Effects of Conflict on Collective Movement Decision-Making

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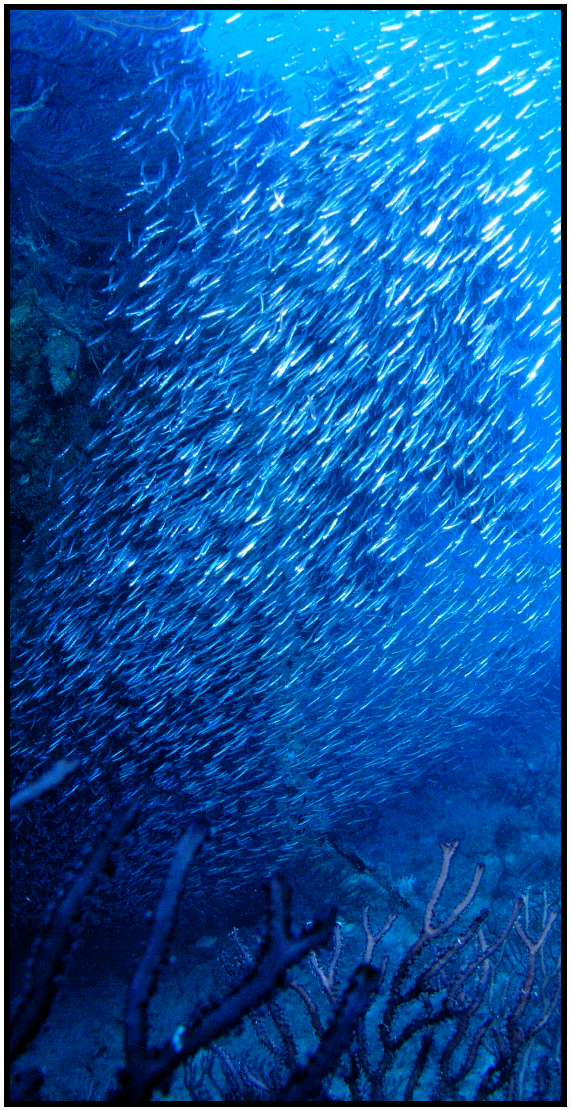
Group Coordination in Artificial Systems

- Coordination of large teams of robots or agents is difficult
- Most approaches are either:
  - Reliant on significant communication, or
  - Limited and specific
- Not practical for interesting environments
- Need an approach that is:
  - Adaptive
  - Not reliant on explicit communication
  - Simple
- Models decision-making process

Inspiration from Natural Systems

- Collective movements requiring coordination frequently observed
- Adapt to complex, dynamic environments
- Frequently require minimal communication
- General and adaptive



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Conflict in Artificial & Natural Systems

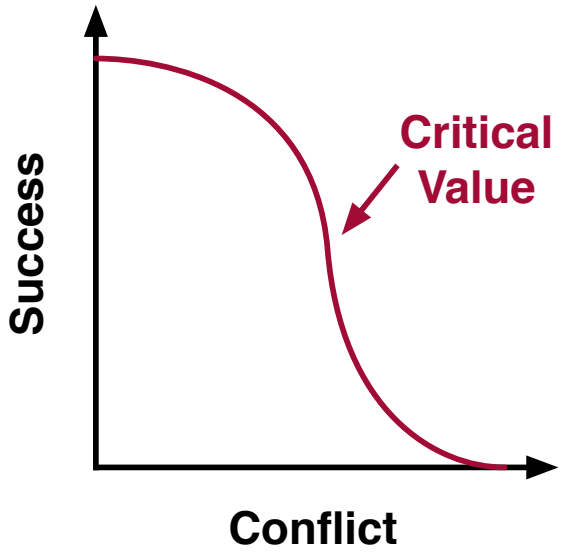
- Even in natural systems, conflicts of interest complicate coordination
- Individuals have different needs, information, and cost
- Conflict is observed universally, but most research focuses on the:
  - Navigation behaviors, or
  - Benefits of particular decision-making models
- Interested in conflict's effects on the decision-making involved in following a leader

Research Questions

How does conflict affect the success of collective movements?

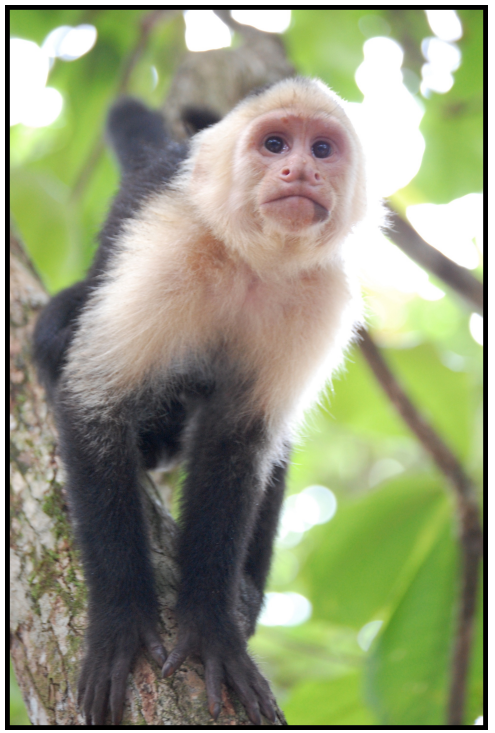
Research Questions (cont'd)

Is there a conflict critical value?



Collective Movement Model

- Modeled after observations of White-faced Capuchin Monkeys [3, 2]
- Group size of 10
- Confirmed in sheep groups of 2–8 members [4]
- Exhibits anonymous mimetism



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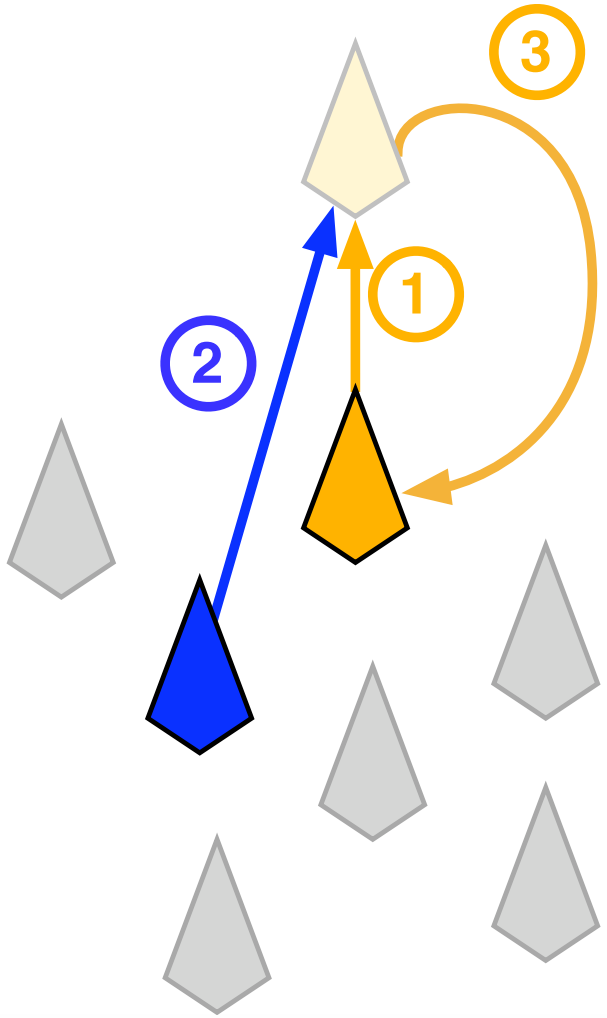
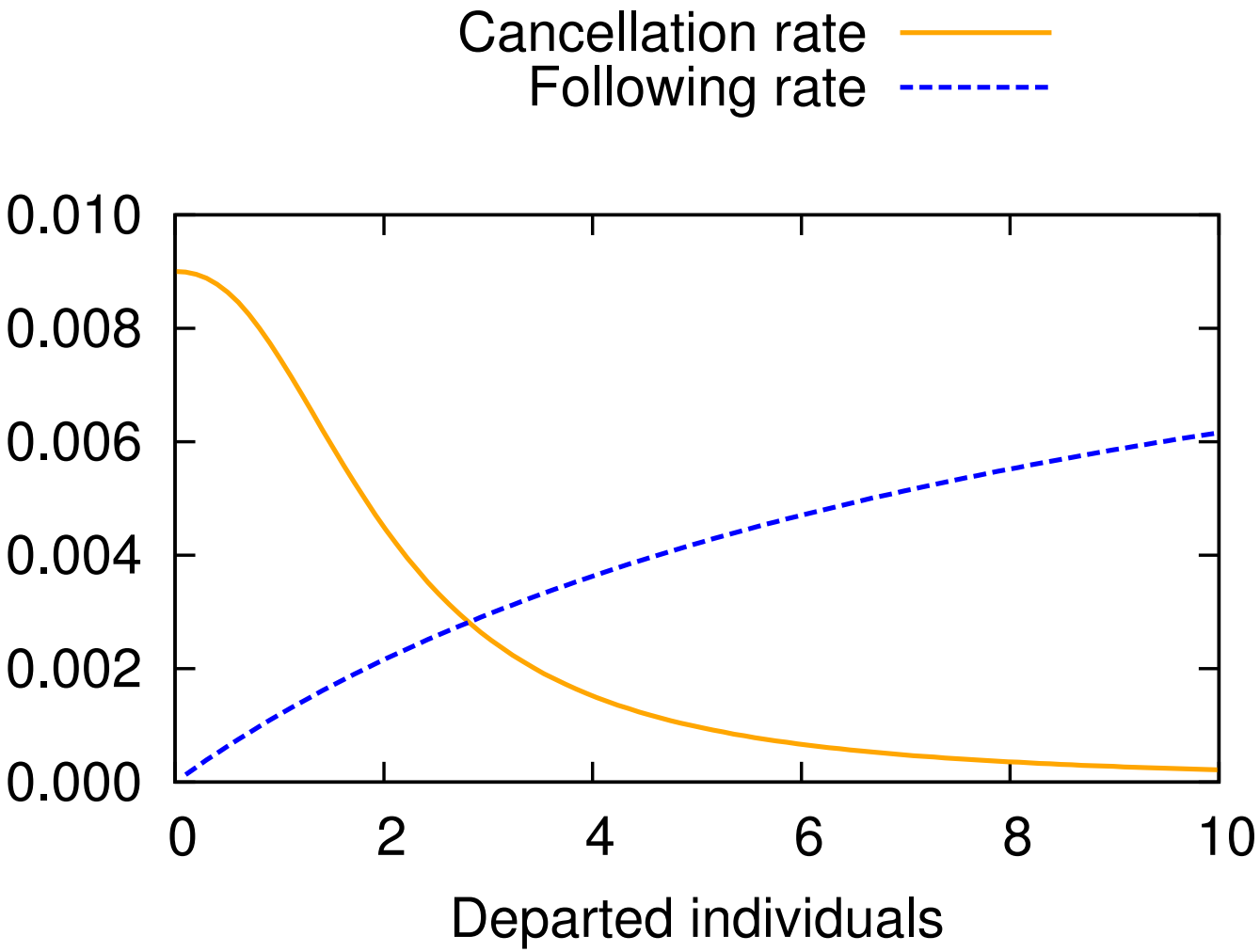
Collective Movement Events

Three decision-making events

1. Initiate a movement
2. Follow an initiator
3. Cancel a movement



Event Calculation



Event details

Original Following Rate Calculation

$$\tau_r = \alpha_f + \beta_f \frac{N - r}{r} \quad (1)$$

- Group size
- Individuals already departed
- α_f and β_f calculated from observation
- Following times drawn from: $1/\tau_r$

Following Rate Calculation with Conflict

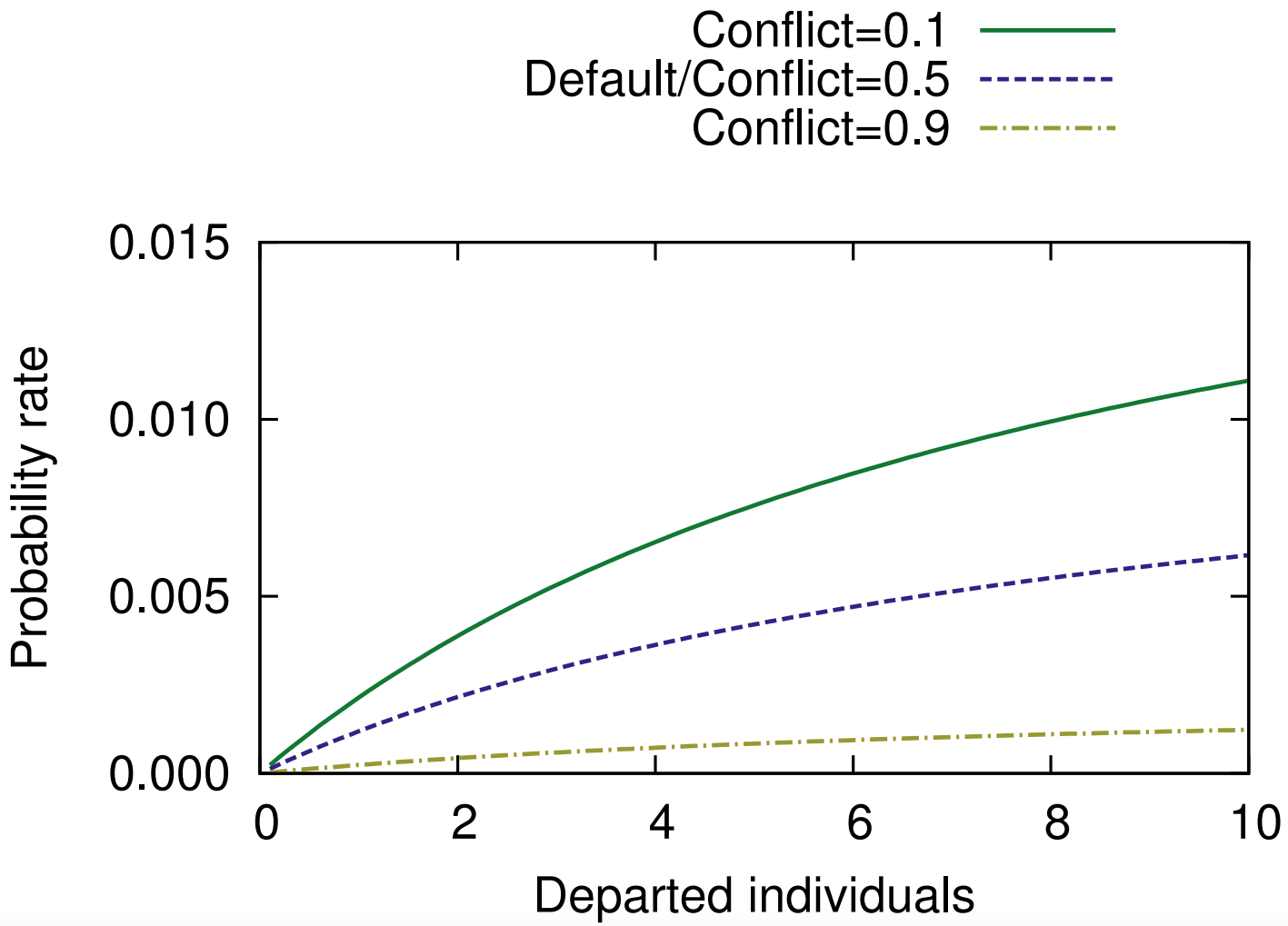
$$k_i \quad \tau_r = \quad k_i \quad \left(\alpha_f + \beta_f \frac{N - r}{r}\right)$$

where k_i is an "over-following factor"

$$k_i = 2 \times (1 - \quad c_i \quad)$$

where c_i is i's conflict value

Effects of Conflict on Following Rate



Implementation of Conflict

ABSTRACT

- No specific biological motivation
- $c_i \in [0, 1]$
- Allowed us to speculate *What if?*

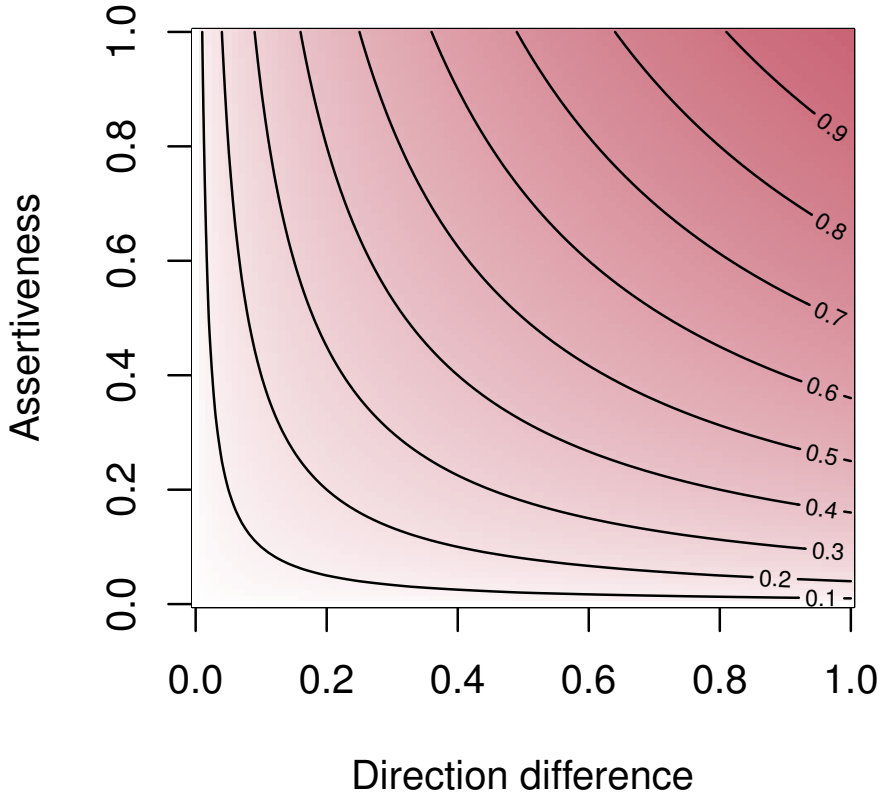
CONCRETE

- Motivated by research in natural systems
- Combination of assertiveness and difference in preferred direction [1]
- $c_i \in [0, 1]$
- Provided more realistic situations

Concrete Conflict Calculation

$$c_i = a_i^{0.5} \times |d_i - d_I|^{0.5}$$

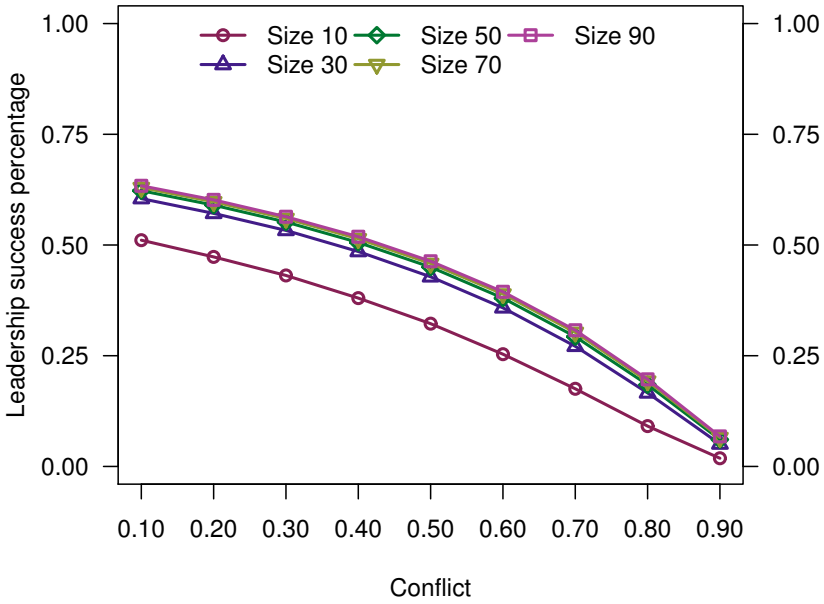
- a_i individual i's assertiveness
- d_i individual i's preferred direction
- d_I initiator's preferred direction
- c_i individual i's conflict value



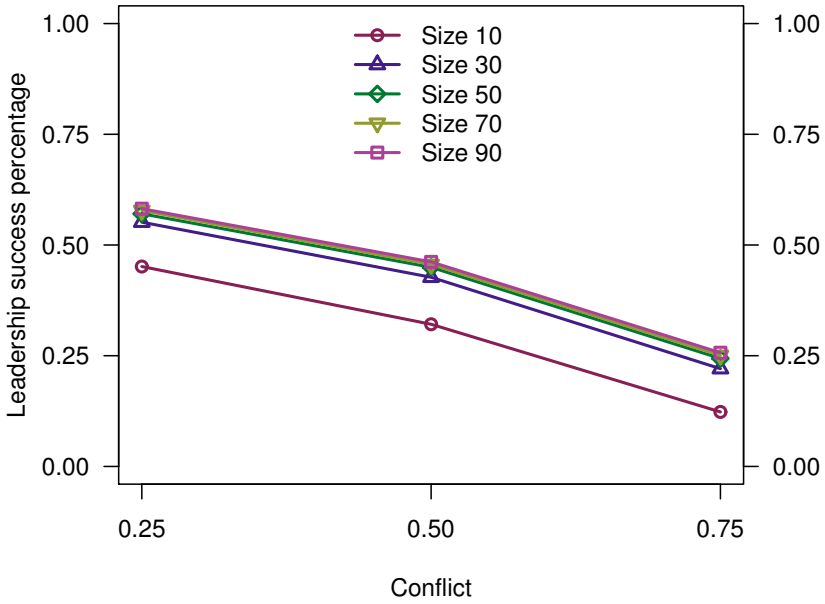
Numerical Simulations

- Evaluated group sizes in range $N = [10, 90]$
- $20,000 \times N$ simulations per evaluation
- Success: All members participating
- `ABSTRACT`
  - Same conflict value
  - Gaussian conflict value with standard deviation $\pm$ 0.1
- `Concrete`
  - Single mean direction with standard deviation
  - Multiple mean directions with standard deviation

Mean Leadership Success Percentage: Abstract



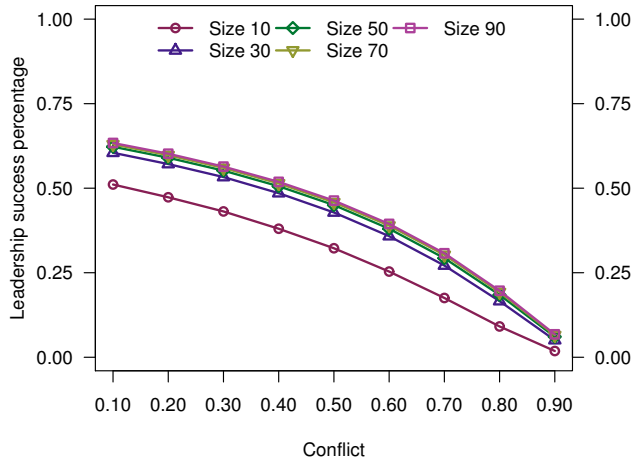
ABSTRACT-SAME



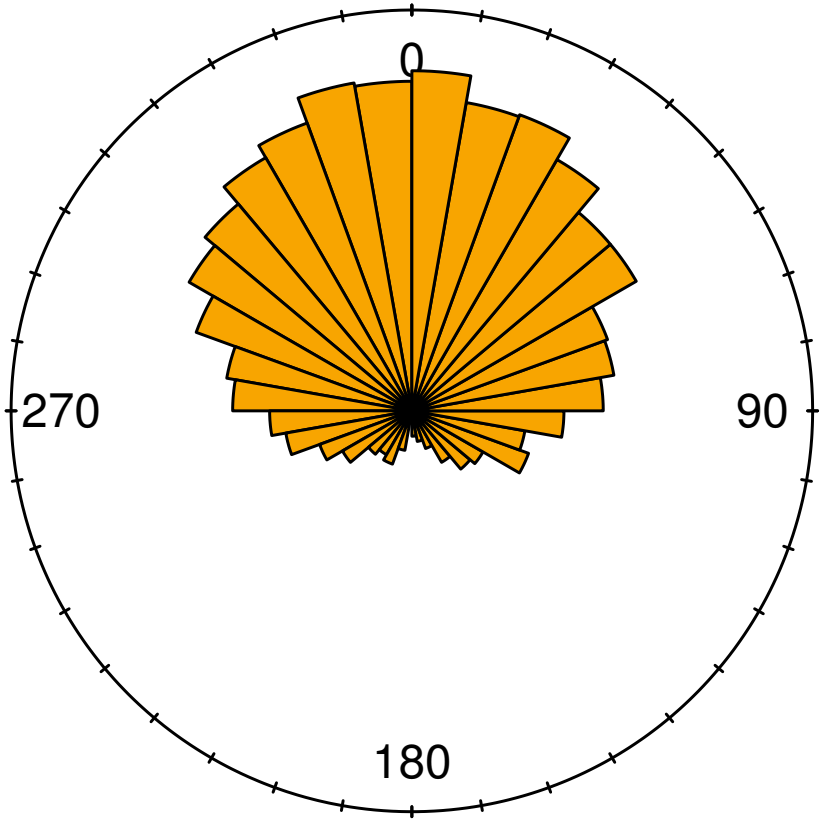
ABSTRACT-GAUSSIAN

Simulation Predictions: Abstract

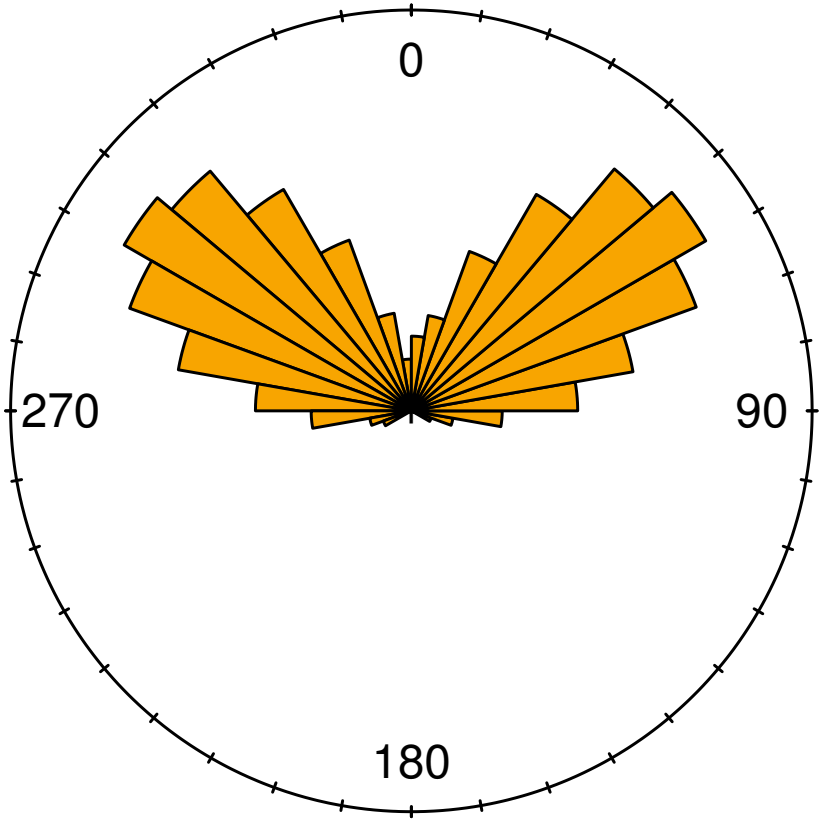
- Increased conflict results in reduced success
- Non-linear effects
- No critical conflict value
- Minimal difference between large group sizes ($< 5\%$)
- Consistent results between treatments, but gaussian had higher standard deviation
- Variations in gaussian balance out



Representative Preferred Direction Distributions

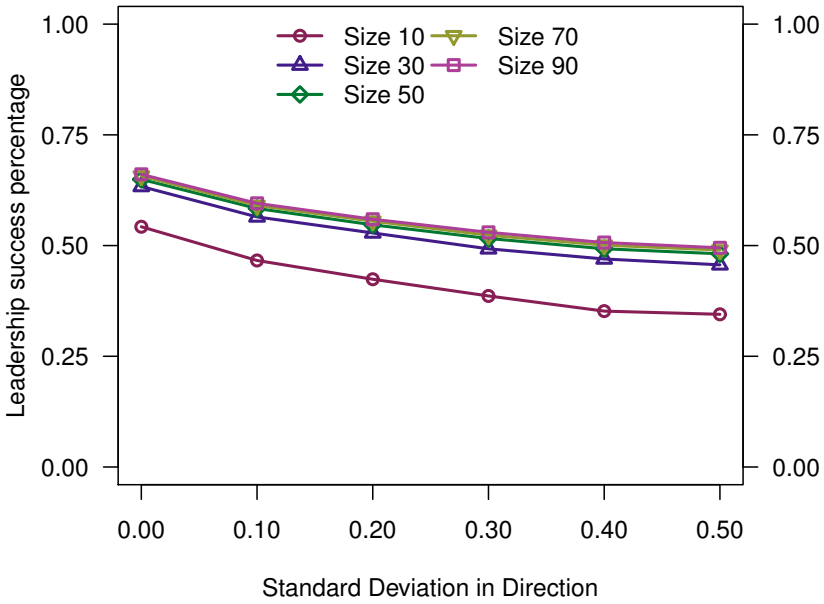


CONCRETE-SINGLE

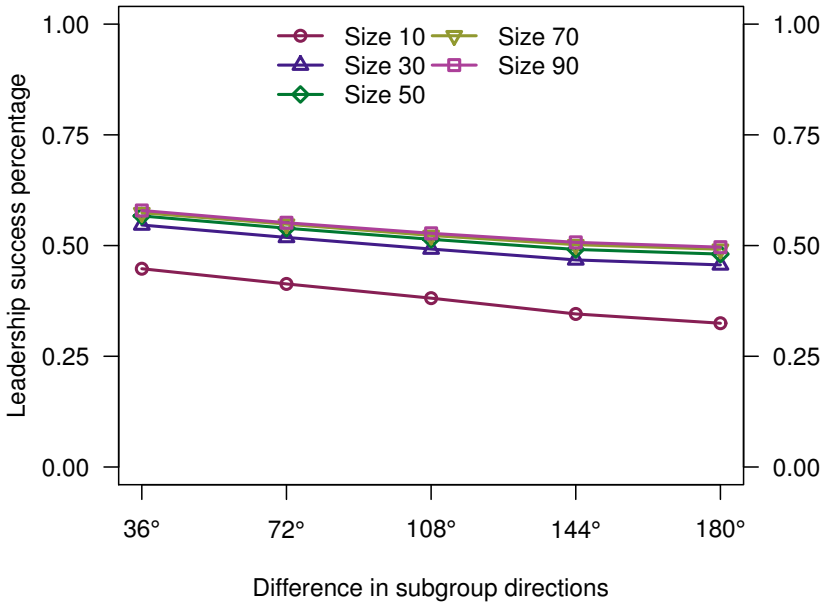


CONCRETE-MULTIPLE

Mean Leadership Success Percentage: Concrete



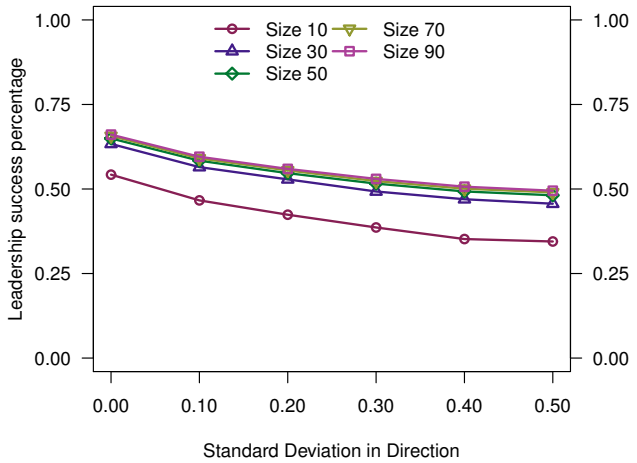
CONCRETE-SINGLE



CONCRETE-MULTIPLE

Simulation Predictions: Concrete

- Increased conflict results in reduced success
- Non-linear effects
- No critical conflict value
- Minimal difference between large group sizes
- Consistent between single and multiple direction conflicts
- Maximum conflict value experienced comparable to 50% ABSTRACT conflict value



Conclusions

- Non-linear effects of conflict
- No critical conflict value resulting in a drastic reduction in leadership success
- Consistent results between all combinations
  - ABSTRACT-SAME
  - ABSTRACT-GAUSSIAN
  - CONCRETE-SINGLE
  - CONCRETE-MULTIPLE
- Maximum CONCRETE conflict values experienced comparable to 50% ABSTRACT conflict value

Future Work

- Dynamic (moving) simulations
  - Conflict changes over time
  - Requires navigation
- Broader meaning of conflict
  - General dissatisfaction
  - Changes over time, even if stationary

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Questions?

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Supplemental

Calculating Initiation Events

- All individuals can initiate movement

$$\tau_i \tag{2}$$

- τ_i calculated from observation
- Initiation times drawn from: $1/\tau_i$

Return

Calculating Following Events

$$\tau_r = \alpha_f + \beta_f \frac{N - r}{r} \quad (3)$$

- Group size
- Individuals already departed
- α_f and β_f calculated from observation
- Following times drawn from: $1/\tau_r$

Return

Calculating Cancelling Events

$$C_r = \frac{\alpha_c}{1 + (r/\gamma_c)^{\varepsilon_c}} \tag{4}$$

- Individuals already departed
- α_c, γ_c and ε_c calculated from observation
- Cancellation times drawn from: C_r

Return