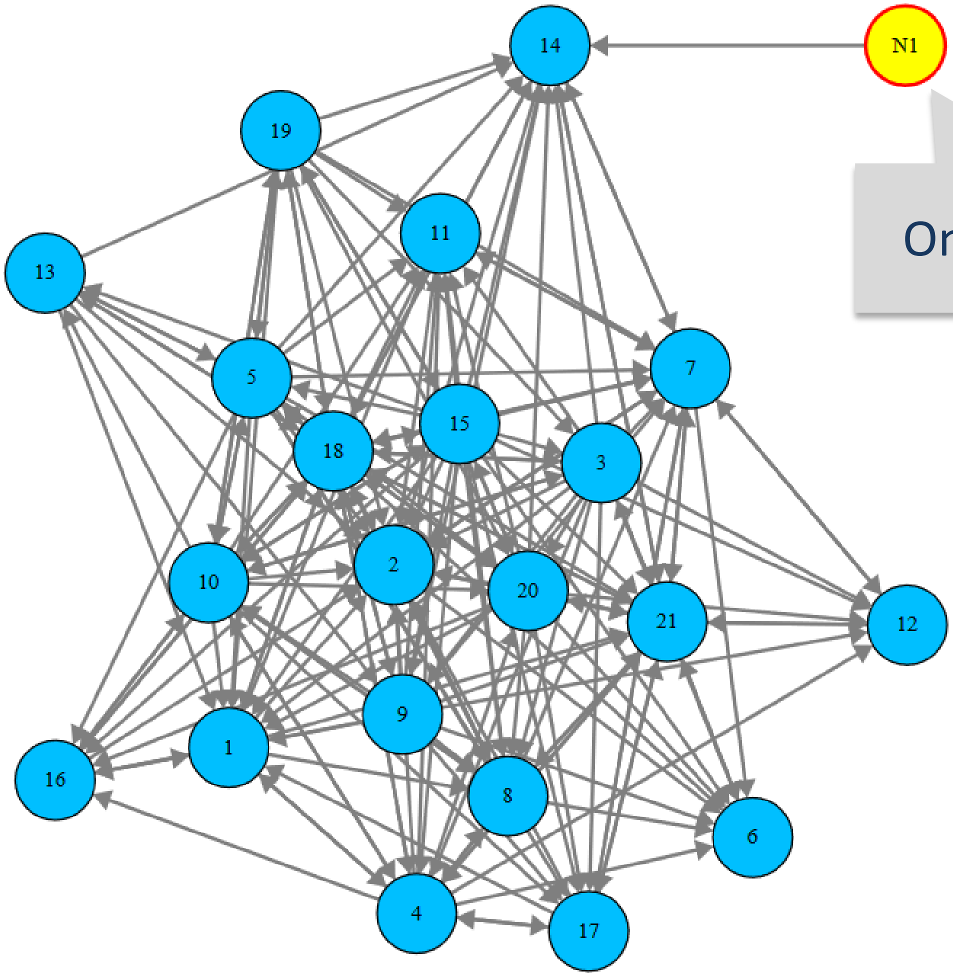
Compute the equilibrium point of the proposed dynamics under linear and nonlinear state-dependent weight functions

Analyze the Impact of News Agencies Using Proposed Dynamics

Using the proposed dynamics to study the effects of the distribution of news agencies' opinions and the distance between polarized opinions of news agencies in Krackhardt's advice network

Diffusion Models and Confirmation Bias

Distribution of News Agency's Opinions



One news agency

Diffusion Models and Confirmation Bias

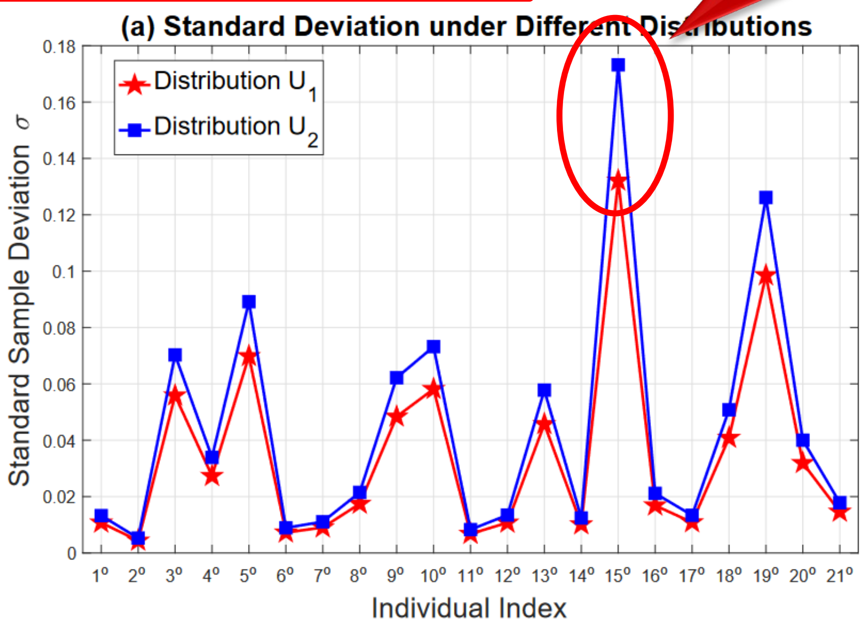
Distribution of News Agency's Opinions

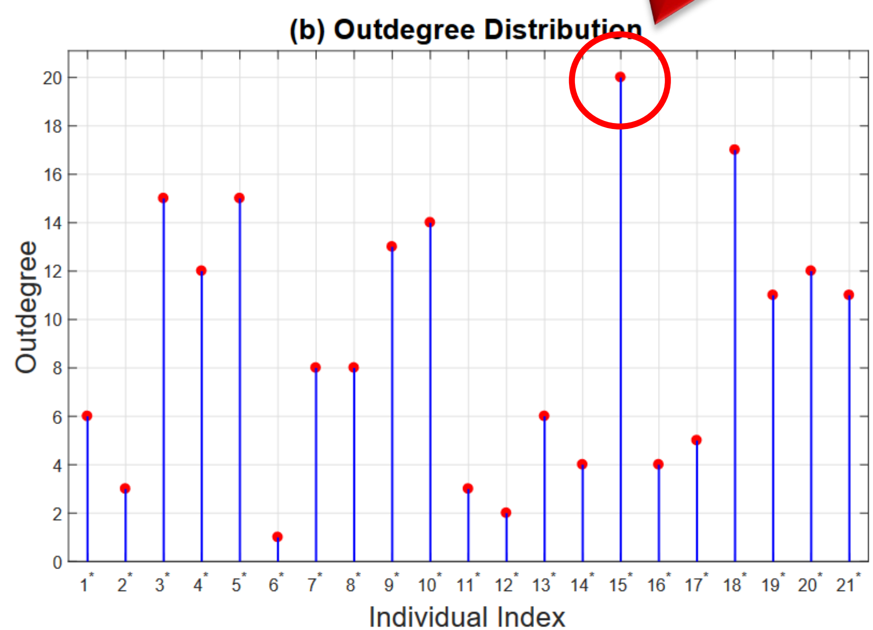
$$U_1: f(y) = \begin{cases} \frac{1}{0.8}, & y\in[0.1, 0.9] \\ 0, & otherwise \end{cases}$$

$$U_2: f(y) = \begin{cases} \frac{1}{0.4}, & y\in[0.1, 0.2]\cup[0.8,1] \\ 0, & otherwise \end{cases}$$

U2 results in bigger sample deviation than U1

News agency influence critical individual



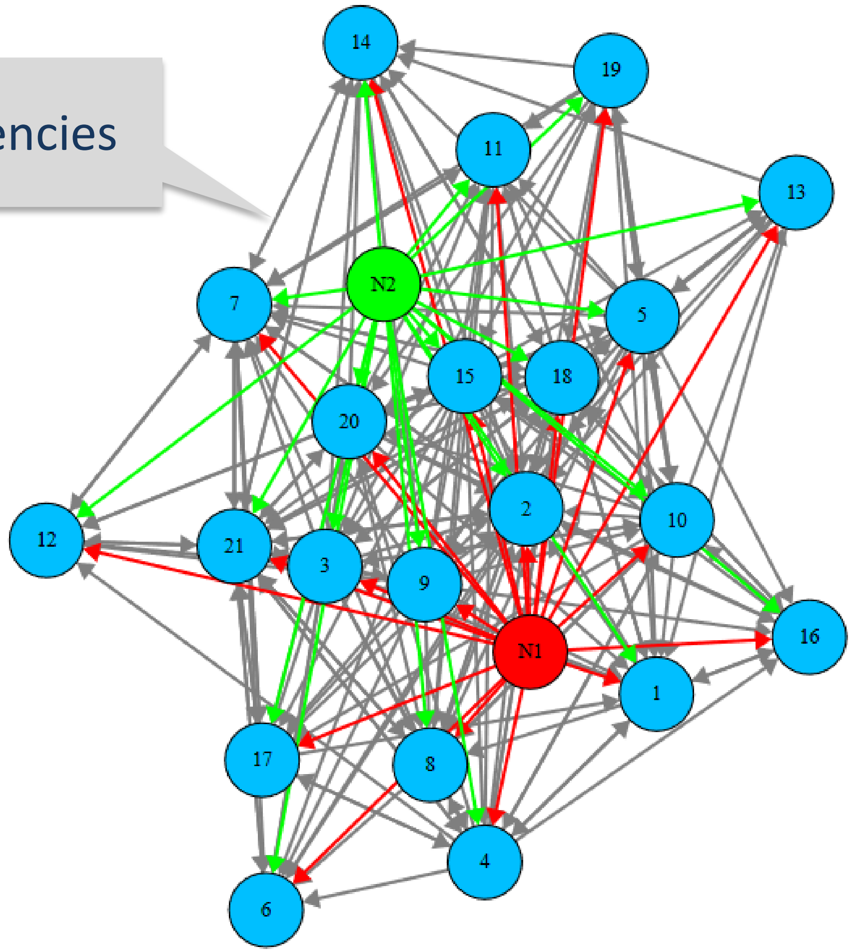


Individual index i^o: news agency N_1 influences individual i solely

Diffusion Models and Confirmation Bias

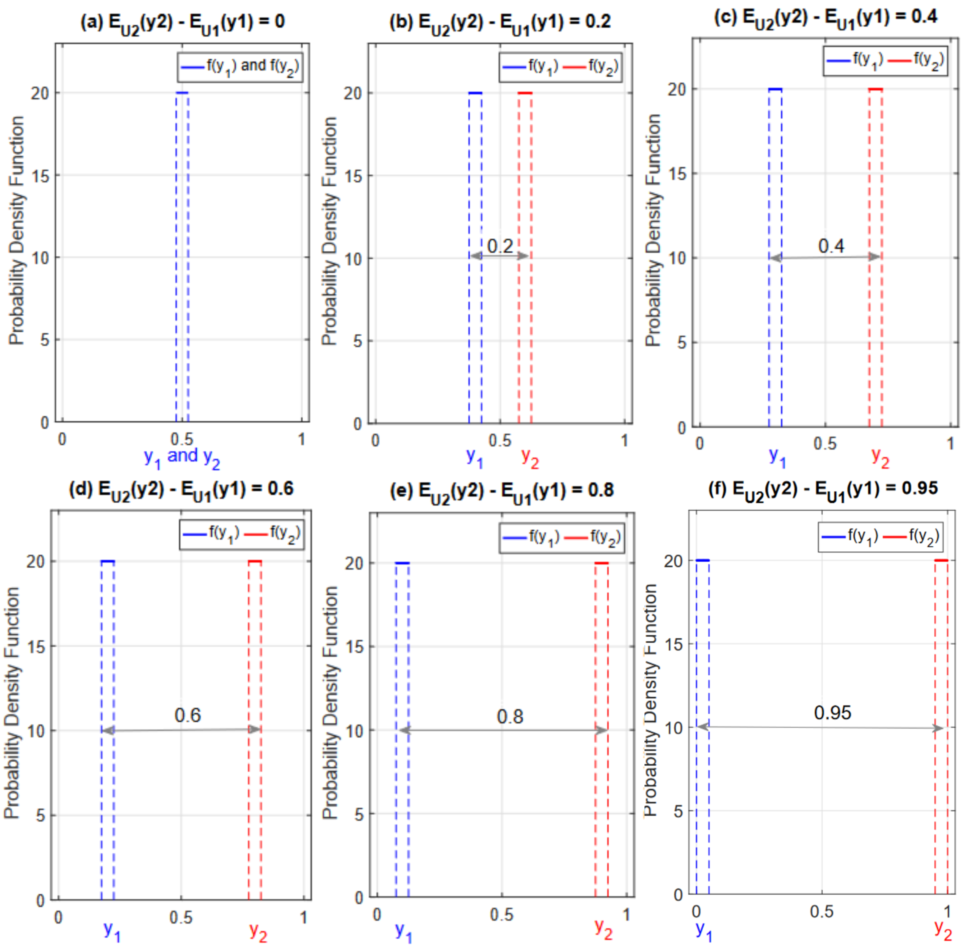
Distance Between Polar Opinions

Two news agencies



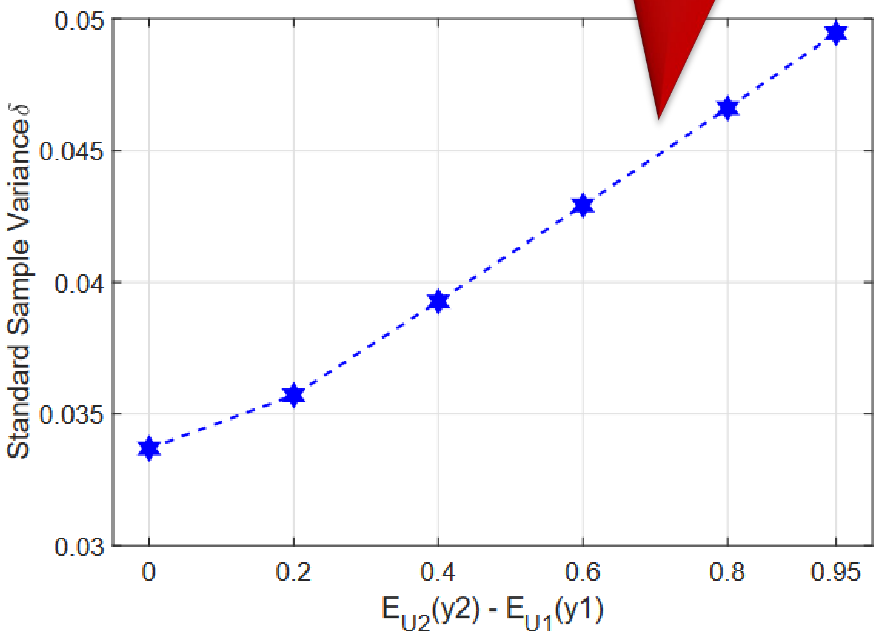
Diffusion Models and Confirmation Bias

Distance Between Polar Opinions



Six uniform distributions of N1 and N2

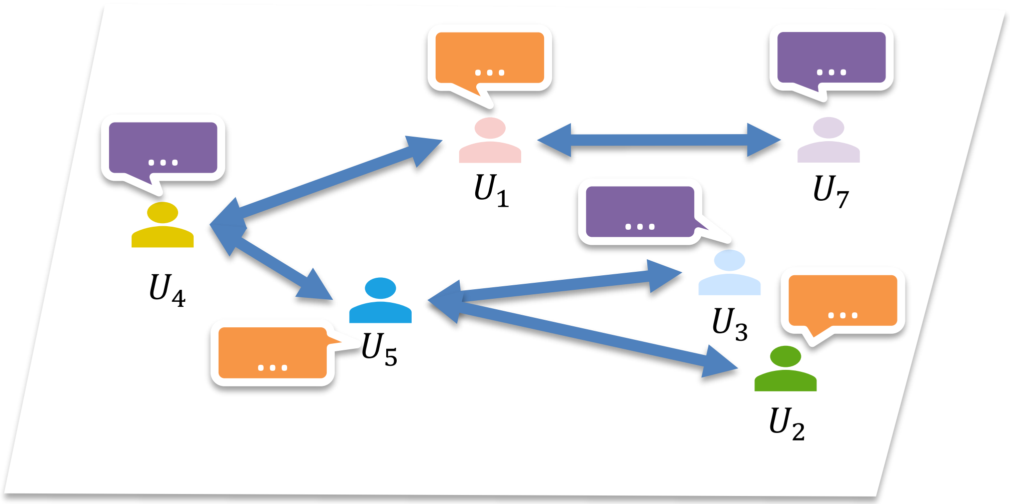
Longer distance between the means of polar opinions results in a larger sample variance



Diffusion Models and Confirmation Bias

Competitive information spread on networks

- Misinformation spread
- Political polarization



Confirmation bias (CB) helps create "echo chambers" within networks

Not considered by prior works

Mao, Yanbing, and Emrah Akyol. "Competitive information spread with confirmation bias." 2019 53rd Asilomar Conference on Signals, Systems, and Computers. IEEE, 2019.

Mao, Yanbing, Emrah Akyol, and Naira Hovakimyan. "Impact of confirmation bias on competitive information spread in social networks." *IEEE Transactions on Control of Network Systems* 8.2 (2021): 816-827.

Diffusion Models and Confirmation Bias

Adopt the Opinion Dynamics and a Linear CB Model

- Adopt the aforementioned opinion dynamics with two competitive information sources and a linear CB model

Analyze the Information Spread with Two Information Sources

- The problem is formulated as a zero-sum game
- This game admits a unique Nash equilibrium which is in pure strategies

Study the Impact of CB on the Nash Equilibrium

- Analyze how the equilibrium-achieving strategies depend on the the innate opinions of the public , network topology parameters, and the CB parameters

Diffusion Models and Confirmation Bias

Opinion Dynamics and the Linear CB Model

$$x_i(k+1) = \underbrace{\alpha_i\big(x_i(k)\big)s_i}_{\text{Innate opinion}} + \underbrace{\sum_{j\in V} w_{ij}x_j(k)}_{\text{Influence from other individuals}} + \underbrace{\overline{w_i}\big(x_i(k)\big){\color{red}h} + \underline{w_i}\big(x_i(k)\big){\color{red}g}}_{\text{Information from two information sources}}, i \in V$$

- $x_i(k) \in [0, 1]$: individual v_i's opinion at time k
- $s_i \in [0,1]$: individual v_i's innate opinion
  - Extreme innate opinions: $\bar{s} \triangleq \max_{i\in V}\{s_i\}, \underline{s} \triangleq \min_{i\in V}\{s_i\}$
- w_{ij}: the influence of individual v_j on v_i

Diffusion Models and Confirmation Bias

Opinion Dynamics and the Linear CB Model

$$x_i(k+1) = \underbrace{\alpha_i(x_i(k))s_i}_{\text{Innate opinion}} + \underbrace{\sum_{j\in V} w_{ij}x_j(k)}_{\text{Influence from other individuals}} + \underbrace{\overline{w_i}(x_i(k))h + \underline{w_i}(x_i(k))g}_{\text{Information from two information sources}}, i \in V$$

- h, g: opinions of competitive information sources
  - $0 \leq g \leq \underline{s} \leq \bar{s} \leq h \leq 1$

Aim

Move the public opinions to the two extremes they present

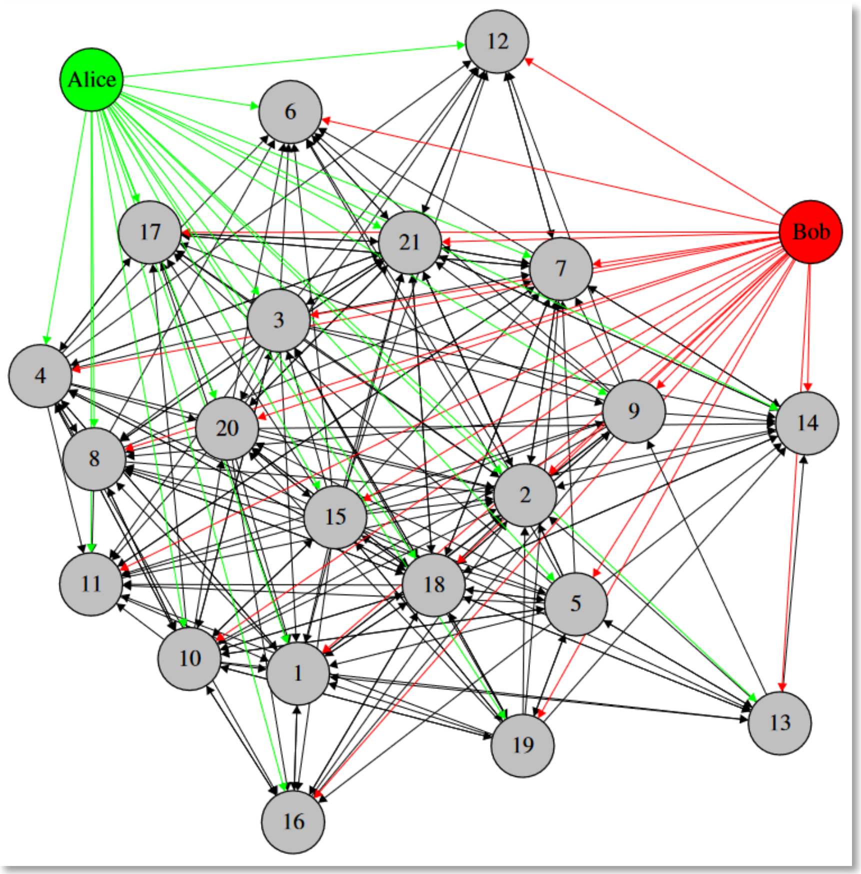
- $\overline{w_i}(x_i(k)), \underline{w_i}(x_i(k))$: state-dependent influence weights on individual v_i
  - $\overline{w_i}(x_i(k)) = \beta - \gamma|x_i(k) - h|$
  - $\underline{w_i}(x_i(k)) = \beta - \gamma|x_i(k) - g|$

Linear CB Models

$\beta, \gamma \in R$: bias parameters

Diffusion Models and Confirmation Bias

Zero-sum Game Problem Formulation



$$\left.\begin{array}{r}\text{Alice } (g \in [0, \underline{s}]) \\ \text{Bob } (h \in [\overline{s}, 1])\end{array}\right\}$$ Competitive Information Sources

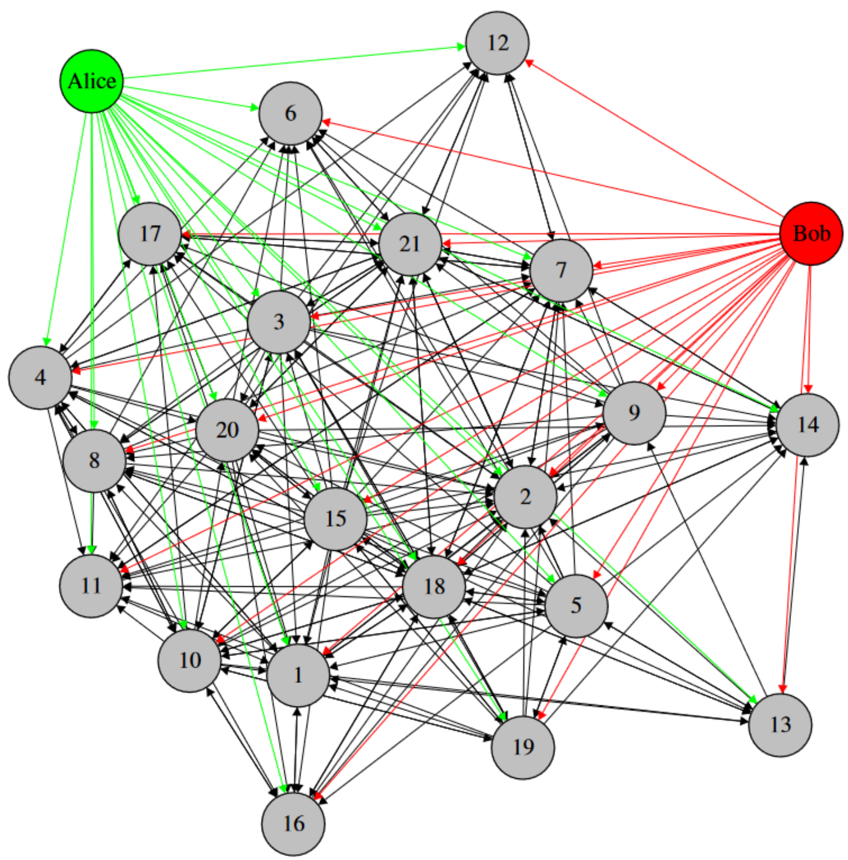
Cost function $f(g, h)$:

- Alice's objective is to maximize $f(g, h)$
- Bob's objective is to minimize $f(g, h)$

Nash equilibrium: a state that gives Alice and Bob no incentive to deviate from their initial strategy.

Diffusion Models and Confirmation Bias

Nash Equilibrium without CB: $\gamma = 0$

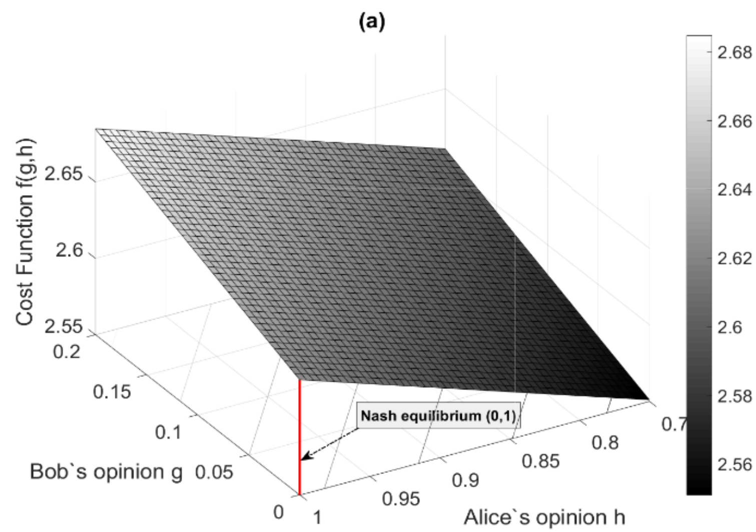


Innate opinions

- $s_1 = s_2 = 0.2$
- Others: $s_i = 0.75$

$\beta = 0.06,$
$\gamma = 0$

The Nash equilibrium is $(g^*, h^*) = (0, 1)$



Diffusion Models and Confirmation Bias

Nash Equilibrium with CB: $\gamma \neq 0$

Innate opinions

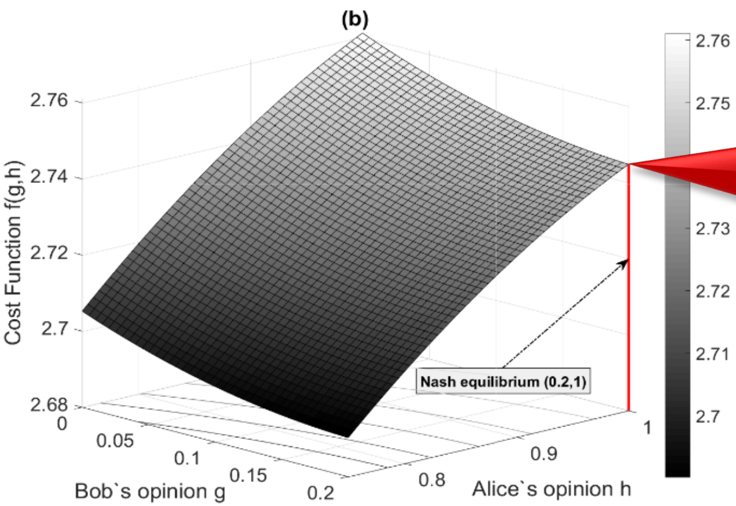
- $s_1 = s_2 = 0.2$
- Others: $s_i = 0.75$

$\beta = \gamma = 0.06$

$\underline{s} = 0.2, \overline{s} = 0.75, \hat{s} = 0.7256$

$\hat{s}$: the average of innate opinions

The Nash equilibrium is $(\boldsymbol{g}^*, \boldsymbol{h}^*) = (\underline{\boldsymbol{s}}, \mathbf{1}) = (\mathbf{0.2}, \mathbf{1})$

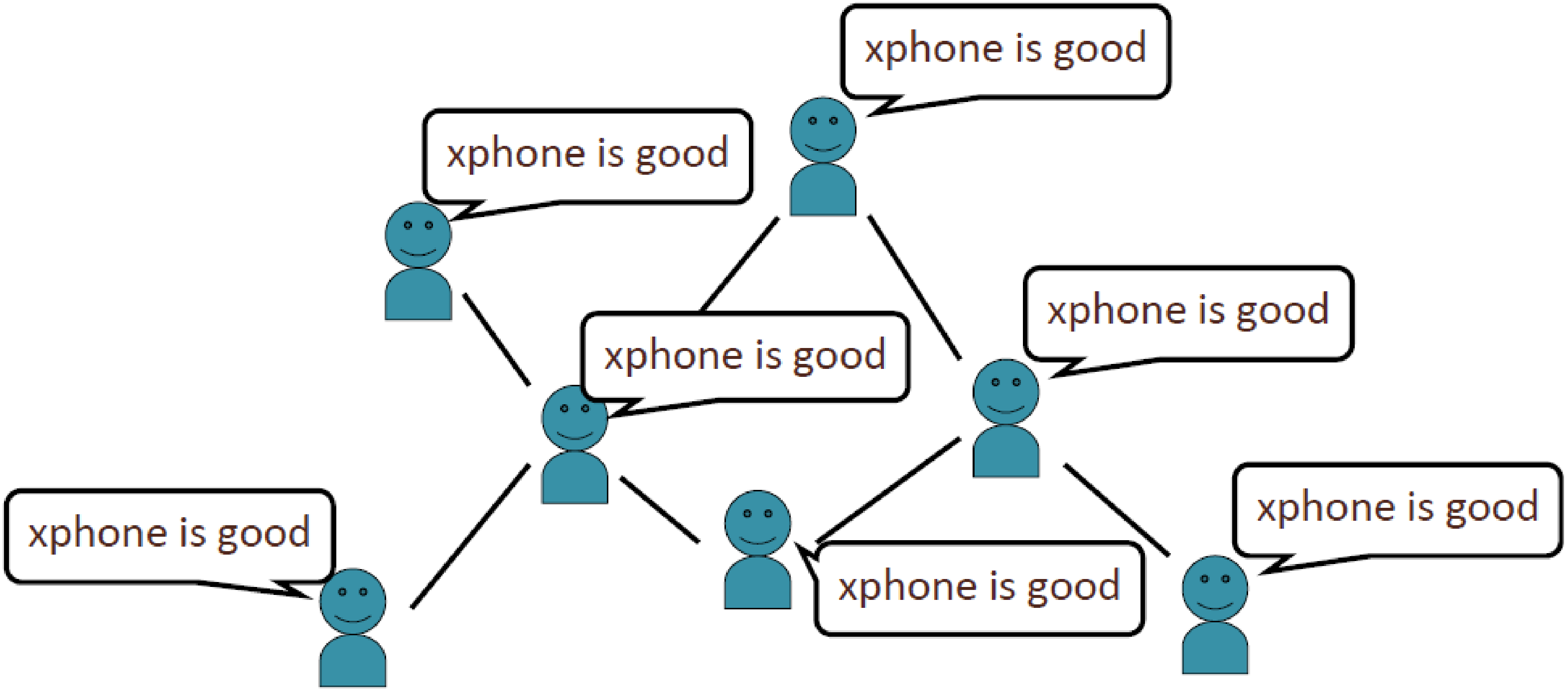


CB moves the Nash equilibrium toward the center only when the innate opinions are not neutral, and this move occurs for only one of the information sources.

Next..

- Psychology theory-informed design
- Background on psychology theories
- Psychology theory-informed design of diffusion models
- Psychology theory-informed design of social influence
- Future directions

Ideal Influence Propagation



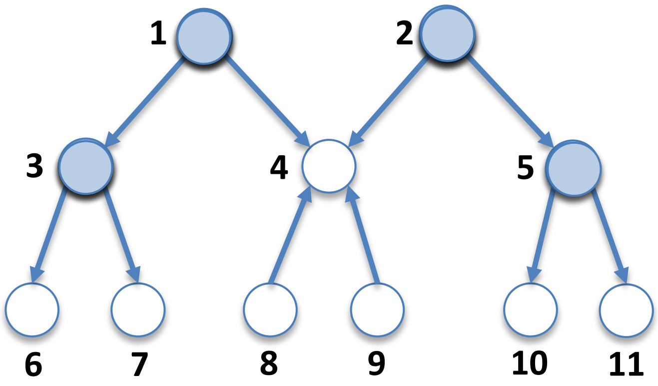
Word-of-Mouth Effect: The information propagation process iterates through friends-of-friends and reaches a large population in the end

H. Li, S. S. Bhowmick, A. Sun. 2013. CINEMA: conformity-aware greedy algorithm for influence maximization in online social networks.
H. Li, S. S. Bhowmick, A. Sun, J. Cui. 2015. Conformity-aware influence maximization in online social networks.

Social Influence Estimation

Influence Function

- Influence function of a seed set S, denoted as σ(S), is the expected number of users influenced by S.
- For a node $v \notin S$, $\sigma(S \cup \{v\}) - \sigma(S)$ is the marginal influence of v with respect to S.



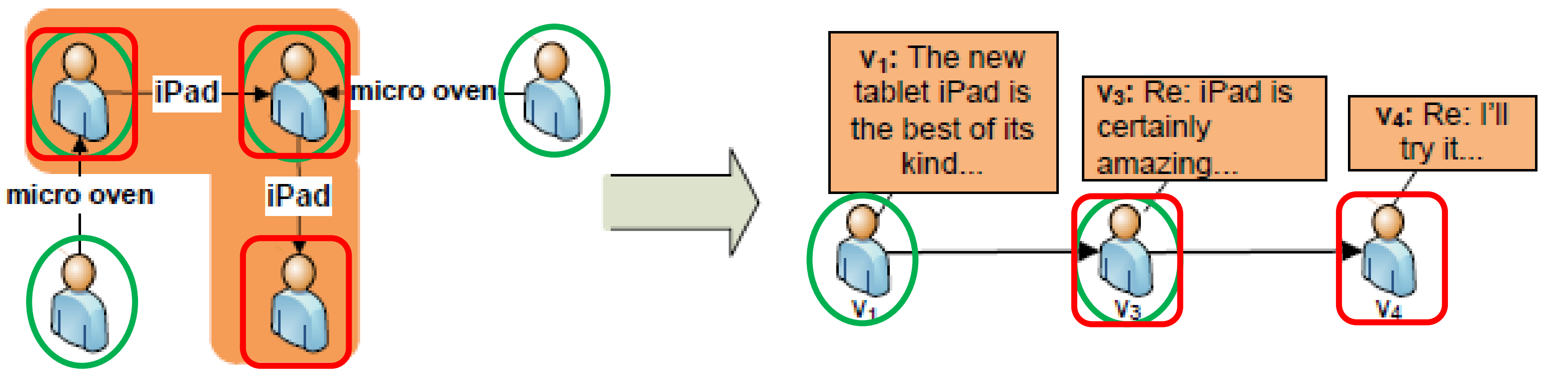
The graph is a simple social network with all weights equal to 1.

Seed	Influenced nodes	σ(S)
v1	v1, v3, v4, v6, v7	5
v1, v2	v1, v2, v3, v4, v5, v6, v7, v10, v11	9

H. Li, S. Yang, M. Xu, S. S. Bhowmick, J. Cui. 2023. Influence Maximization in Social Networks: A Survey.

Psychology-informed Social Influence Propagation

There are different roles in influence propagation.



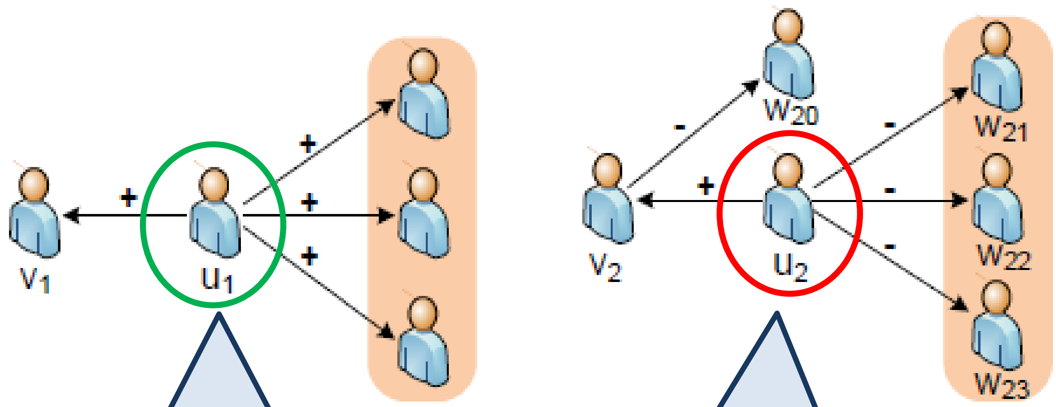
- **Influencer** (individual who is influencing others) → influence $\Phi(u)$

- **Influencee** (individual who is influenced by others) → conformity $\Omega(u)$

H. Li, S. S. Bhowmick, and A. Sun. 2011. "Casino: towards conformity-aware social influence analysis in online social networks.

Psychology-informed Social Influence Propagation

Different person may show different persona during the conversation with others.



- **Easily influenced**: mostly conform to the others' opinions

- **Hardly influenced**: mostly show opposite opinions

H. Li, S. S. Bhowmick, and A. Sun. 2011. "Casino: towards conformity-aware social influence analysis in online social networks.

Psychology-informed Social Influence Estimation

$Prob[u \to v]$ could be affected by *Φ(u)* and *Ω(v)*. However, some research mainly focus on *Φ(u)*.

Existing work may not exhibit satisfactory result with respect to influence and conformity.

How to quantify the different persona of different person? → Conformity.

H. Li, S. S. Bhowmick, and A. Sun. 2011. Casino: towards conformity-aware social influence analysis in online social networks.

Overview of Modeling Conformity Theory

Social Influence Estimation

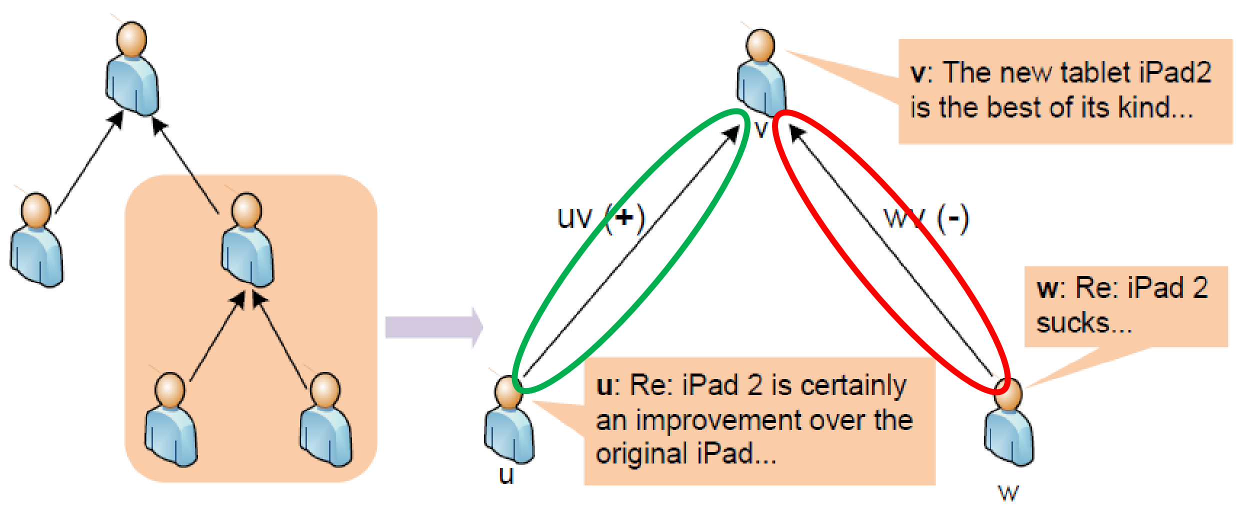
- Quantify the influence w.r.t. the *conformity* of each individual
- Distinguish and quantify the effects of the *different types of conformities*.

Influence Maximization

- Leverage *conformity* in computing the propagation probabilities of nodes
- Incorporate *friend conformity and group conformity* in group-based IM task

Conformity-aware Social Influence Estimation - *CASINO*

Signed Network: An edge representing trust relationship is labeled as positive, otherwise negative. And G(V, E) can be represented using a pair of graphs $G^+(V, E^+)$ and $G^-(V, E^-)$.



H. Li, S. S. Bhowmick, and A. Sun. 2011. "Casino: towards conformity-aware social influence analysis in online social networks.

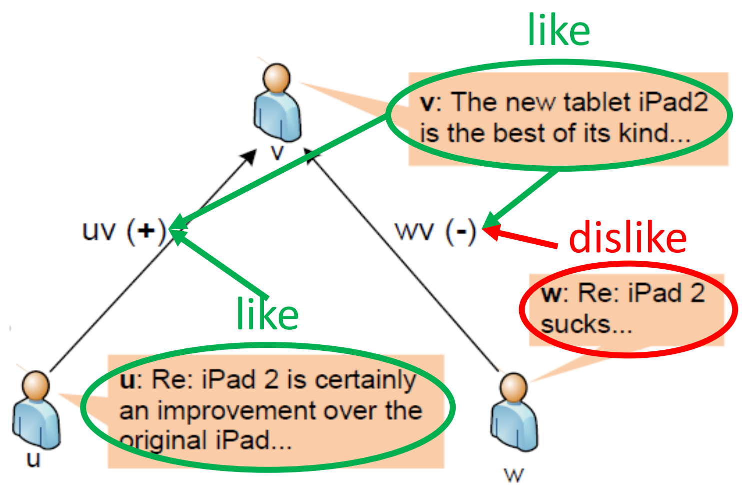
Conformity-aware Social Influence Estimation - *CASINO*

Edge Labeling

- Social networks may provide edge signs (i.e., Epinions) or not (i.e., Blog)
- Sentiment based analysis using LingPipe (e.g., Twitter)
- Sentiments: dislike, somewhat dislike, neutral, somewhat like, like

Signed Network

- Positive/negative: sentiments at both ends are similar?
- Similar: sentiment similarity threshold is less than ε



H. Li, S. S. Bhowmick, and A. Sun. 2011. "Casino: towards conformity-aware social influence analysis in online social networks.

Conformity-aware Social Influence Estimation - *CASINO*

Basic intuitions
Number of conforming followers → high influence Number of conformed people → high conformity

Considering negative edges
Number of negative followers → low influence Number of negative following → low conformity

Investigate the mutual effect between them

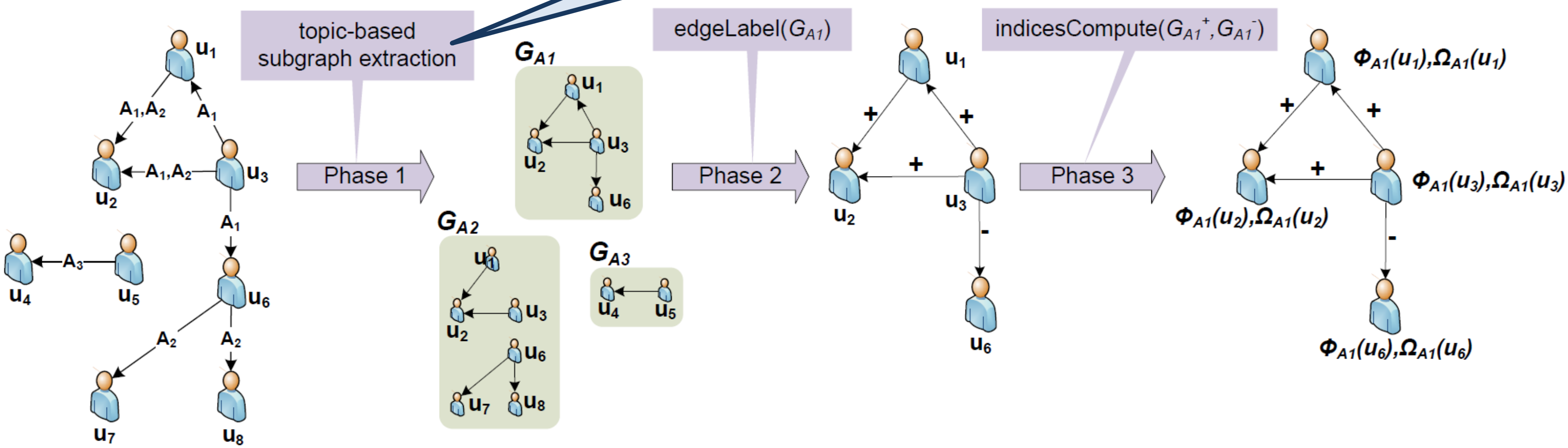
- **Influence and conformity Indices:**
  - $\Phi(v) = \sum_{\overrightarrow{uv} \in E^+} \Omega(u) - \sum_{\overrightarrow{uv} \in E^-} \Omega(u)$
  - $\Omega(u) = \sum_{\overrightarrow{uv} \in E^+} \Phi(v) - \sum_{\overrightarrow{uv} \in E^-} \Phi(v)$

H. Li, S. S. Bhowmick, and A. Sun. 2011. "Casino: towards conformity-aware social influence analysis in online social networks.

Conformity-aware Social Influence Estimation - *CASINO*

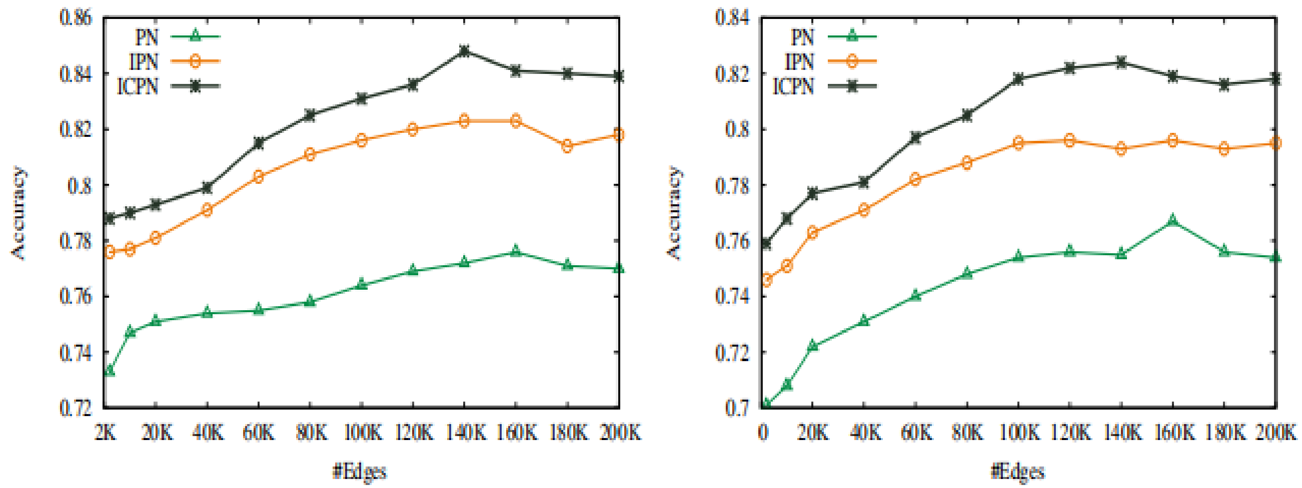
Complete indices calculation process!

- A node's influence in one component is not significantly affected by nodes in other components.



H. Li, S. S. Bhowmick, and A. Sun. 2011. "Casino: towards conformity-aware social influence analysis in online social networks.

Conformity-aware Social Influence Estimation - *CASINO*



(a) Epinions (b) Slashdot

I: influence
C: conformity
P: positive
N: negative

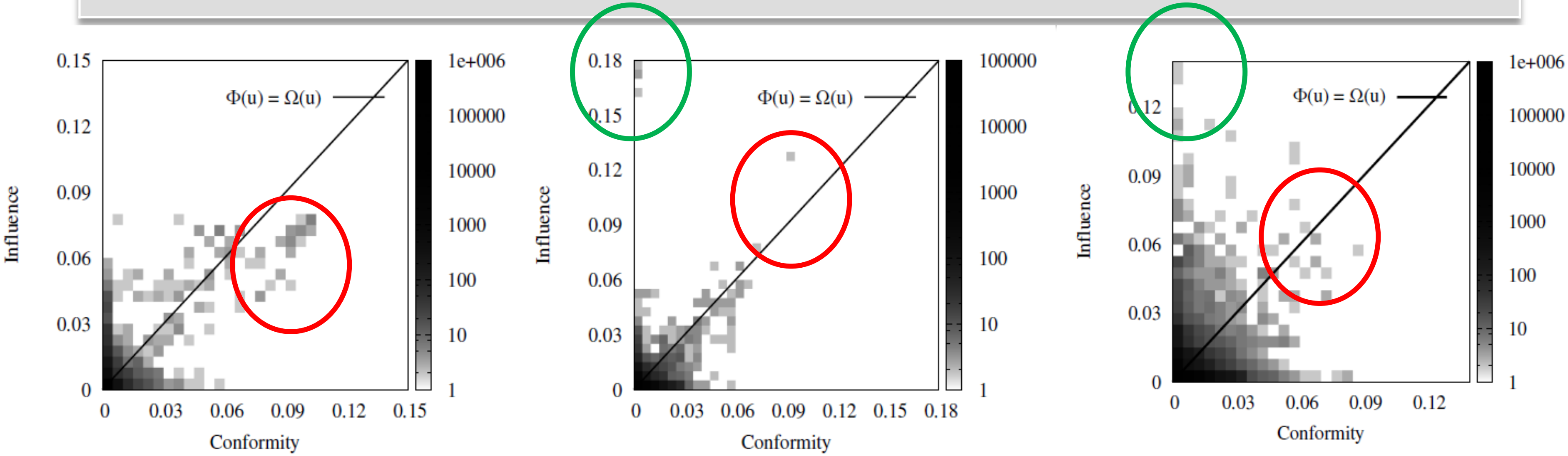
Signed edge prediction: ICPN > IPN > PN

- Considering influence of nodes improves prediction accuracy.
- Considering both influence and conformity further improves the accuracy.

H. Li, S. S. Bhowmick, and A. Sun. 2011. “Casino: towards conformity-aware social influence analysis in online social networks.

Conformity-aware Social Influence Estimation - *CASINO*

- The most influential nodes hardly conform to others in Twitter and Slashdot.

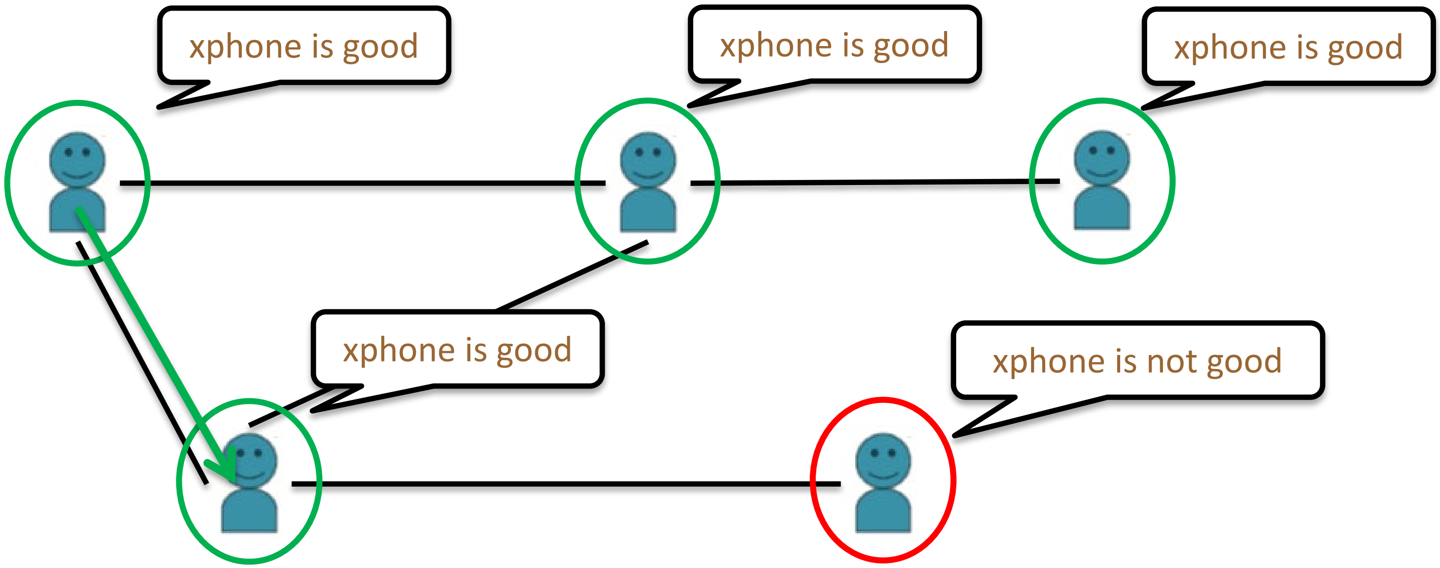


(a) Epinions (b) Slashdot (d) Twitter (All)

- The most conforming nodes also influence others (in all the three networks).

H. Li, S. S. Bhowmick, and A. Sun. 2011. "Casino: towards conformity-aware social influence analysis in online social networks.

Conformity-aware Social Influence Estimation - *Confluence*



Conformity → individual conformity
→ peer conformity
→ group conformity

J. Tang, S. Wu, J. Sun. 2013. Confluence: conformity influence in large social networks.

Conformity-aware Social Influence Estimation - *Confluence*

Conformity → individual conformity / peer conformity / group conformity

how easily user v's behavior conforms to her friends

A specific action performed by user v at time t

(a, v_i, t): user v_i performed action a ∈ A (A: action history) at time t

ε is a threshold of difference between the time when the two users v and v' performed the same action a

Exists a friend v' who performed the same action at time t'

$$icf(v) = \frac{|(a, v, t) \in A_v | \exists (a, v', t') : e_{vv'} \in E \wedge \epsilon \geq t - t' \geq 0|}{|A_v|}$$

All actions by user v

J. Tang, S. Wu, J. Sun. 2013. Confluence: conformity influence in large social networks.

Conformity-aware Social Influence Estimation - *Confluence*

Conformity → individual conformity, peer conformity, group conformity

how likely the user v's behavior is influenced by one particular friend v'

A specific action performed by user v' at time t'

User v follows v' to perform the action a at time t

$$pcf(v, v') = \frac{|(a, v', t') \in A_{v'} | \exists (a, v, t) : e_{vv'} \in E \wedge \epsilon \geq t - t' \geq 0|}{|A_{v'}|}$$

All actions by user v'

J. Tang, S. Wu, J. Sun. 2013. Confluence: conformity influence in large social networks.

Conformity-aware Social Influence Estimation - *Confluence*

Conformity → individual conformity → peer conformity → group conformity

conformity of user v's behavior to groups that the user belongs to

τ-group action: an action performed by more than a percentage τ of all users in the group C_k

A specific τ-group action

User v conforms to the group to perform the action a at time t

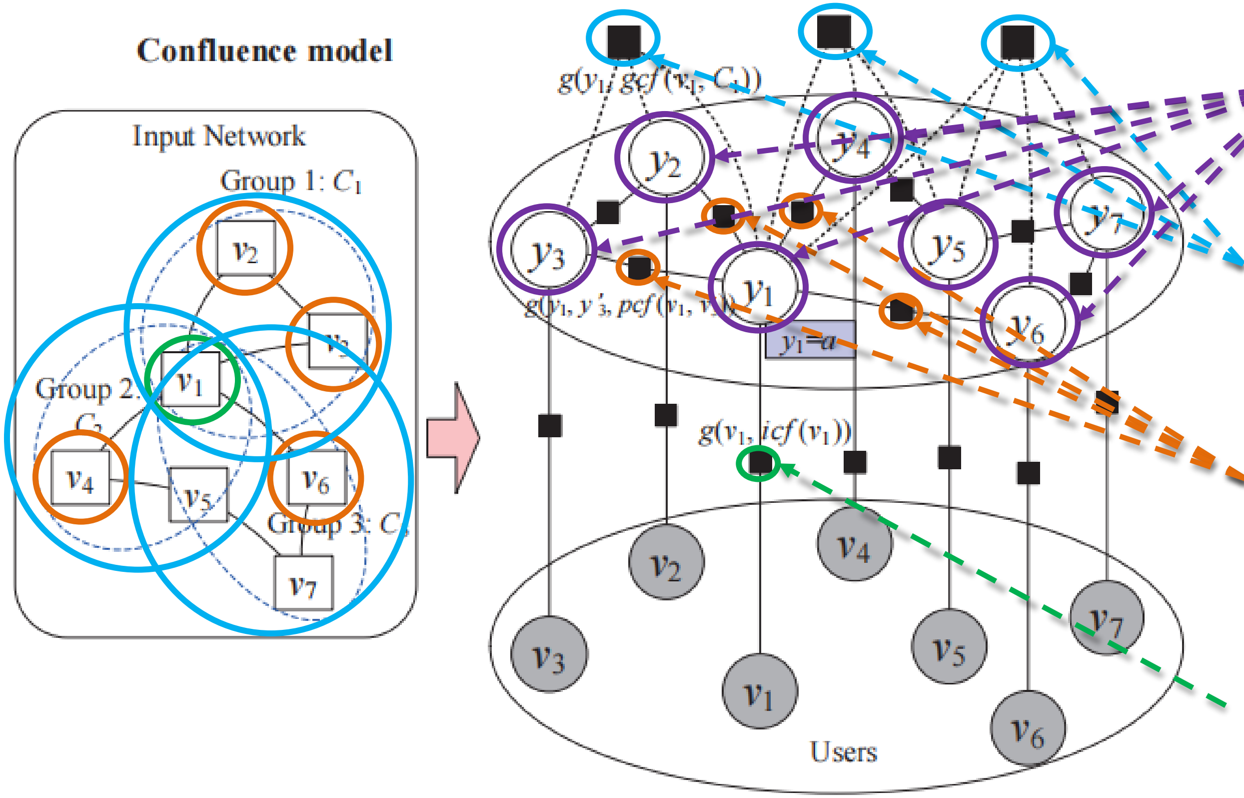
$$gcf^{\tau}(v, C_{vk}) = \frac{|(a, v', t') \in A^{\tau}_{C_k} \exists (a, v, t) : \mathbb{I}[c_{ik}] \wedge \epsilon \geq t - t' \geq 0|}{|A^{\tau}_{C_k}|}$$

All τ-group actions performed by users in the group C_k

J. Tang, S. Wu, J. Sun. 2013. Confluence: conformity influence in large social networks.

Conformity-aware Social Influence Estimation - *Confluence*

Graphical representation of the Confluence model!



Random variable y: Action

Group conformity factor three groups for v1 $g(v_1, gcf(v_1, C_?))$

Peer conformity factor four peers for v1 $g(y_1, y_?, pcf(v_1, v_?))$

Individual conformity factor one for each user $g(v_1, icf(v_1))$

J. Tang, S. Wu, J. Sun. 2013. Confluence: conformity influence in large social networks.

Conformity-aware Social Influence Estimation - *Confluence*

By integrating all the factor functions together, and according to the Hammersley-Clifford theorem, it can obtain the following log-likelihood objective function.

$$
\begin{aligned}
\mathcal{O}(\theta) &= \log P_\theta(Y|G,A) \\
&= \sum_{i=1}^{N}\left[\sum_{j=1}^{d} \alpha_j f(y_i, x_{ij}) + \beta_i g(y_i, icf(v_i))\right] \\
&\quad + \sum_{e_{ij}\in E} \mathbb{I}[y'] \gamma_{ij} g(y_i, y'_j, pcf(v_i, v_j)) \\
&\quad + \sum_{i=1}^{N}\sum_{k=1}^{m} \mathbb{I}[c_{ik}] \mu_{ik} g(y_i, gcf(v_i, C_k)) - \log Z
\end{aligned}
$$

capture the correlation between the user's attribute x_{ij}(the j-th attribute of user v_i) and user's action

$$g(y_i, icf(v_i)) = \frac{\sum_{k=1}^{|A_{v_i}|} (\frac{1}{2})^{\frac{t-t'}{\lambda}} \mathbb{I}[y'_j \wedge e_{ij} \in E]}{|A_v|}$$

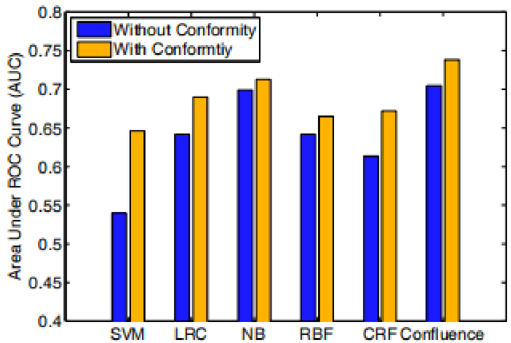
$$g(y_i, y'_j, pcf(v_i, v_j)) = (\frac{1}{2})^{\frac{t-t'}{\lambda}} pcf(v_i, v_j)$$

$$g(y_i, y'_j, pcf(v_i, v_j)) = (\frac{1}{2})^{\frac{t-t'}{\lambda}} pcf(v_i, v_j)$$

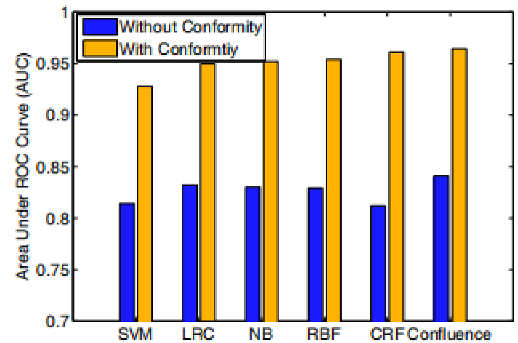
θ = ({α}, {β}, {γ}, {μ}) is a parameter configuration estimated from the training data (i.e., historic users' actions). It can quantify the importance of the different types of conformities for each user.

J. Tang, S. Wu, J. Sun. 2013. Confluence: conformity influence in large social networks.

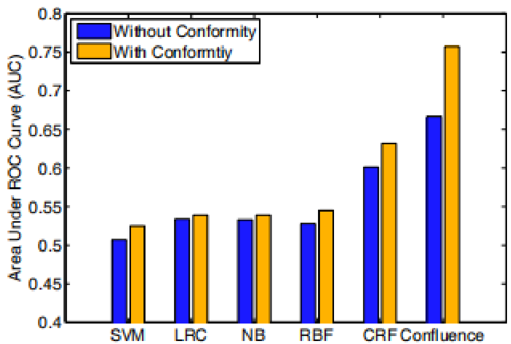
Conformity-aware Social Influence Estimation - *Confluence*



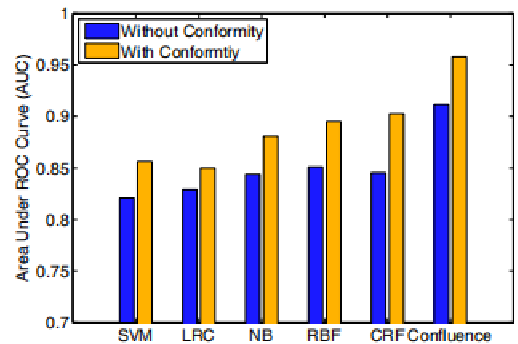
(a) Flickr



(b) Gowalla



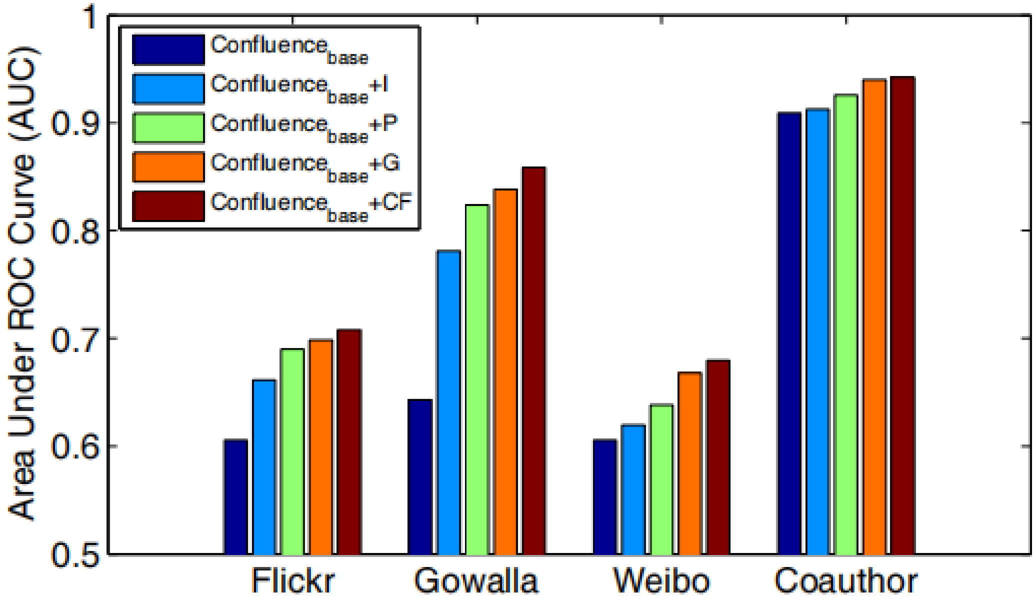
(c) Weibo



(d) Co-Author

J. Tang, S. Wu, J. Sun. 2013. Confluence: conformity influence in large social networks.

Conformity-aware Social Influence Estimation - *Confluence*



- **$\text{Confluence}_{\text{base}}$: Confluence method without any social based features**
- **I: individual conformity**
- **P: peer conformity**
- **G: group conformity**
- **CF: conformity features**

Effects of different levels of conformities:

- Without the conformity based factors, the prediction performance drop significantly.
- The group conformity is more important than the other types.

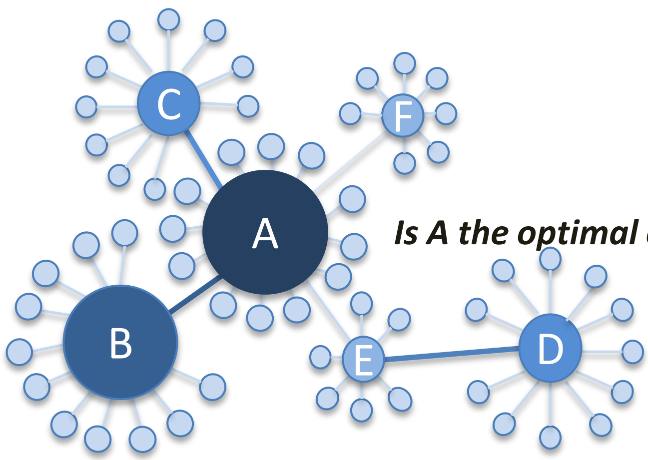
J. Tang, S. Wu, J. Sun. 2013. Confluence: conformity influence in large social networks.

From Social Influence *Estimation* to *Maximization*

Definition of Influence Maximization

Given G = (V, E) and a positive integer k, select a set S^* of k users from V as the seed set to maximize the influence spread $\sigma(S^*)$,

$$S^* = \operatorname{argmax}_{S \subseteq V \wedge |S| \leq k} \sigma(S)$$



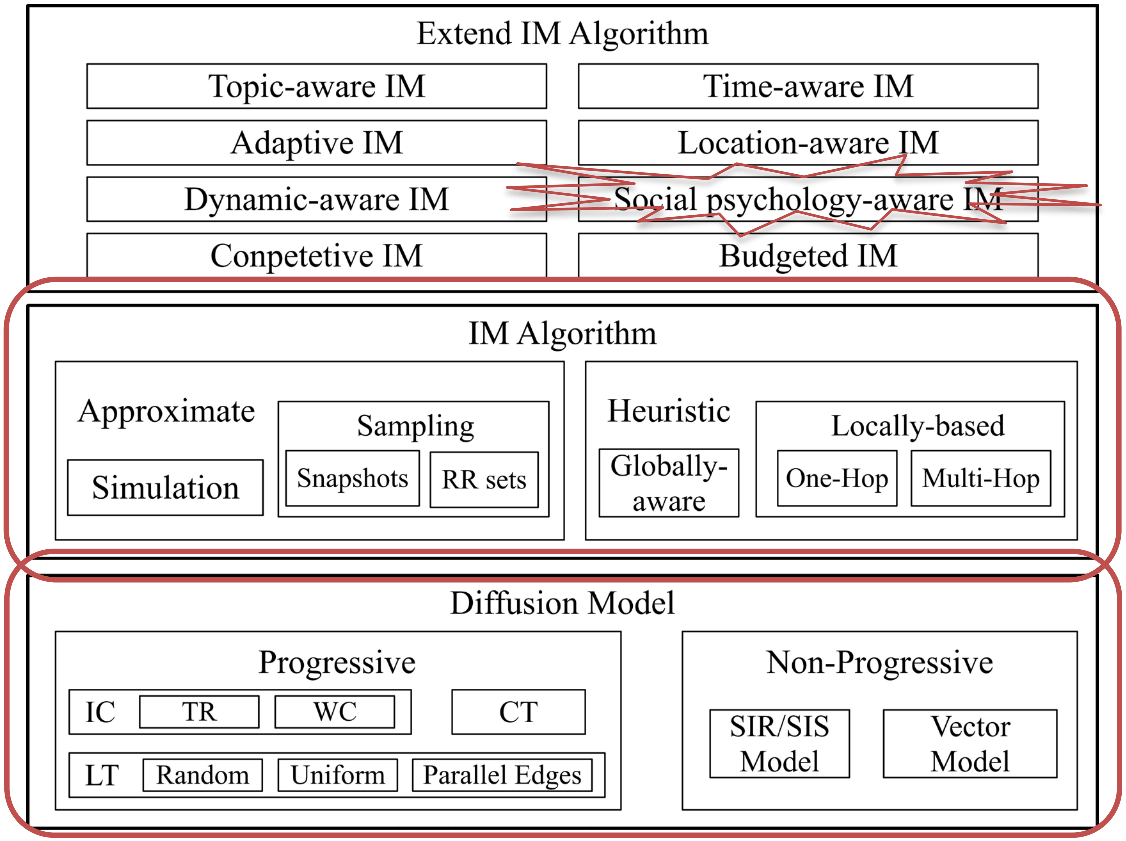
Is A the optimal choice?

Viral Marketing:

Now, a marketer may provide some individuals in a social network with free products in exchange for them to spread the good word about it.

H. Li, S. Yang, M. Xu, S. S. Bhowmick, J. Cui. 2023. Influence Maximization in Social Networks: A Survey.

Taxonomy of Research Related to Influence Maximization Problem



Li et al. clearly organize and differentiate existing research related to IM problem.

The foundation of the IM problem includes diffusion models and influence estimation.

H. Li, S. Yang, M. Xu, S. S. Bhowmick, J. Cui. 2023. Influence Maximization in Social Networks: A Survey.

Approximate Algorithm of Influence Maximization

Greedy Algorithm

Kempe et al.[4] presented the first approximate algorithm based on hill-climbing strategy, which is illustrated as follows.

David Kempe, Jon M. Kleinberg, and Éva Tardos. 2003. Maximizing the spread of influence through a social network.

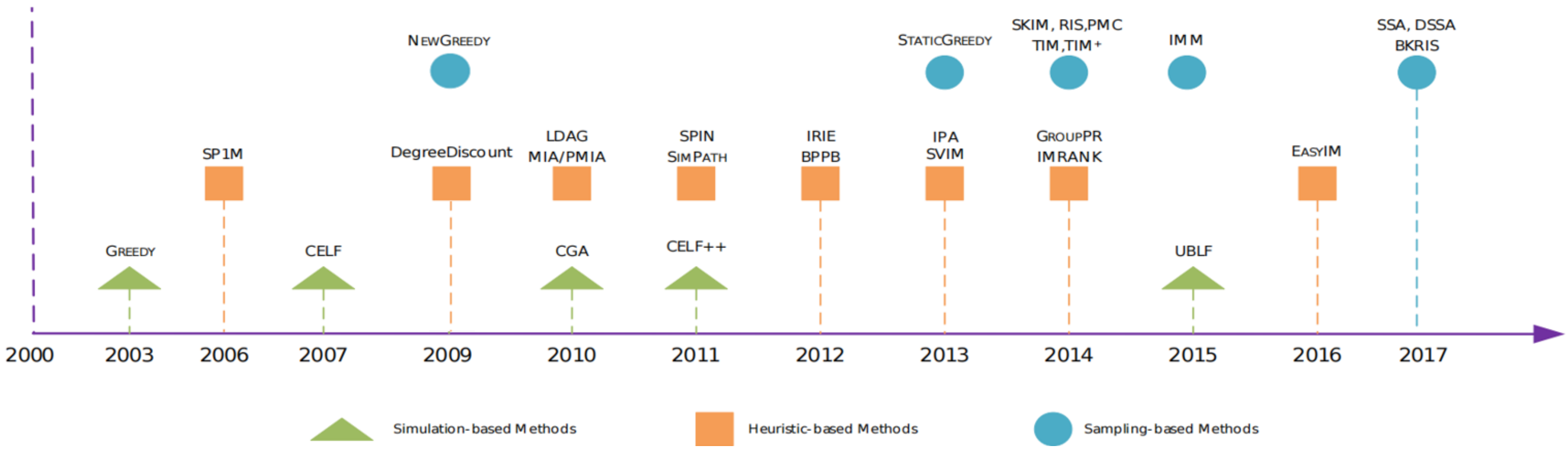
Heuristic Algorithm of Influence Maximization

High-degree Heuristic

- Degree is frequently used for selecting seeds in IM problem. For example, the high-degree heuristic chooses nodes v in order of decreasing degrees d_v.

D. Kempe, J. M. Kleinberg, and É. Tardos. 2003. Maximizing the spread of influence through a social network.

Classical IM Solutions



The figure shows more representative work and milestones for classical IM solutions across all three categories.

Although these works have made significant progress in terms of performance, conformity theory is often ignored in these models.

H. Li, S. Yang, M. Xu, S. S. Bhowmick, J. Cui. 2023. Influence Maximization in Social Networks: A Survey.

Conformity-aware Social Influence Maximization - *CINEMA*

The formal definition of C^2 model
Let A_i be the set of nodes activated in the i-th round and $A_0 = S$. For any $(u, v) \in E$ such that $u \in A_i$ and $v \notin A_i$, v is influenced by u in the next $(i+1)$-th round with probability $\Phi(u)\Omega(u)$ Thus, $P[v \in A_{i+1}] = 1 - \prod_{u \in A_i, (u,v) \in E} (1 - \Phi(u)\Omega(u))$

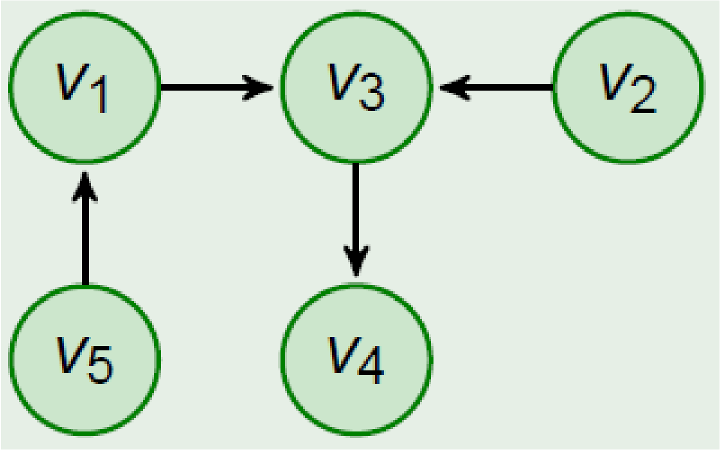
Besides, this effort is also extended by considering context-specific influence and conformity of nodes in C^3, which incorporates topic-aware influence and conformity into C^2.

H. Li, S. S. Bhowmick, A. Sun. 2013. CINEMA: conformity-aware greedy algorithm for influence maximization in online social networks.
H. Li, S. S. Bhowmick, A. Sun, J. Cui. 2015. Conformity-aware influence maximization in online social networks.

Conformity-aware Social Influence Maximization - *CINEMA*

Under IC model with p=0.5, let X denote the set of activated edges, then σ(v1) can be computed as

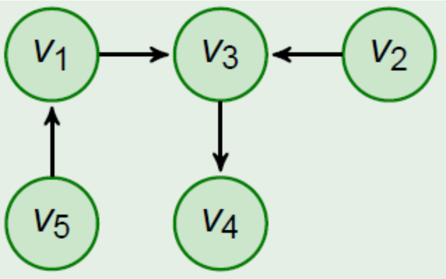
$$\sigma(v_1) = \text{Prob}[\overrightarrow{v_1 v_3} \notin X] \times 1 + \text{Prob}[\overrightarrow{v_1 v_3} \in X, \overrightarrow{v_3 v_4} \notin X] \times 2 + \text{Prob}[\overrightarrow{v_1 v_3} \in X, \overrightarrow{v_3 v_4} \in X] \times 3$$



Candidate Seeds List (IC model p=0.5)	
Node	σ(·)
v_5	1.875
v_1	1.75
v_2	1.75
v_3	1.5
v_4	1

H. Li, S. S. Bhowmick, A. Sun. 2013. CINEMA: conformity-aware greedy algorithm for influence maximization in online social networks.

Conformity-aware Social Influence Maximization - *CINEMA*



Indices (computed by CASINO)		
Node	Influence	Conformity
v_1	0.68	0.21
v_2	0.68	0.11
v_3	0.18	0.94
v_4	0.03	0.21
v_5	0.18	0.11

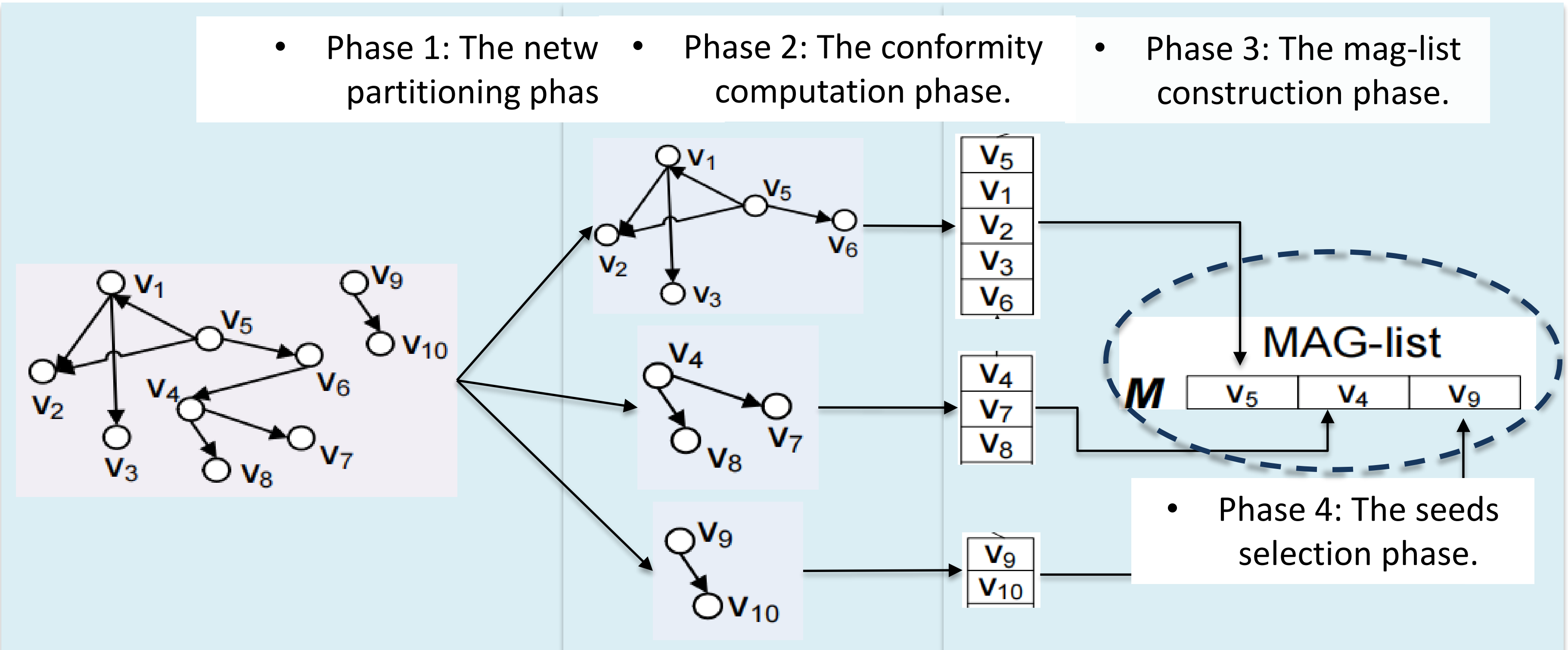
Candidate Seeds List (C^2 model)	
Node	$\sigma(\cdot)$
v_1	1.73
v_2	1
v_5	1.49
v_3	1
v_4	1

Under IC model → select $S=\{v_5\}$
Under C^2 model → select $S=\{v_1\}$

H. Li, S. S. Bhowmick, A. Sun. 2013. CINEMA: conformity-aware greedy algorithm for influence maximization in online social networks.

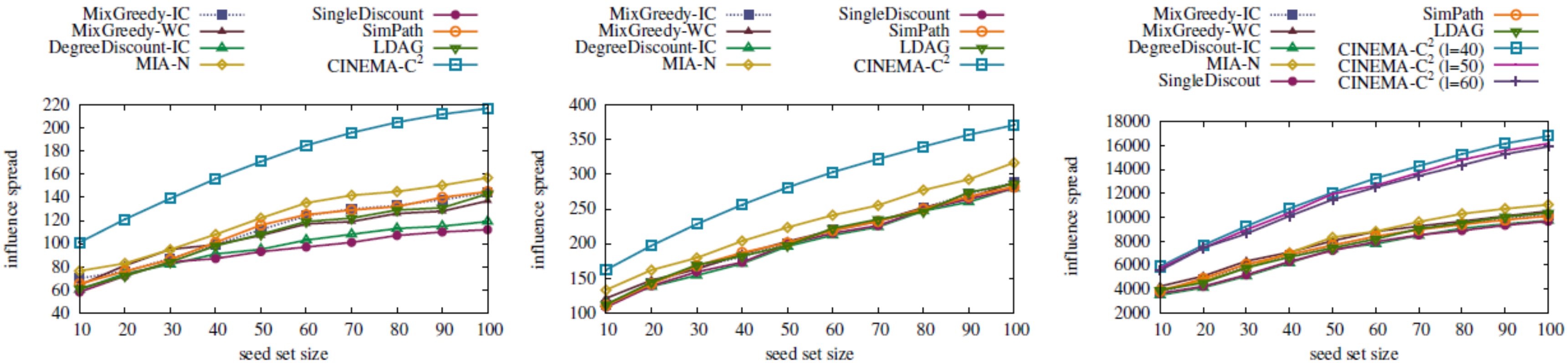
Conformity-aware Social Influence Maximization - *CINEMA*

Complete seed set selection process!



H. Li, S. S. Bhowmick, A. Sun. 2013. CINEMA: conformity-aware greedy algorithm for influence maximization in online social networks.

Conformity-aware Social Influence Maximization - *CINEMA*

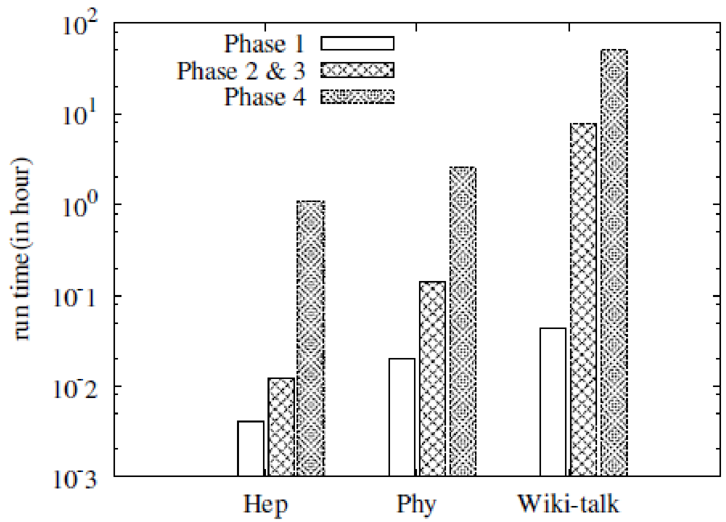


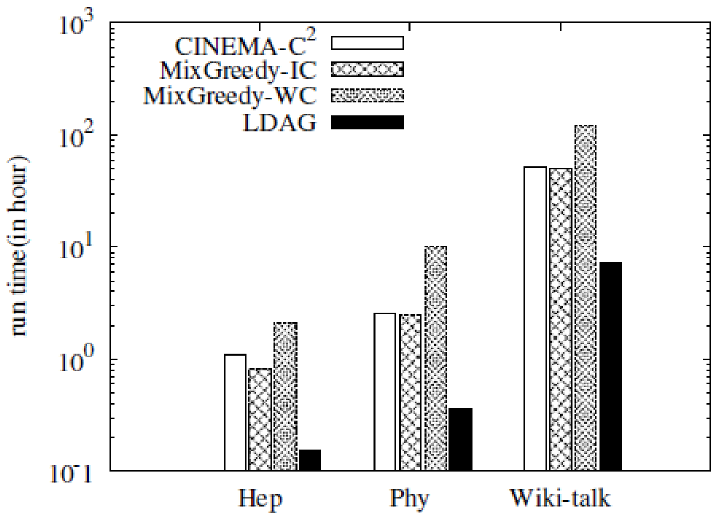
(a) Spread of Hep (b) Spread of Phy (c) Spread of Wiki-talk

- All the other approaches exhibit poor performance under C2 model
- They only account for 60%, 66%, 57% the performance of CINEMA

H. Li, S. S. Bhowmick, A. Sun. 2013. CINEMA: conformity-aware greedy algorithm for influence maximization in online social networks.

Conformity-aware Social Influence Maximization - *CINEMA*



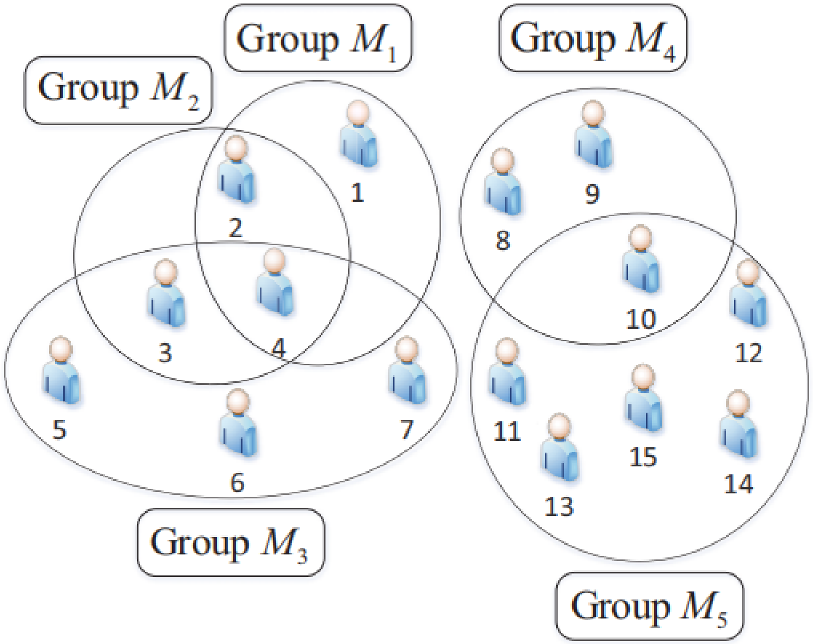


- Seeds selection phase (phase/step 4) dominates the running time
- The running time of CINEMA is similar to MixGreedy-IC

H. Li, S. S. Bhowmick, A. Sun. 2013. CINEMA: conformity-aware greedy algorithm for influence maximization in online social networks.

Conformity-aware Social Influence Maximization - *GIM*

For user u, user profile A_u contains d attributes denoted as $A_u = \{a_{1,u}, a_{2,u}, \ldots, a_{d,u}\}$.

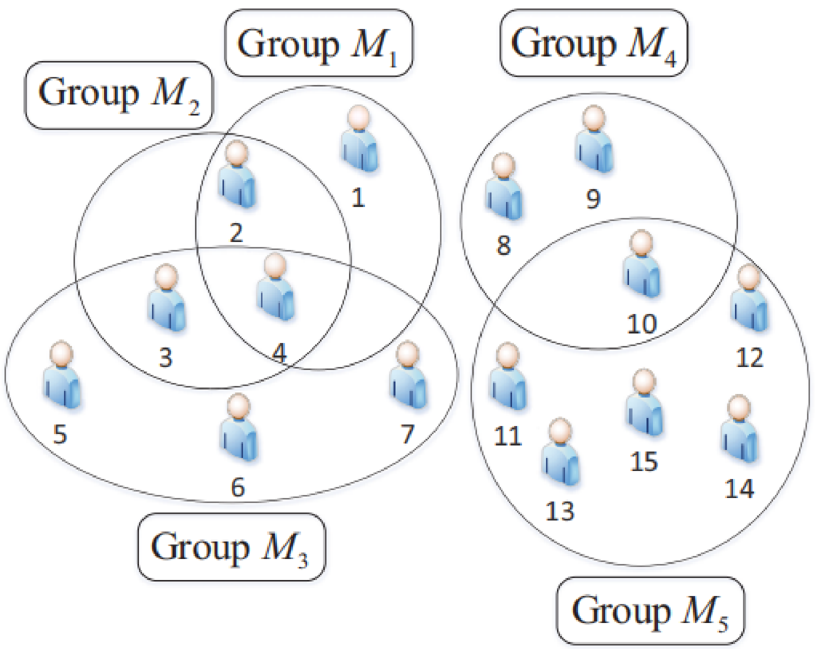


Users' profiles	
User	Profile={Gender, Basketball, Tennis, Football, Movie, Book}
U_1	A_u={1, 1, 0, 0, 0, 0}
U_2	A_u={0, 1, 1, 0, 0, 0}
U_3	A_u={1, 0, 1, 1, 0, 0}
U_4	A_u={0, 1, 1, 1, 0, 0}
U_5	A_u={1, 0, 0, 1, 0, 0}
U_6	A_u={0, 0, 0, 1, 0, 0}
U_7	A_u={1, 0, 0, 1, 0, 0}
…	…

Y. Li, X. Gan, L. Fu, X. Tian, Z. Qin, Y. Zhou. 2018. Conformity-Aware Influence Maximization with User Profiles.

Conformity-aware Social Influence Maximization - *GIM*

Use discriminative attributes to describe a group. It explains well for one group and differentiates this group from the others.



Groups' profiles	
Group	Profile={Gender, Basketball, Tennis, Football, Movie, Book}
M_1	P_{M_1}={0, 1, 0, 0, 0, 0}
M_2	P_{M_2}={0, 0, 1, 0, 0, 0}
M_3	P_{M_3}={0, 0, 0, 1, 0, 0}
M_4	P_{M_4}={0, 0, 0, 0, 1, 0}
M_5	P_{M_5}={0, 0, 0, 0, 0, 1}

Y. Li, X. Gan, L. Fu, X. Tian, Z. Qin, Y. Zhou. 2018. Conformity-Aware Influence Maximization with User Profiles.

Conformity-aware Social Influence Maximization - *GIM*

Conform to
- Friends → similarity between a pair of friends' profiles
- Group → similarity between profiles of user and group

$$sim(A_u, A_v) = \frac{A_u \cdot A_v}{\sum_{a_{i,u} \in A_u} a_{i,u}}$$

$$sim(A_u, P_{M_j}) = \frac{A_u \cdot P_{M_j}}{\sum_{a_{i,u} \in A_u} a_{i,u}}, u \in M_j$$

Generally, information Q can also be marked by multiple features.

$$sim(A_u, Q) = \frac{\sum_{i=1}^{d} a_{i,u} \cdot q_i}{h}$$

(h: the number of information attributes)

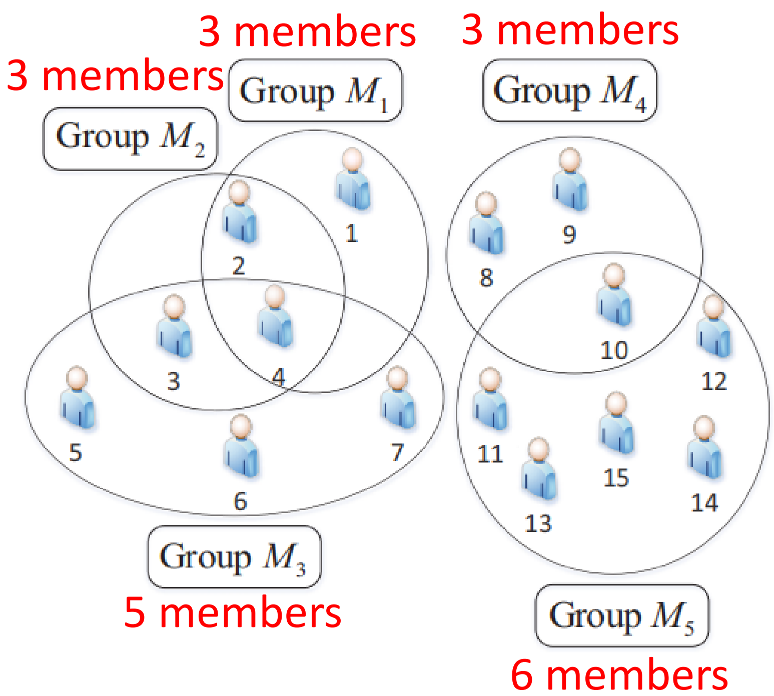
$$pro(u,v) = sim(A_u, A_v) \times sim(A_u, P_{M_j}) \times sim(A_u, Q)$$

Y. Li, X. Gan, L. Fu, X. Tian, Z. Qin, Y. Zhou. 2018. Conformity-Aware Influence Maximization with User Profiles.

Conformity-aware Social Influence Maximization - *GIM*

Group selection

- Arrange the groups in a decreasing order w.r.t. *sizes*.
- According to *k*, assign one seed for each group.
- When group M_j has been assigned with seeds, its neighbor groups will not be allocated any seed.



M^R = {M5, M3, M4, M2, M1}

k=2, {M5, M3}

M^C = {M5, M3}

Y. Li, X. Gan, L. Fu, X. Tian, Z. Qin, Y. Zhou. 2018. Conformity-Aware Influence Maximization with User Profiles.

Conformity-aware Social Influence Maximization - *GIM*

Seed selection

- total number of nodes in each group *u* is involved in → high cardinality
- the similarity between involved groups and *u* → high similarity

$$rank(u) = \sum_{M_j \not\subset T, u \in M_j} |M_j| \times sim\left(A_u, P_{M_j}\right)$$

(T: the set of groups in M that already have seeds allocated)

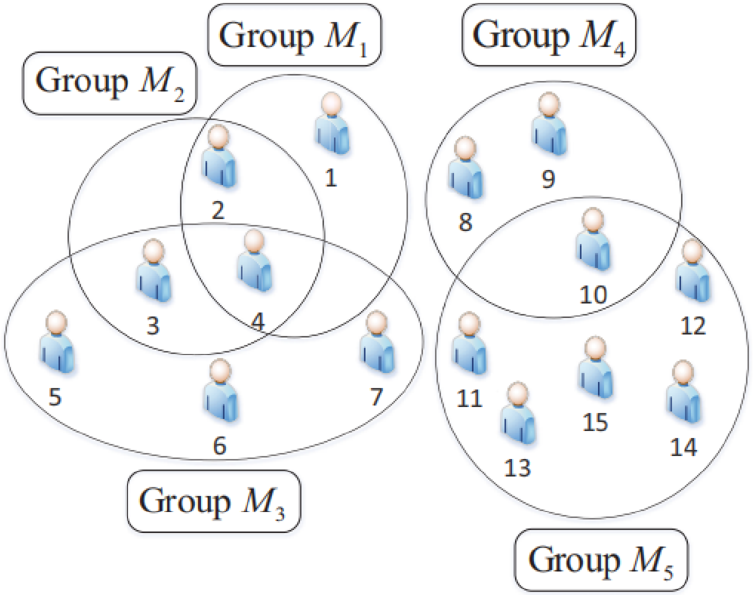
$$\sigma(S) = \sum_{u \in S} rank(u)$$

Y. Li, X. Gan, L. Fu, X. Tian, Z. Qin, Y. Zhou. 2018. Conformity-Aware Influence Maximization with User Profiles.

Conformity-aware Social Influence Maximization - *GIM*

Complete seed set selection process!

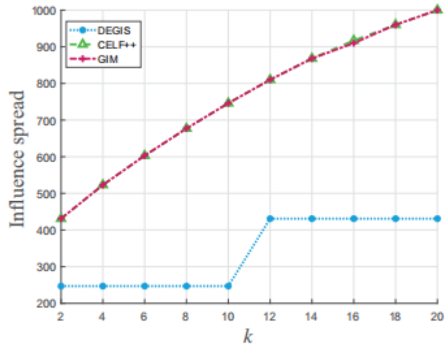
We assume that each vertex has the same similarity 0.5 for each group on the profile and k = 2. And we know that M^C = {M5, M3}.



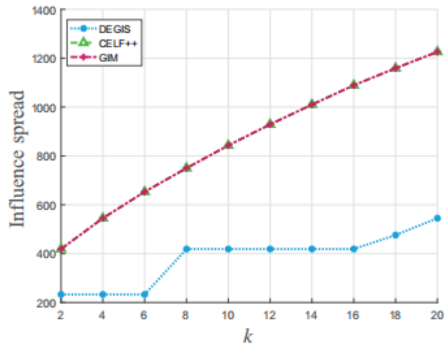
Group	$rank(\cdot)$ values for each user
E	$rank(10) = 3 \times 0.5 + 6 \times 0.5 = 4.5$ $rank(11) = 6 \times 0.5 = 3$ $rank(12) = rank(13) = rank(14) = rank(15)$ $= rank(11) = 3$ $rank(8) = rank(9) = 3 \times 0.5 = 1.5$
C	$rank(4) = 3 \times 0.5 + 3 \times 0.5 + 5 \times 0.5 = 5.5$ $rank(3) = 3 \times 0.5 + 5 \times 0.5 = 4$ $rank(2) = 3 \times 0.5 + 3 \times 0.5 = 3$ $rank(5) = rank(6) = rank(7) = 5 \times 0.5 = 2.5$ $rank(1) = 3 \times 0.5 = 1.5$

Y. Li, X. Gan, L. Fu, X. Tian, Z. Qin, Y. Zhou. 2018. Conformity-Aware Influence Maximization with User Profiles.

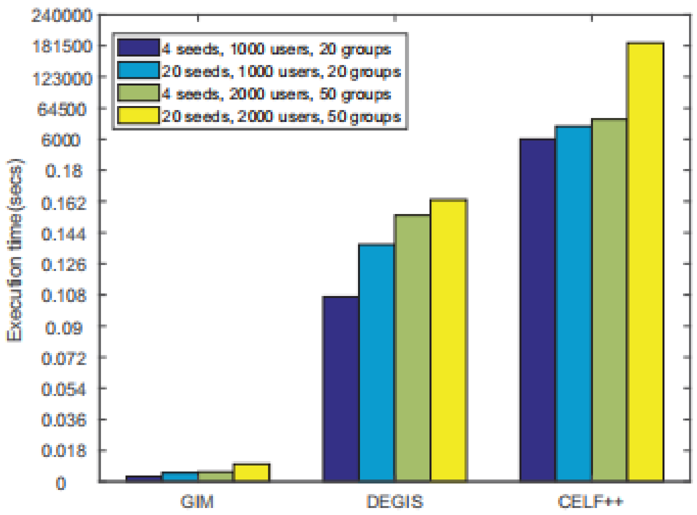
Conformity-aware Social Influence Maximization - *GIM*



(a) User number $n = 1000$, group number $m = 20$



(b) User number $n = 2000$, group number $m = 50$



Y. Li, X. Gan, L. Fu, X. Tian, Z. Qin, Y. Zhou. 2018. Conformity-Aware Influence Maximization with User Profiles.

Psychology-aware social influence Est. and Max.: Besides Conformity

- Normative vs. Informational conformity: leads to the same influence
- Attention attenuation: LT diffusion model -> RLT model; est. and max. following RLT
- Confirmation bias: Topic-aware IM & Cost-aware VM

H. Li, S. Yang, M. Xu, S. S. Bhowmick, J. Cui. 2023. Influence Maximization in Social Networks: A Survey.

Next..

- Psychology theory-informed design
- Background on psychology theories
- Psychology theory-informed design of diffusion models
- Psychology theory-informed design of social influence
- Future directions

Expansion to Larger Social Computing Problems

Goal

- Trigger rethinking of existing social computing solutions

Community Search

- Social psychology influence interactions between individuals
- Existing community search techniques are psychology-oblivious

Bias and Fairness

- A lot of research activities in recent times.
- Solutions are typically not informed by psychology theories

Expansion to Larger Social Computing Problems

Fake News Propagation

- Confirmation bias plays a significant role.
- Techniques can benefit from psychology-informed design.
- Potential to improve understanding and accuracy.

Social Data Quality

- Collaborative editing of Wikipedia
- Influenced by confirmation bias, conformity.

Expansion of Psychological Theories

Goal

- Tip of the iceberg
- Conformity theory
- Confirmation bias
- Interference theory
- Attenuation theory

Role Theory

- Roles that people occupy provide context that shape behaviour
- Potential to contribution to information propagation

Expansion of Psychological Theories

Social Impact Theory

- Amount of influence a person experiences in group settings:
  - Strength (power or social status) of the group
  - Immediacy (psychological or physical distance)
  - Number of people in the group exerting the influence
- Useful for understanding social influence

Cognitive Psychology

- Study of how people think and process information
- Cognitive load theory
- Check out our tutorial at **SIGMOD 2024**!

Data-driven Quantitative Model of Psychological Theories

Goal

- Existence of massive human-related data
- Can we model psychological theories at scale?
- Data-driven techniques to influence psychology

Early Efforts

- Modeling of confirmation bias
- Conformity

Conclusions

Think about the role psychology theories can play in designing social computing solutions

Review relevant research on this inter-disciplinary topic