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Decision Support and Operation Design for Mission-Critical Applications

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Medical Diagnosis and Treatment

- When to rely on automation
  - Algorithmic recommendations
- Trust and Explainability

Medical Triage

Adapted from DARPA ITM

Small Unit Triage

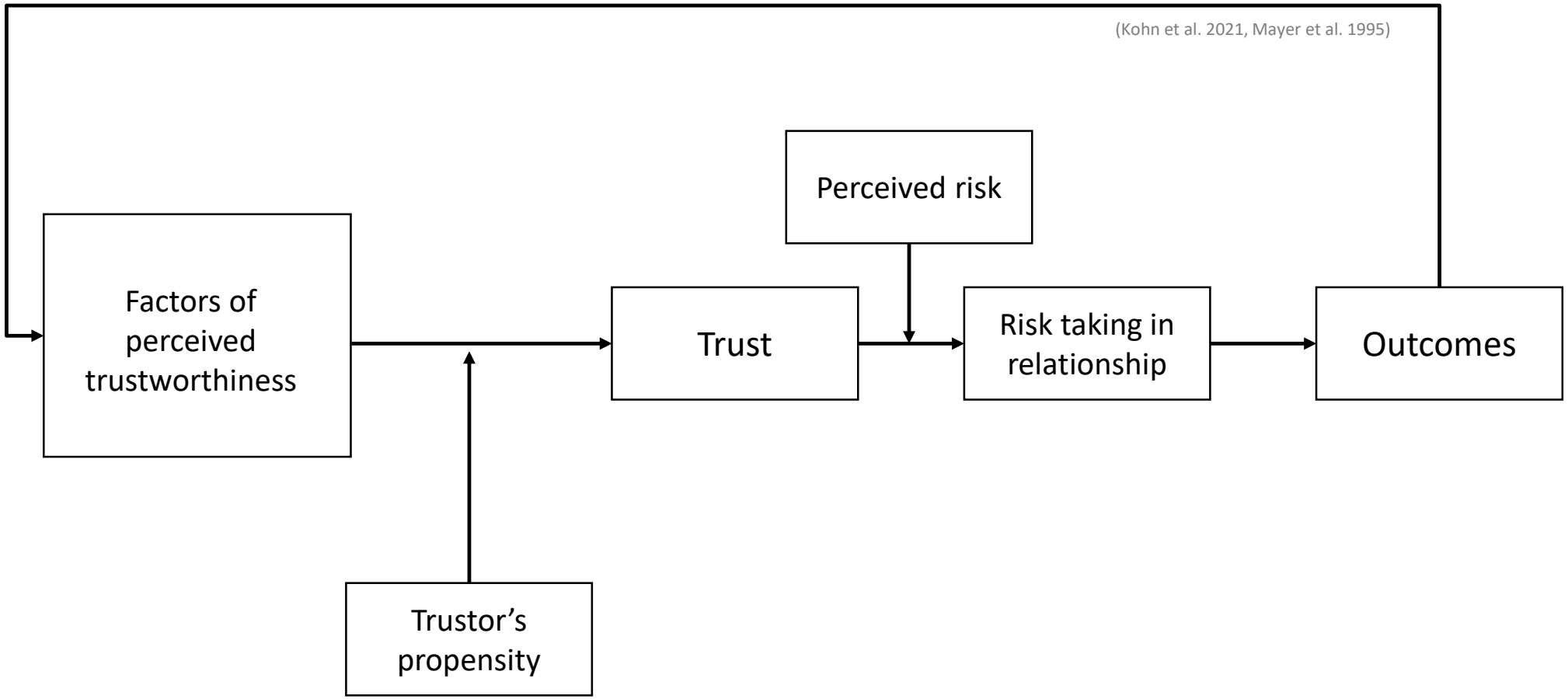
https://www.afsoc.af.mil/News/Photos/igphoto/2001868908/

Triage for Mass Casualty

By JO1 MARK D. FARAM, USN - [1], Public Domain, https://commons.wikimedia.org/w/index.php?curid=2152632

Trust model

Trust: "the willingness of a party to be **vulnerable to the actions of another** party based on the expectation that the other will perform a particular action important to the trustor, **irrespective of the ability to monitor or control** that other party." Mayer et al. 1995



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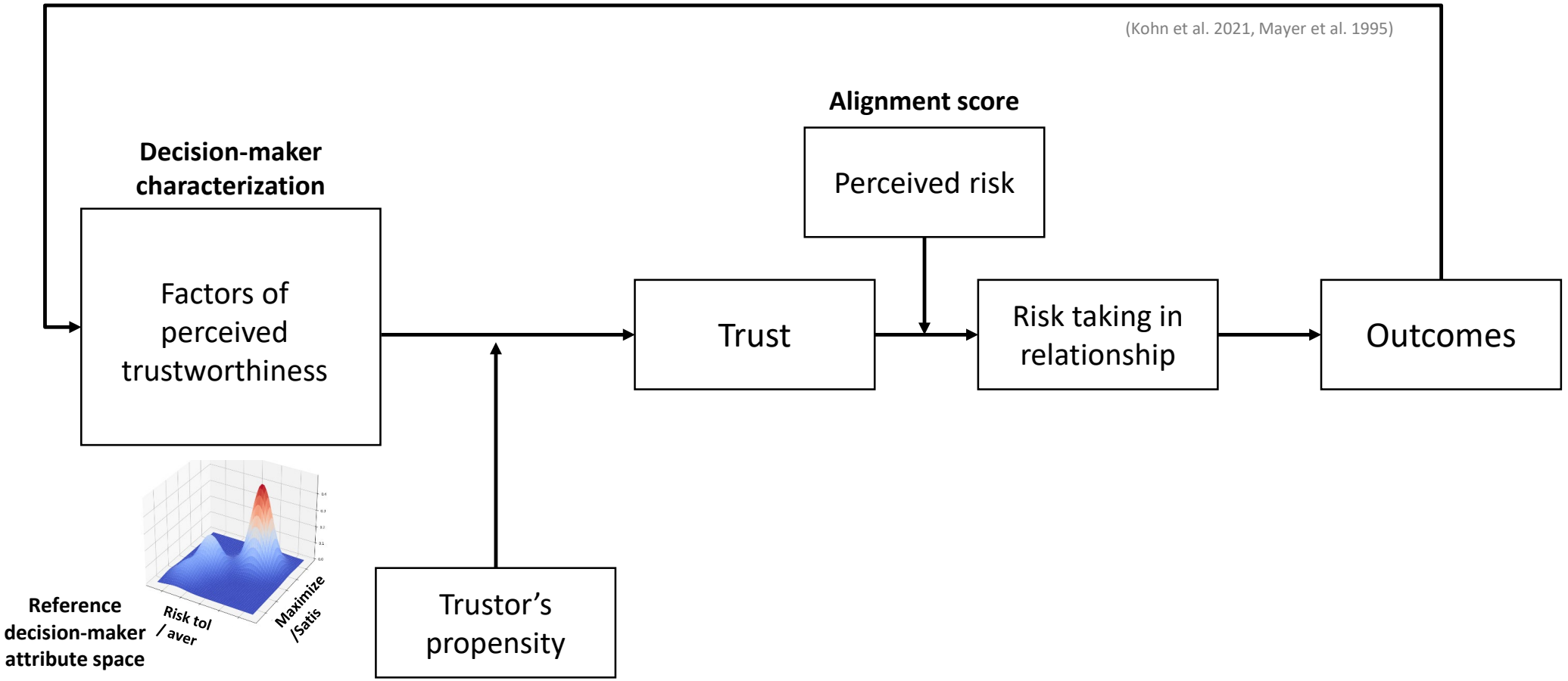
(Kohn et al. 2021, Mayer et al. 1995)



Soldier-Robot Teaming

- Teaming in face of a dynamic adversary
- Target search and location in hazardous environments
- Task assignment and optimal resource allocation
- Information fusion in the battlefield

Improving Coordination and Cooperation in Heterogeneous Crowds of Soldiers and Robots (Analytic Framework for AI/AA)

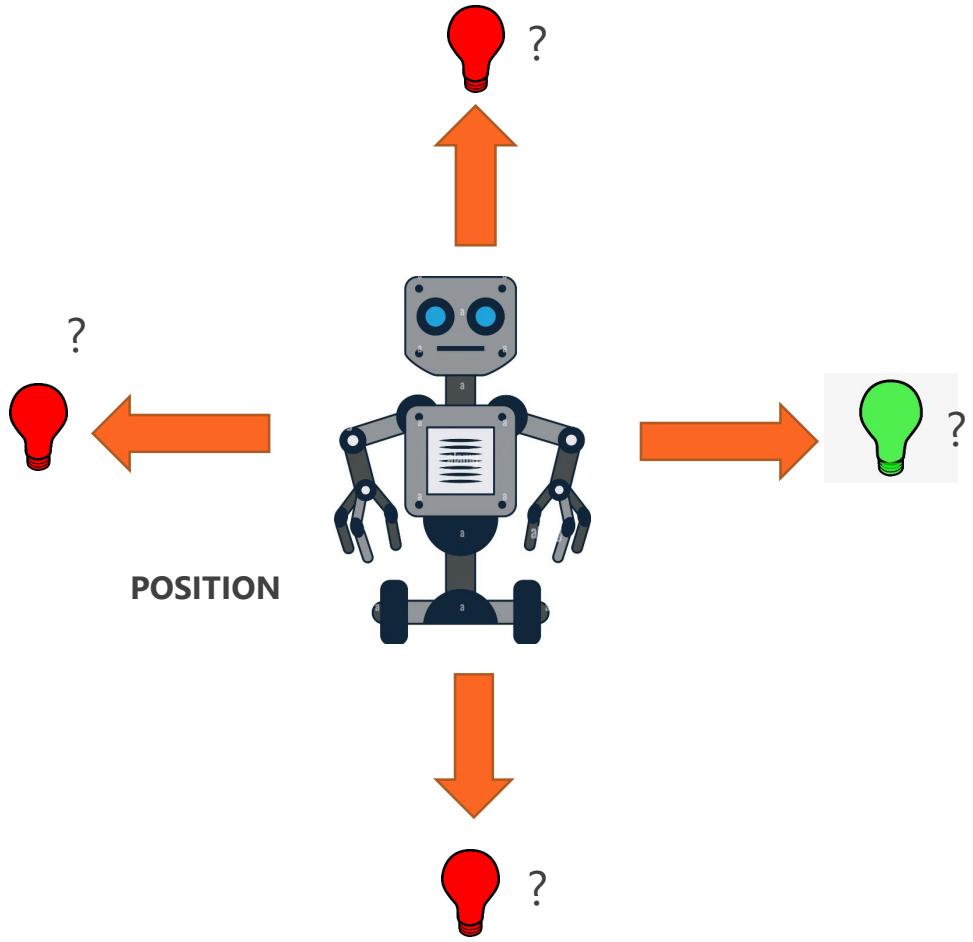
Multi-Armed Bandits for Target Search

1. Limited information of the environment. Position in the space and past positions and signals acquired. Actions in different positions have different consequences.

2. The decision maker can guide the agent in different directions, but some directions can get the agent closer to the target.

3. The closeness to the target is inferred from signal detection that is acquired in each step.

4. The target position is unknown and signals are subject to noise and random variations. Learn the target location by accumulating historical information.



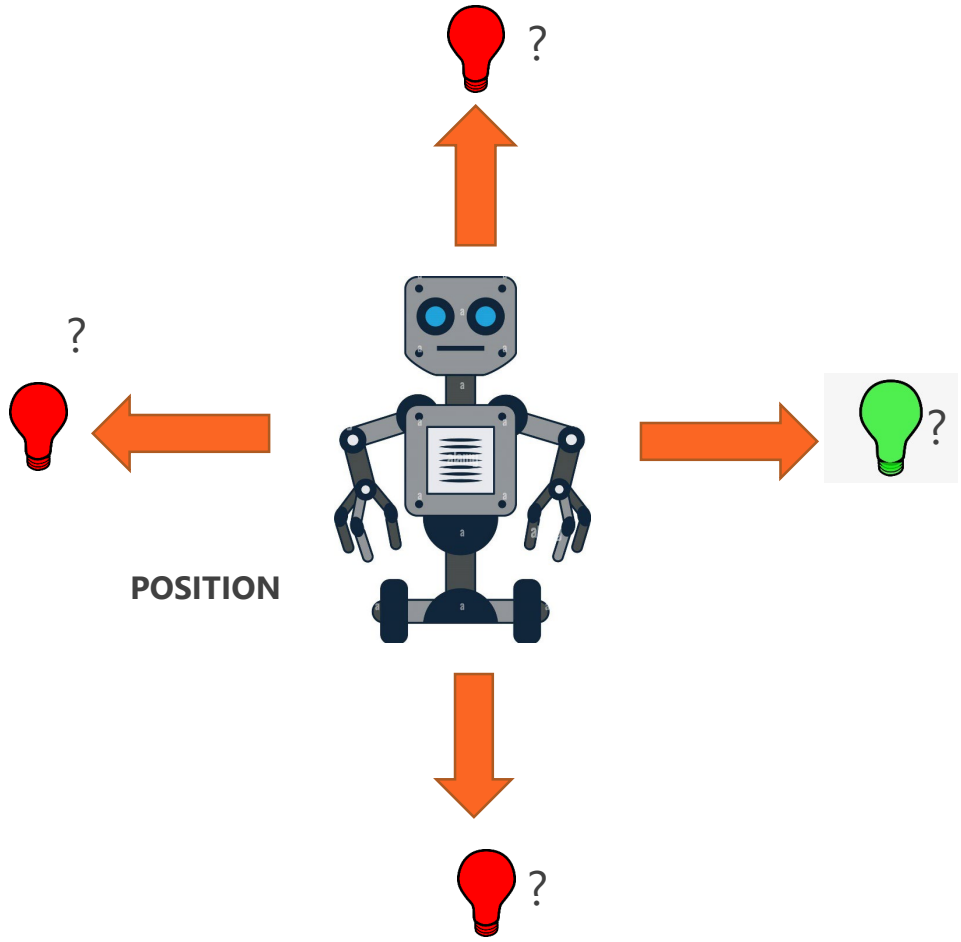
Multi-Armed Bandits for Target Search

1. Limited information of the environment. Position in the space and past positions and signals acquired. Actions in different positions have different consequences. **CONTEXT/STATE**

2. The decision maker can guide the agent in different directions, but some directions can get the agent closer to the target. **ARMS**

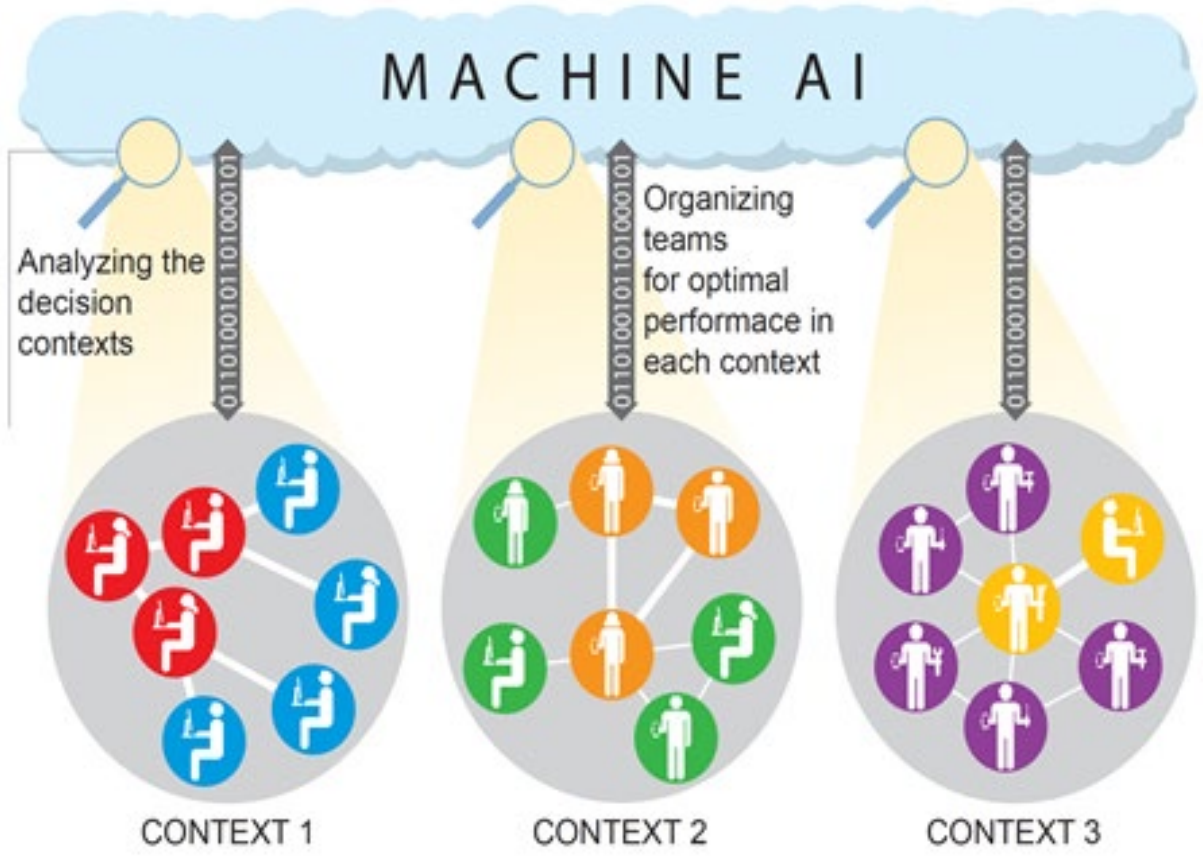
3. The closeness to the target is inferred from signal detection that is acquired in each step. **REWARDS**

4. The target position is unknown and signals are subject to noise and random variations. Learn the target location by accumulating historical information. **EXPLORATION-EXPLOTATION TRADE-OFF**



Human-Agent Teaming in Mission Critical Applications

- How to combine complementary capabilities of humans and autonomous agents?
  - Soldier-Robot Teaming
  - Self-driving cars
- How to determine and adapt team size and structure?



Adapting Team Structure to Context

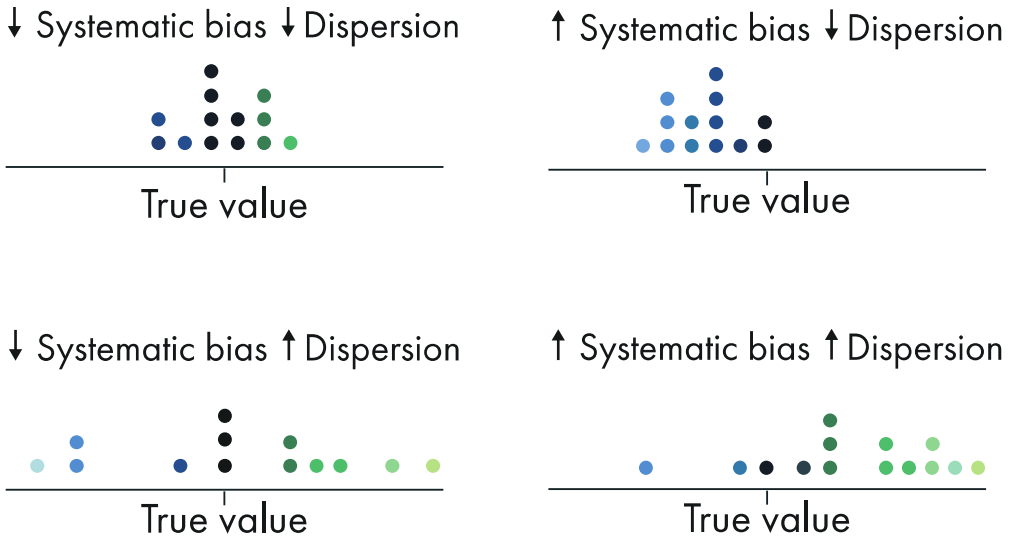
- Individual level attributes
  - Ability level
  - Social perceptiveness
  - Cognitive style diversity
  - Diversity
    - Skill diversity
    - Cognitive style diversity
    - Identity diversity
    - Functional diversity
  - Personality traits
- Group size
- Incentives / nature of the task
- Social Influence
- Distribution of information
- Aggregation mechanism

When Social Influence Promotes Wisdom of Crowds (Context-Dependent Framework)

Estimation context

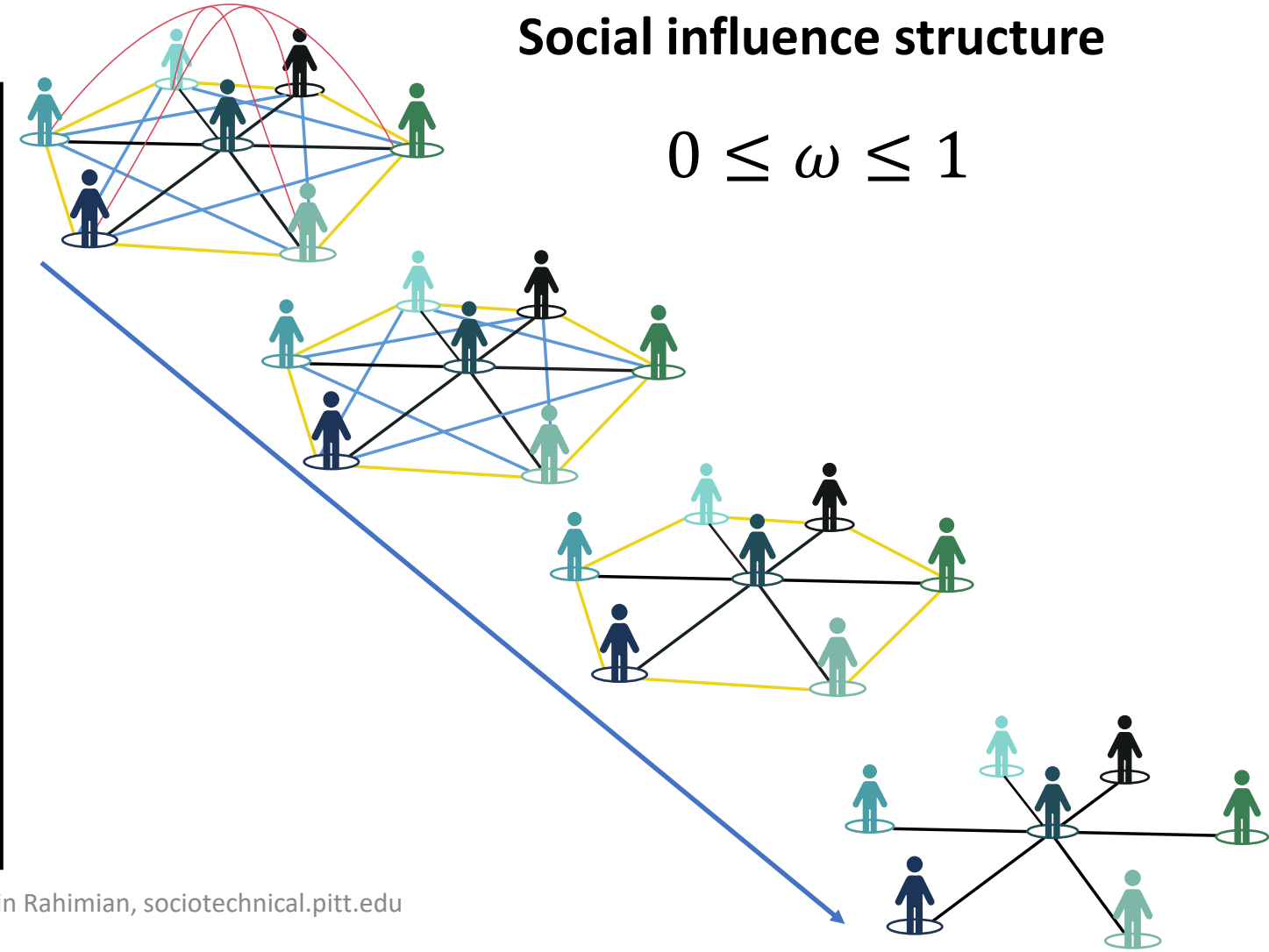
μ: *Systmatic bias* σ: *Dispersion*

θ: *True value*



Social influence structure

$0 \leq \omega \leq 1$



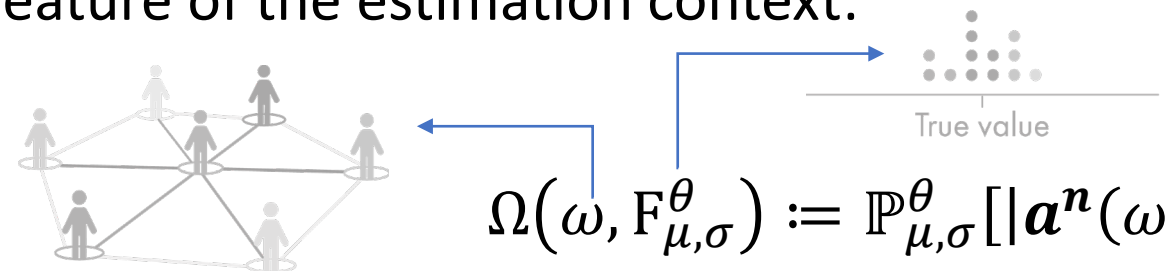
Context-dependent Framework

Each agent is endowed with an independent and identically distributed initial estimate: $\boldsymbol{a_i}$

Collective estimate: $\boldsymbol{a^n}(\omega) = \omega \boldsymbol{a}_1 + (1 - \omega)\frac{1}{n}\sum_{i=1}^{n} \boldsymbol{a}_i$

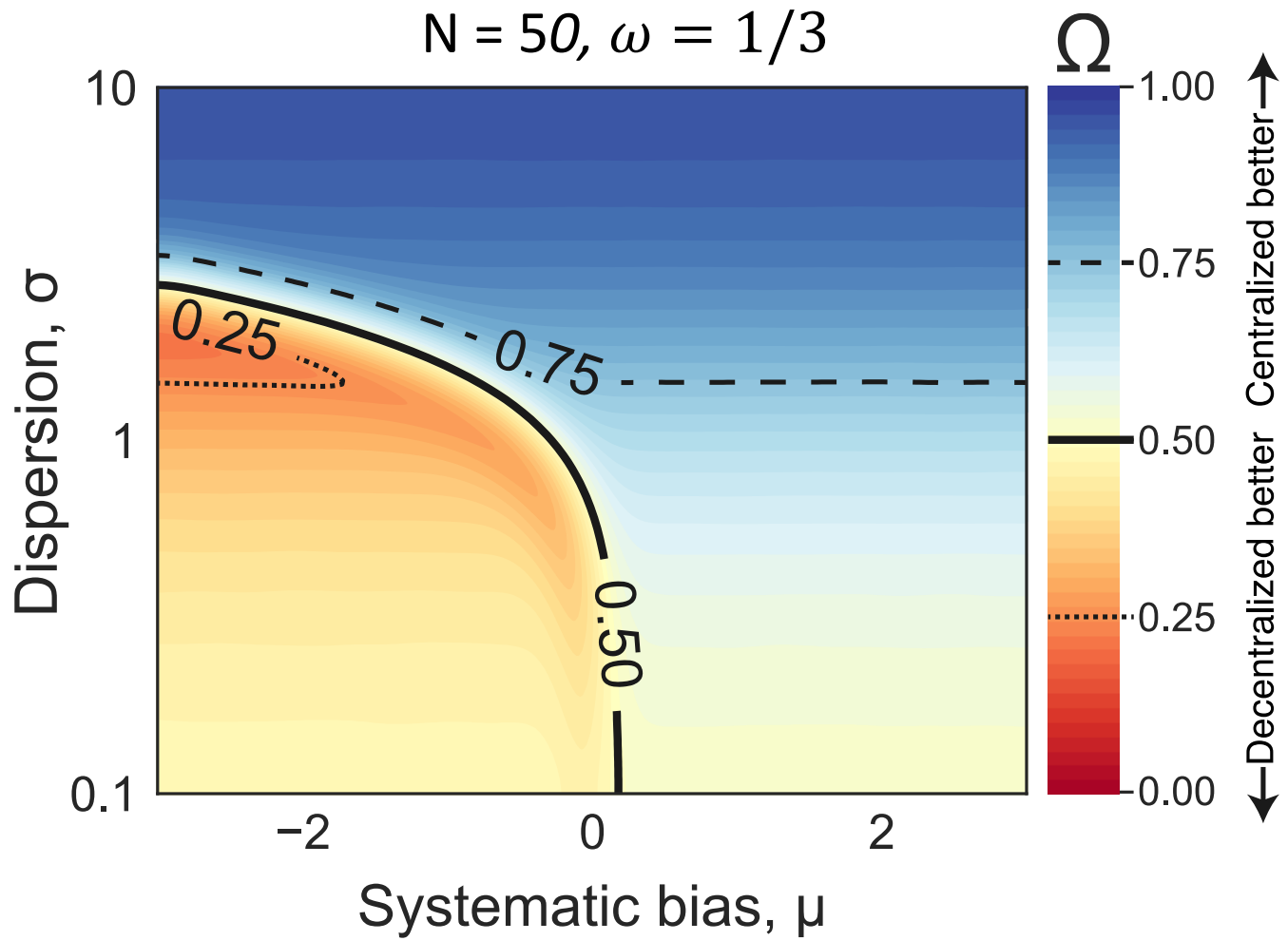
$\boldsymbol{a^n}(0)$	collective estimate generated by decentralized influence structure.
$\boldsymbol{a^n}(\omega), \omega > 0$	collective estimate generated by a centralized influence structure.

Feature of the estimation context:

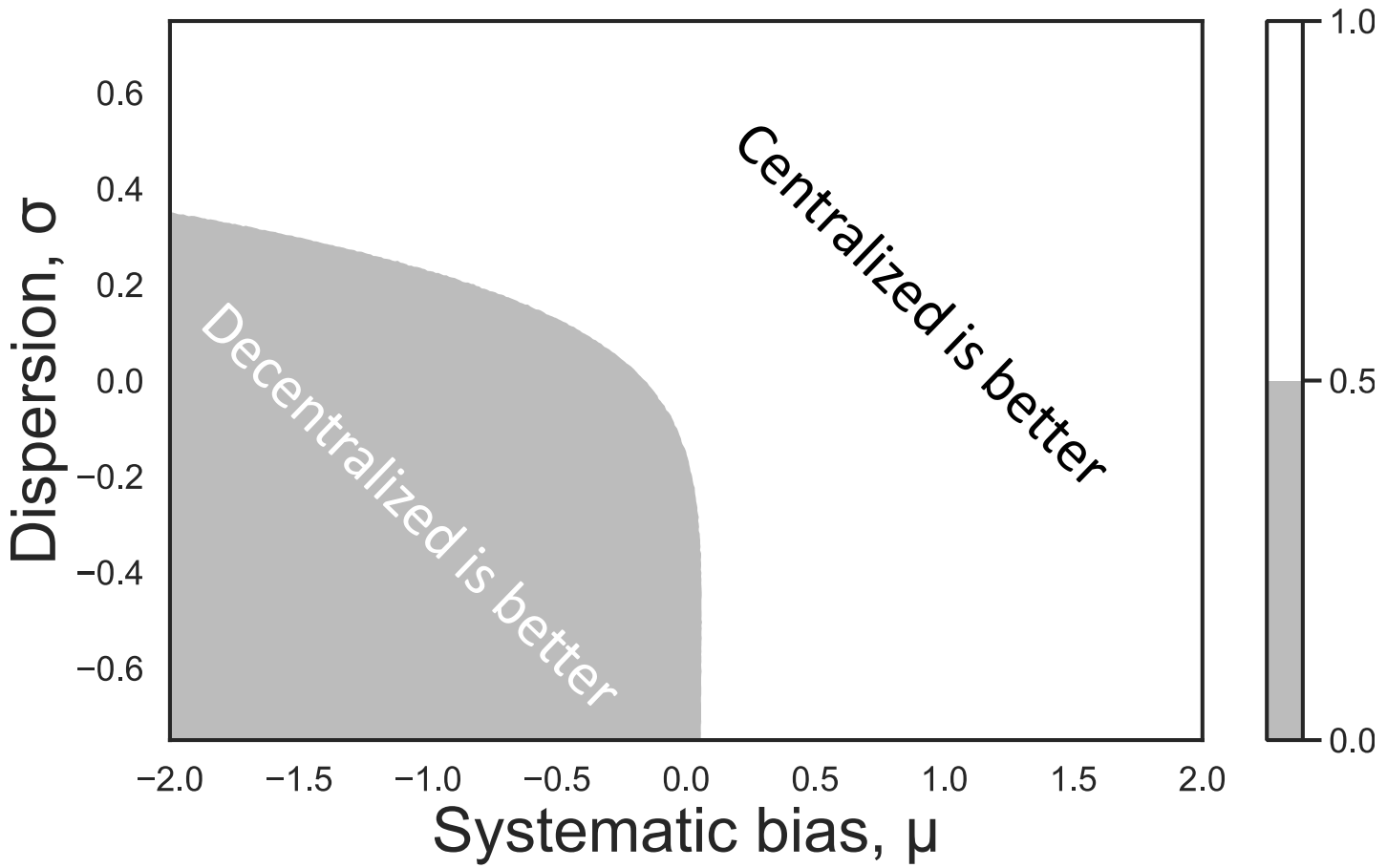


$$\Omega\left(\omega, \mathrm{F}^{\theta}_{\mu,\sigma}\right) \coloneqq \mathbb{P}^{\theta}_{\mu,\sigma}[|\boldsymbol{a^n}(\omega) - \theta| < |\boldsymbol{a^n}(0) - \theta|]$$

Simulation Results



Empirical Results: prior work



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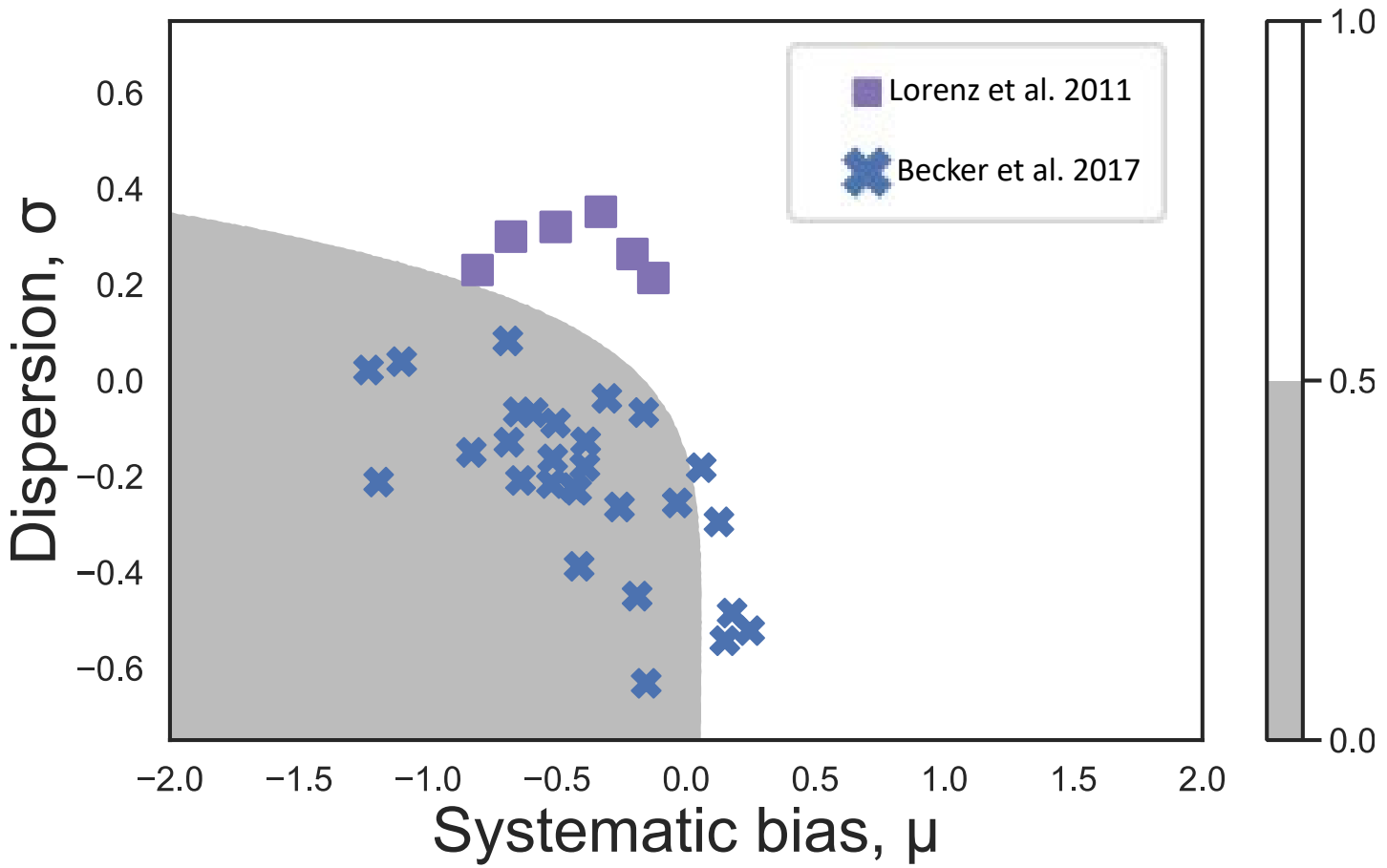

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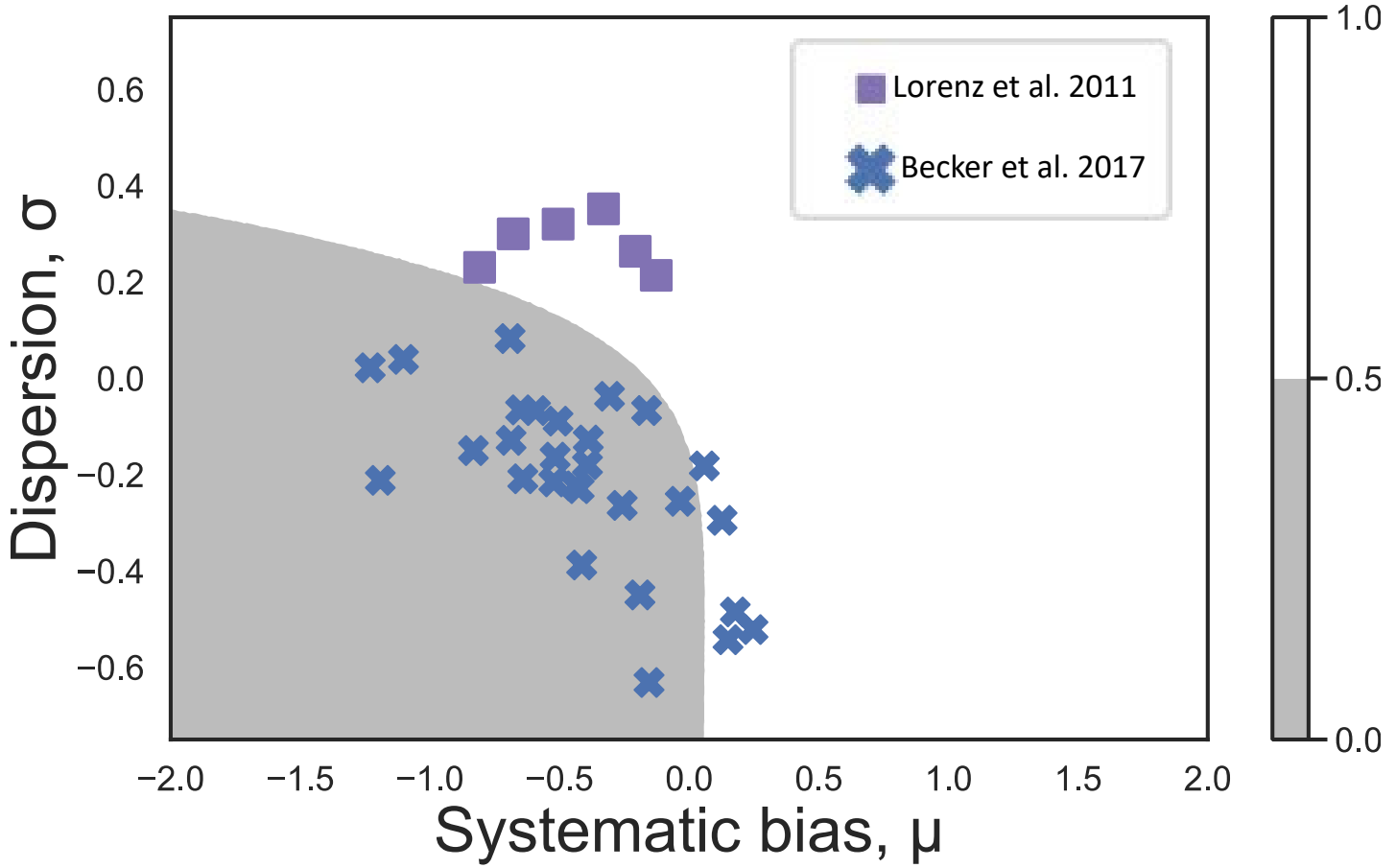

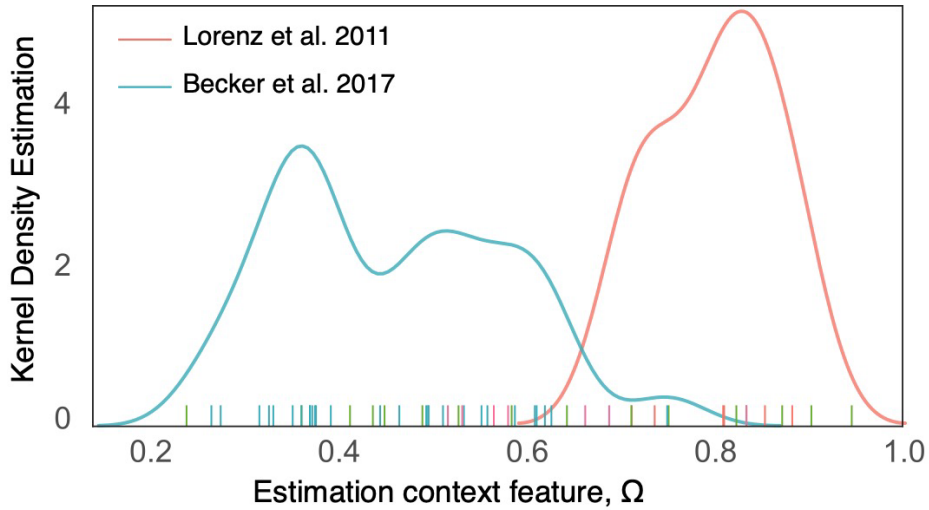

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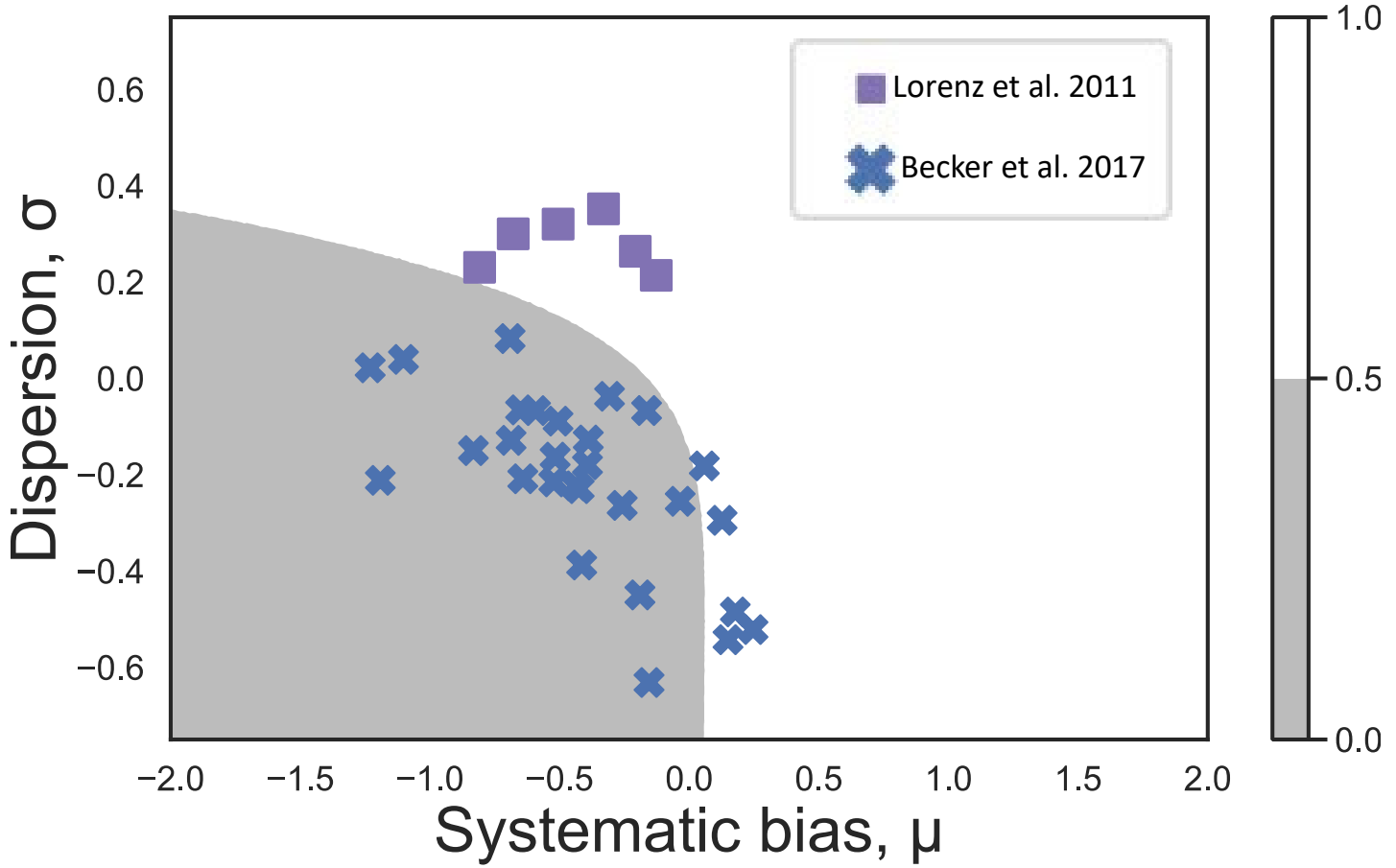

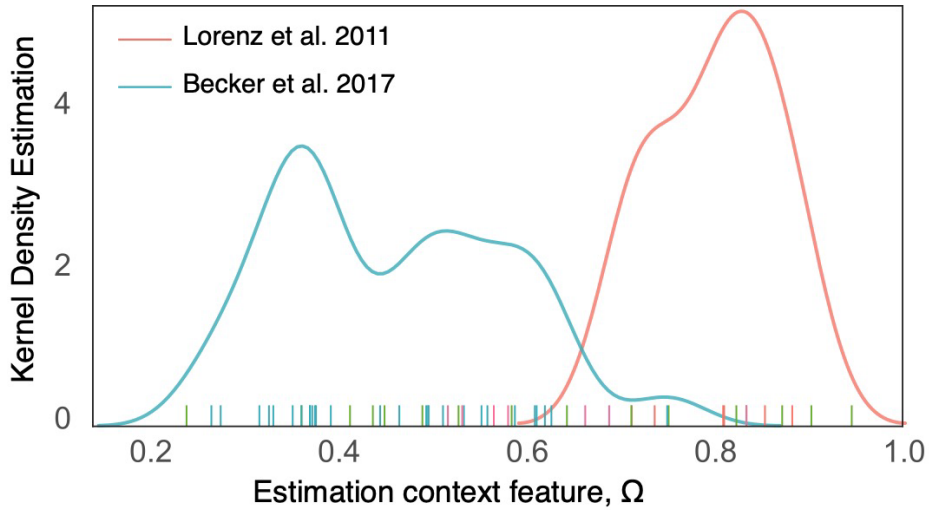

Can collective accuracy be improved by algorithmically rewiring social networks' structure without knowledge of the ground truth?

$$(c-\theta)^2 = \frac{1}{n}\sum_{i=1}^{n}(s_i-\theta)^2 - \frac{1}{n}\sum_{i=1}^{n}(s_i-c)^2$$

Crowd Error	=	**Average Error**	-	**Diversity**
How far is the crowd from the "truth," as a collective		How far each of us individually is from the "truth" on average		How different each of us are from one another on average

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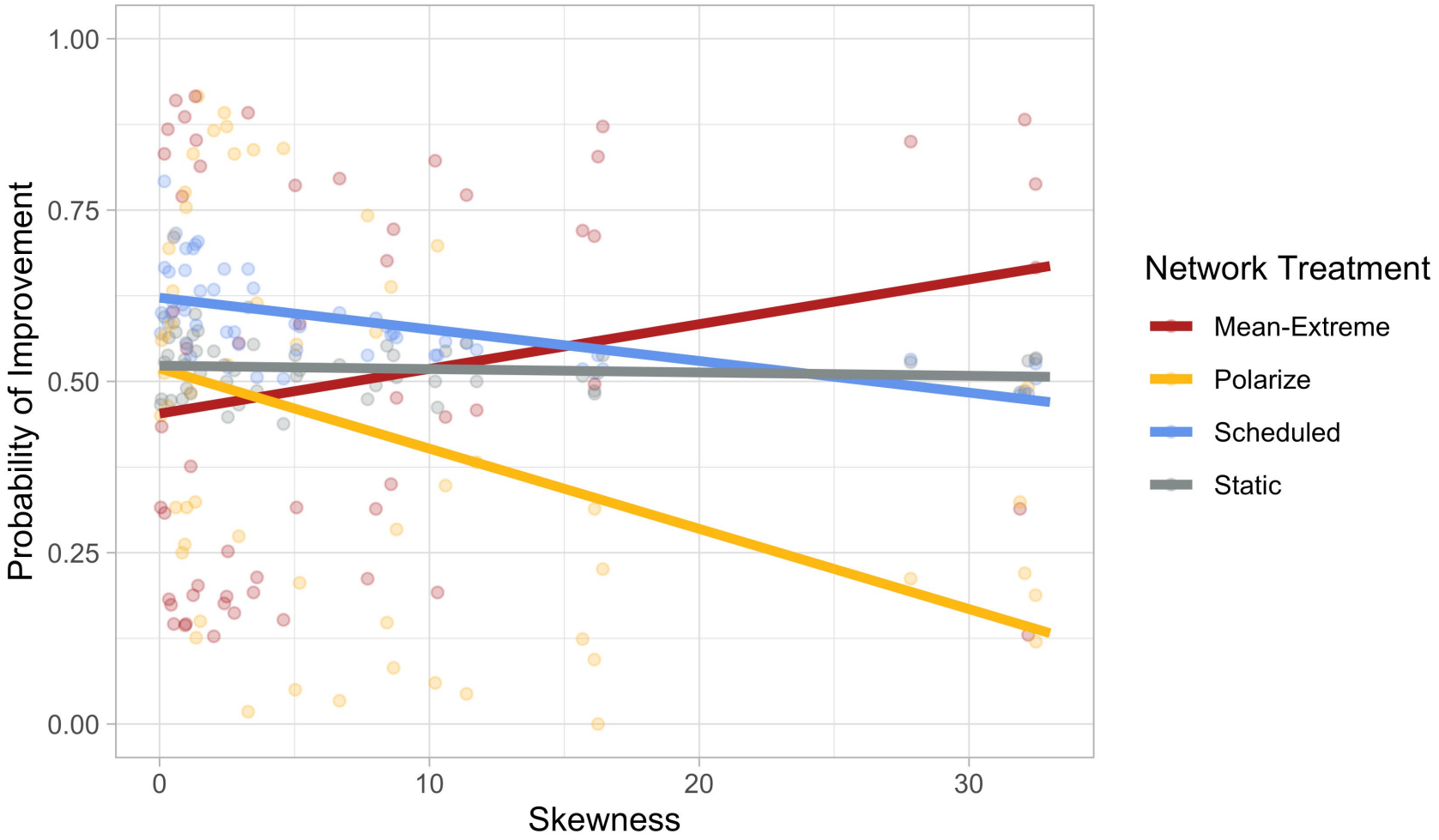
$\theta = "truth"$
$s_i = individual\ i's\ prediction$

$c = crowd\ prediction$
$(c-\theta) = crowd\ error$

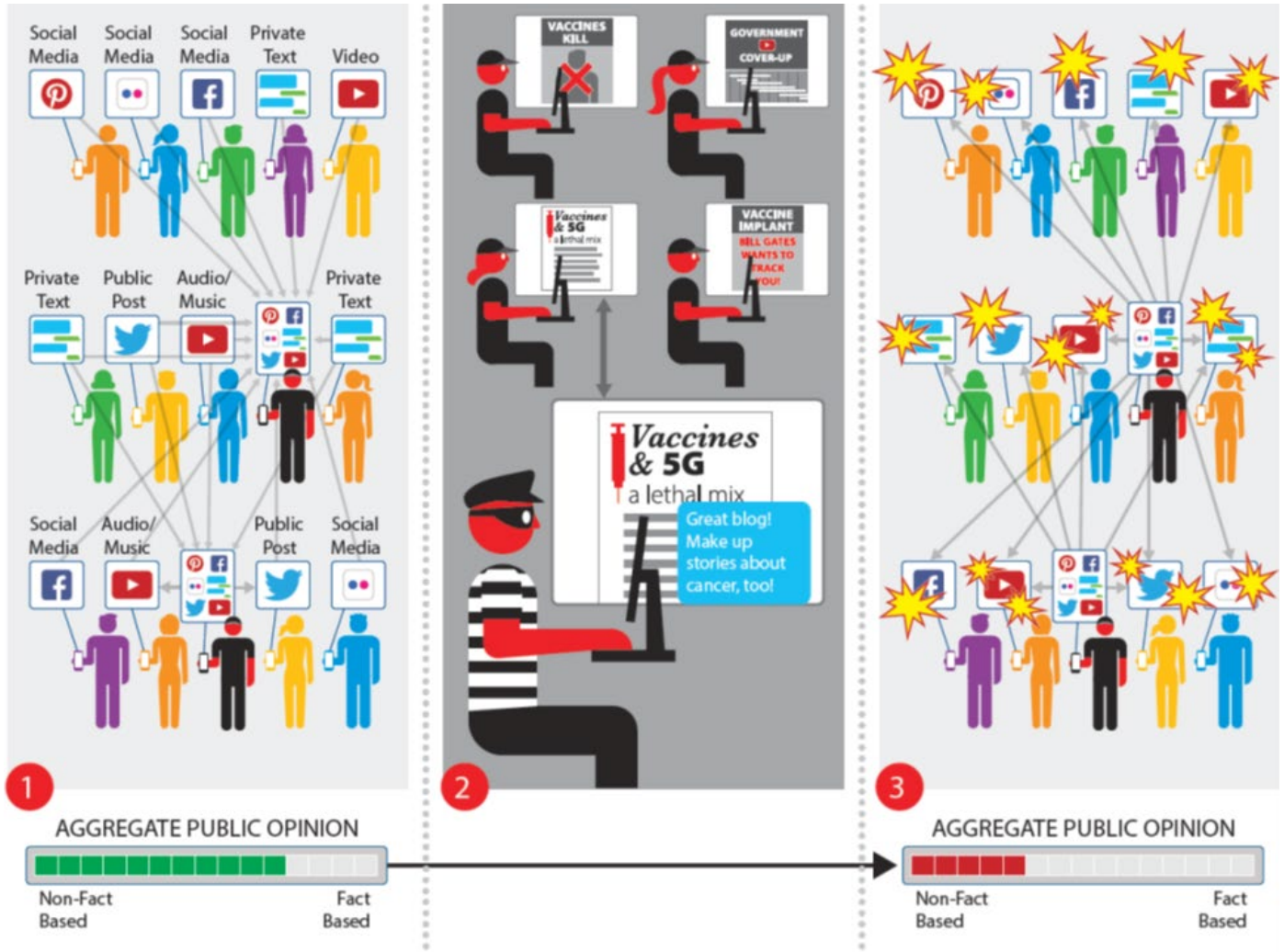
$(s_i - c) = i's\ squared\ error\ (from\ crowd)$
$(s_i - \theta) = i's\ squared\ error\ (from\ truth)$

Page (2008). The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies.



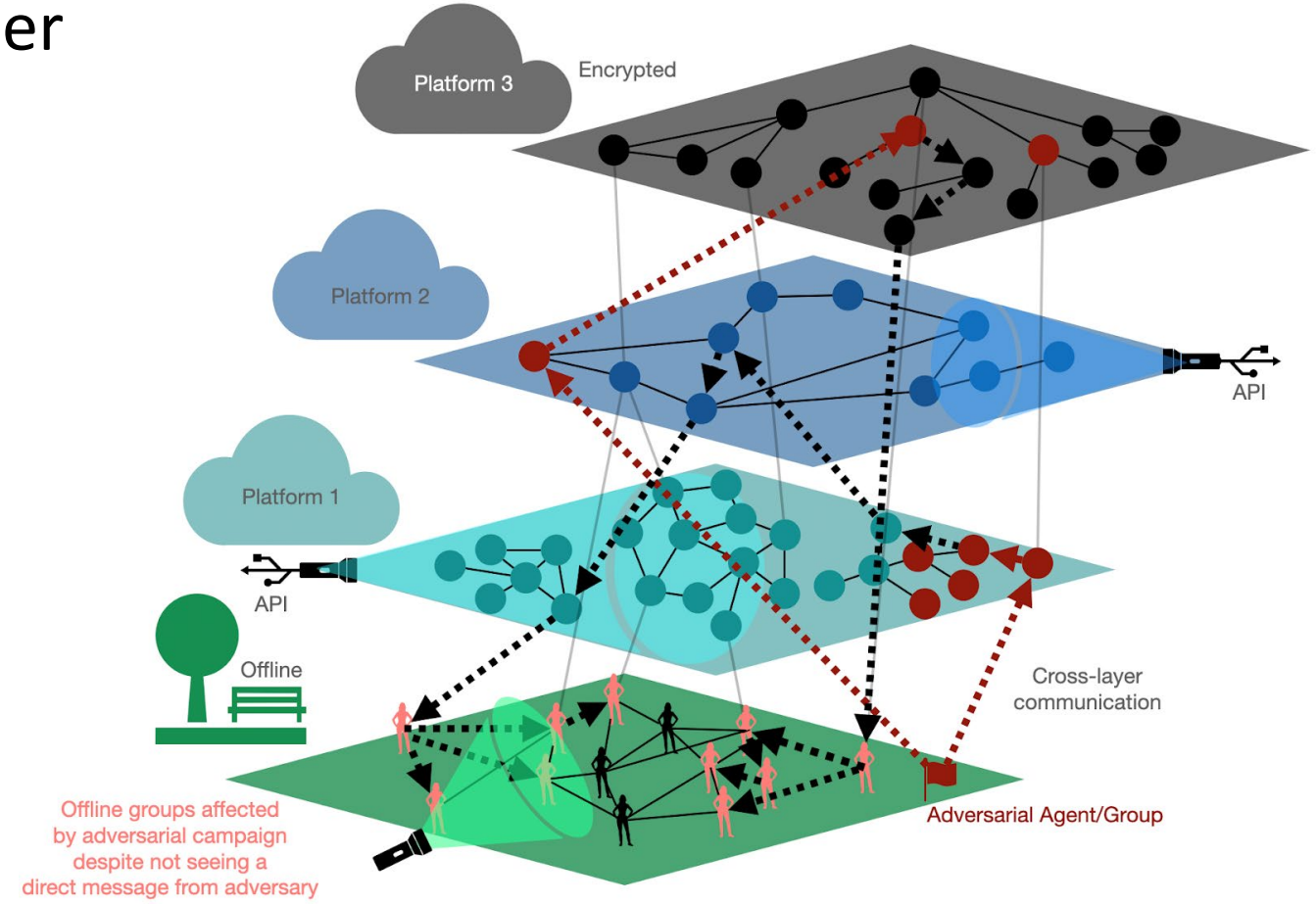
Operation Design in Mission-Critical Applications

- Adversarial information operations
  - U.S. bioweapon
    - AIDS (1980s)
    - Ebola (2014)
    - COVID (2019)
    - Ukraine (2022-)



Adversarial information operations

- Spreading faster and farther
  - Newspapers
  - Broadcast
  - Social media
  - Multimedia messaging
  - Online and offline



Data collection & intervention design

- Large-scale, limited-information & resource-constrained environments

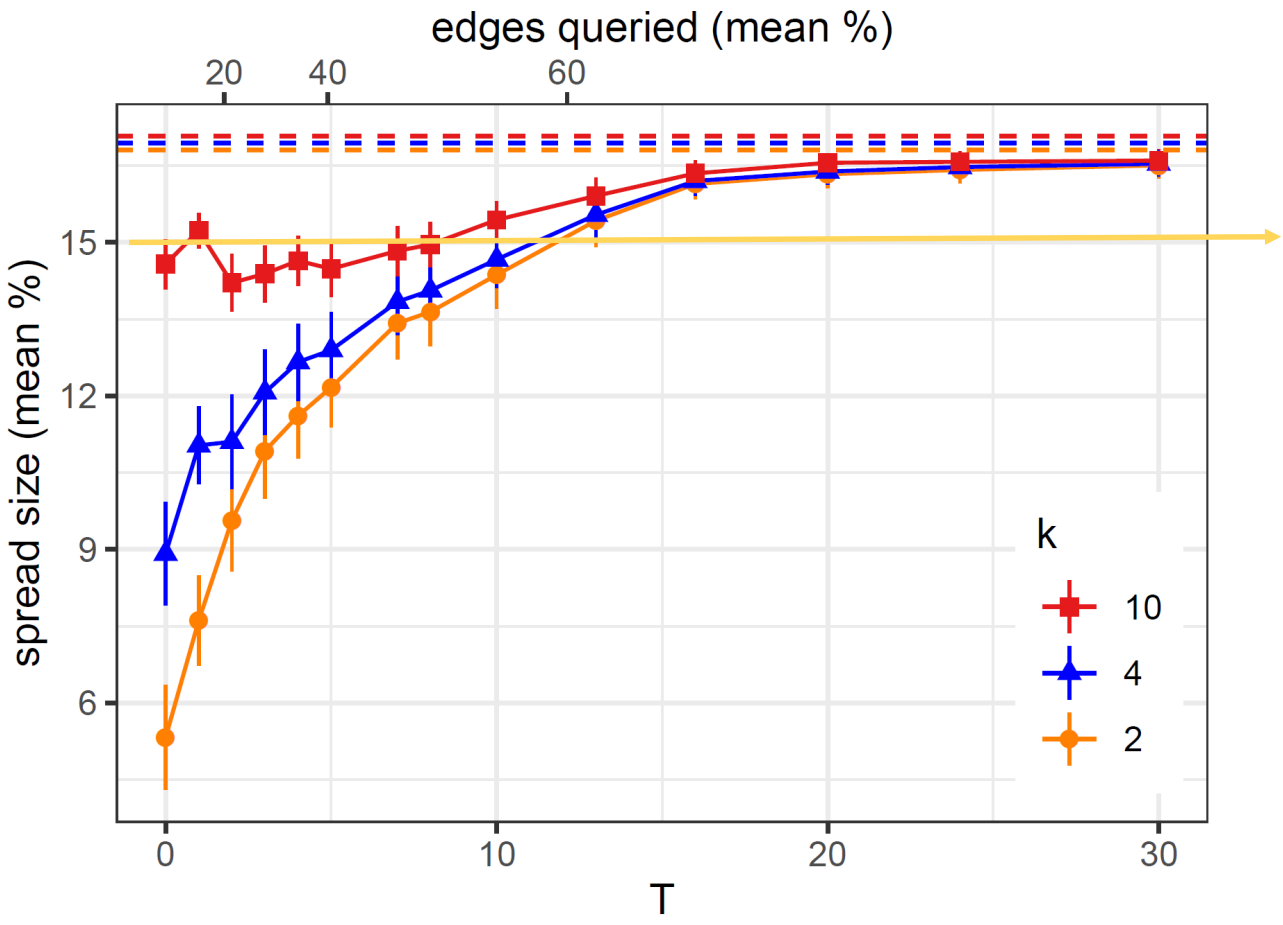
Random seeding

One-hop seeding (i.e., nomination, acquaintance targeting)

Max in-degree, degree distribution

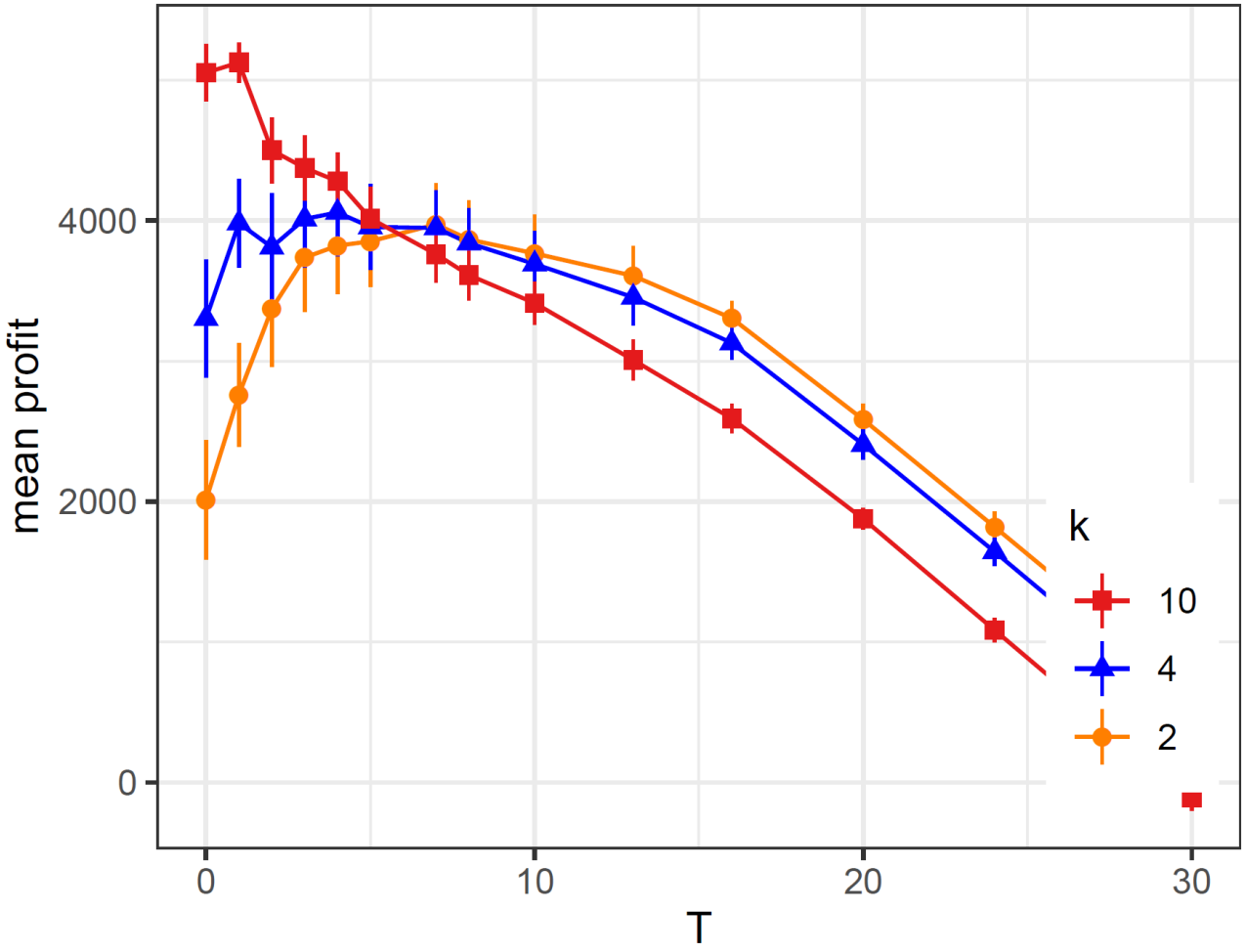
Influence maximization, optimal seeding

Trading off seed nodes for more queries



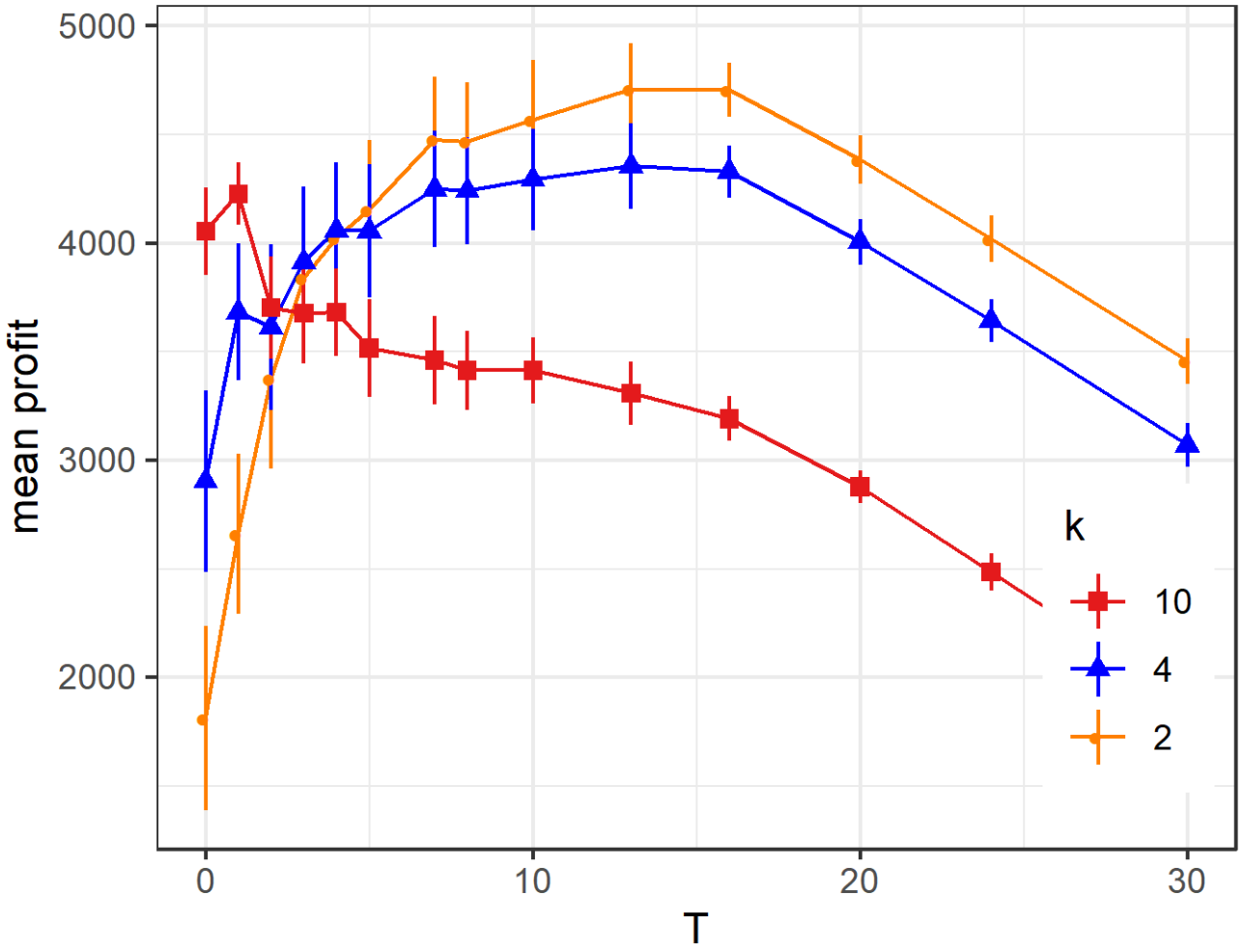
We can seed less nodes with more queries keeping the performance fixed (at 15%)

More seeds or more network data?



- Edge queries
  - unit revenue per adopter
  - $C_S = 100$, cost per seed
  - $C_T = 200$, cost per query iteration
  - Seeds half the cost of query iteration
  - More, random seeds is better

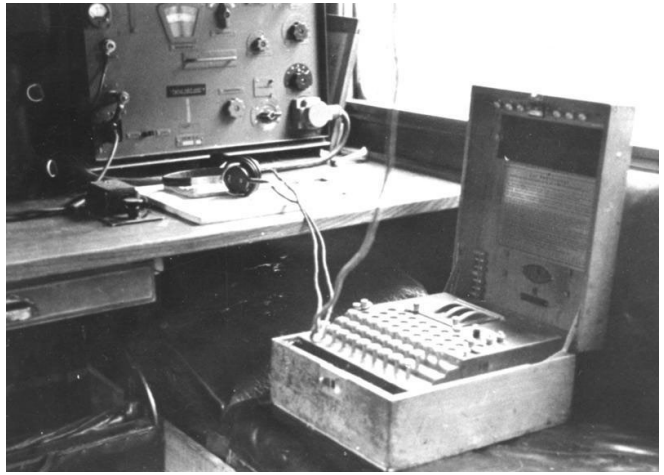
More seeds or more network data?

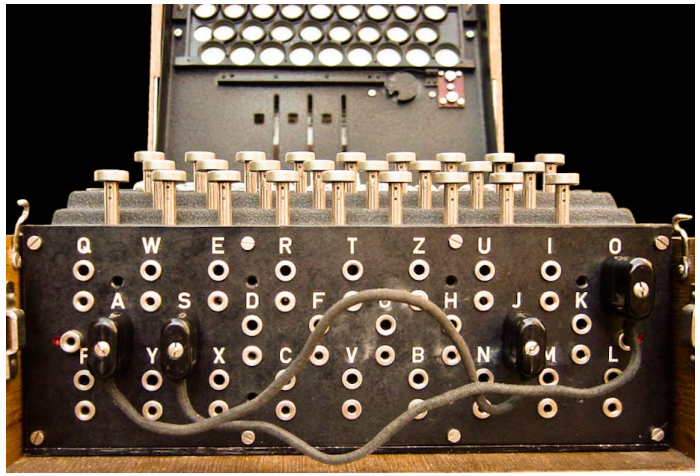


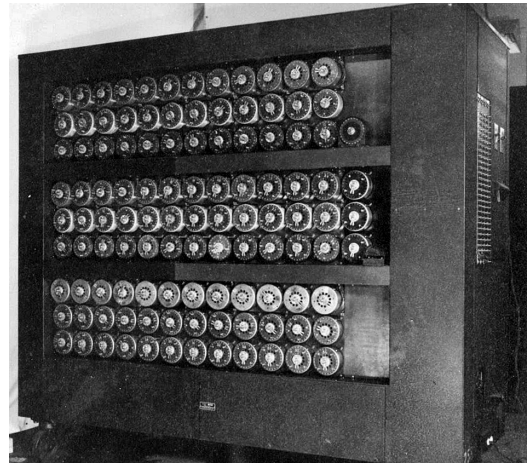
- Edge queries
  - If seeds are each twice as costly as query iterations
    - $C_S = 200, C_T = 100$
  - We should query the network, but incompletely

Hiding information acquisition resources

- Trading off performance for security
- Forward-looking value of information
- Differential privacy







Thanks! - Q&A

Please reach out!

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