Adapting to a Changing Environment Using Winner and Loser Effects

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Motivation

- Improve group cooperation and coordination
- Transitory leadership
- Example: Robot search and rescue team

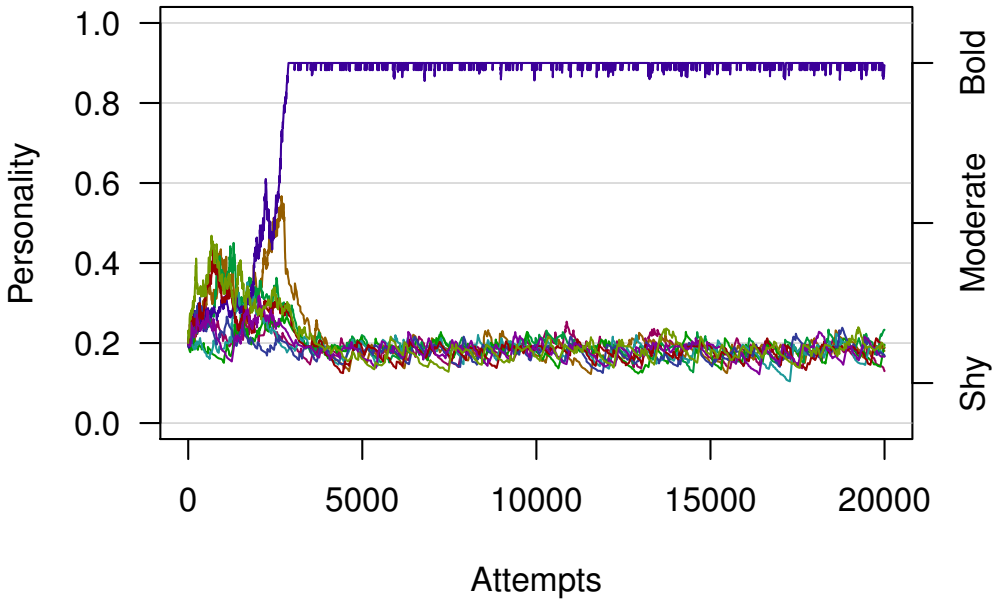
Image by Boonsri Dickinson and available at
http://www.smartplanet.com/blog/science-scope/robots-to-the-rescue-searching-for-survivors-checking-on-structural-damage-in-japan/

Behavioral Attributes

- Personality
  - Set of correlated traits that affect behavior
  - Bold $\rightarrow$ leaders
  - Shy $\rightarrow$ followers
- Winner and Loser Effects
  - Experiences change personality
  - Success $\rightarrow$ more experiences
  - Failure $\rightarrow$ fewer experiences

Previous Work

- Static environment
- Adaptive personality using winner and loser effects
- Stable differentiation
- Leaders emerge



Research Hypothesis

Winner and loser effects produce personalities with stable, transitory leaders who change roles in response to changes in the environment

Collective Movement Model

- Biologically inspired
- Modeled after observations of White-faced Capuchin Monkeys [2, 1]
- Confirmed in sheep groups of 2–8 members [3]
- No movement

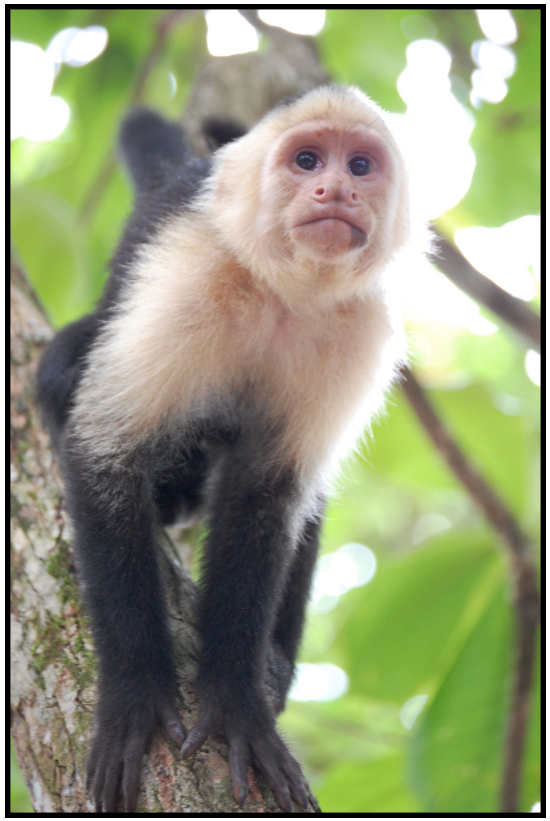
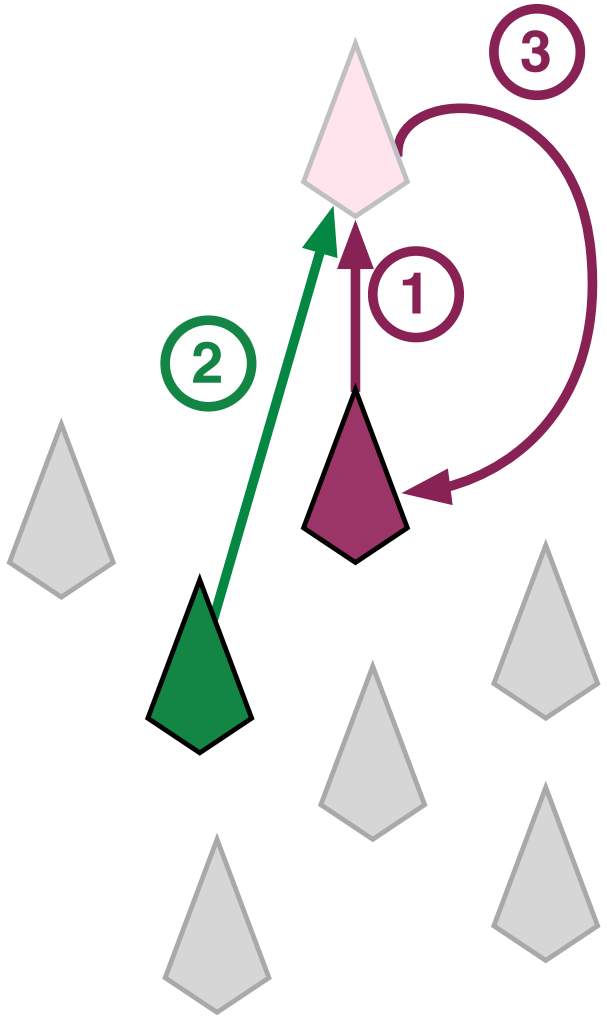


Image available at http://a-z-animals.com/animals/white-faced-capuchin/pictures/1895/

Decision Events

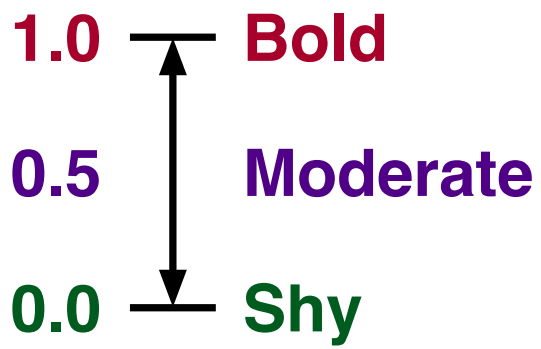
Three decision-making events

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

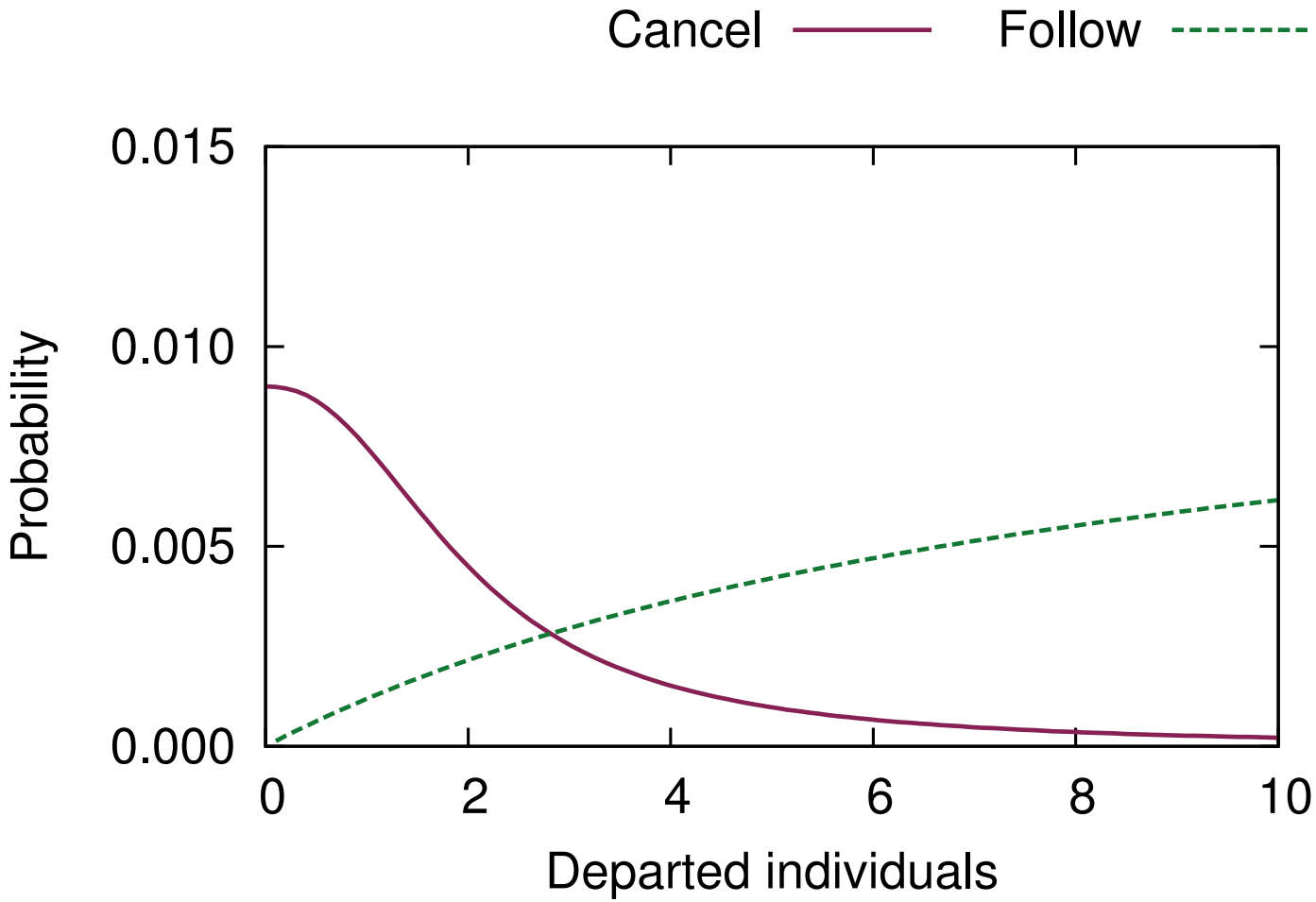


Integrating Personality

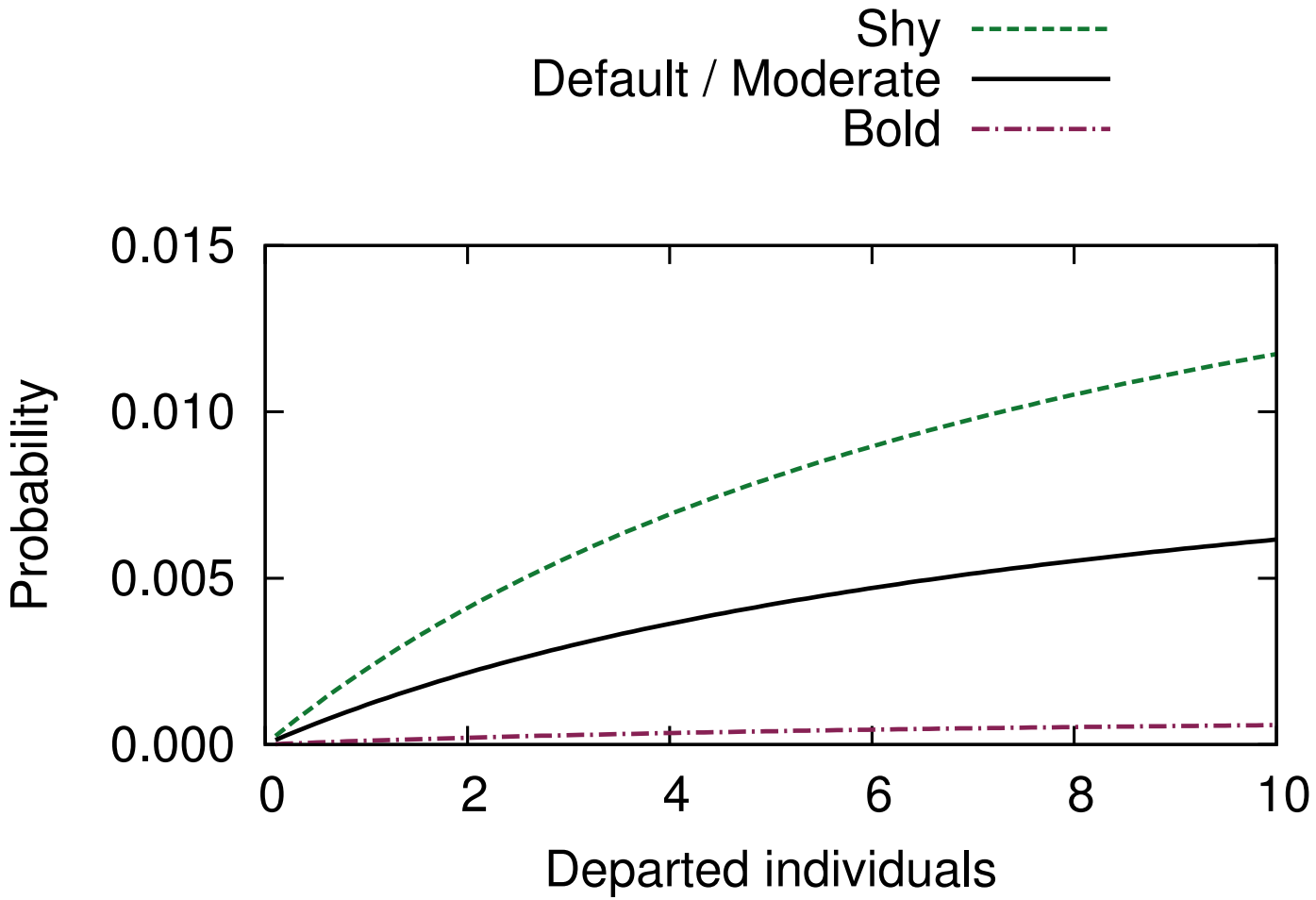
- **Bold**:
  ⇧ Initiate, ⇩ Follow, ⇩ Cancel
- **Shy**:
  ⇩ Initiate, ⇧ Follow, ⇧ Cancel
- Limited personalities to [0.1,0.9]
- Assumed default personality of 0.5



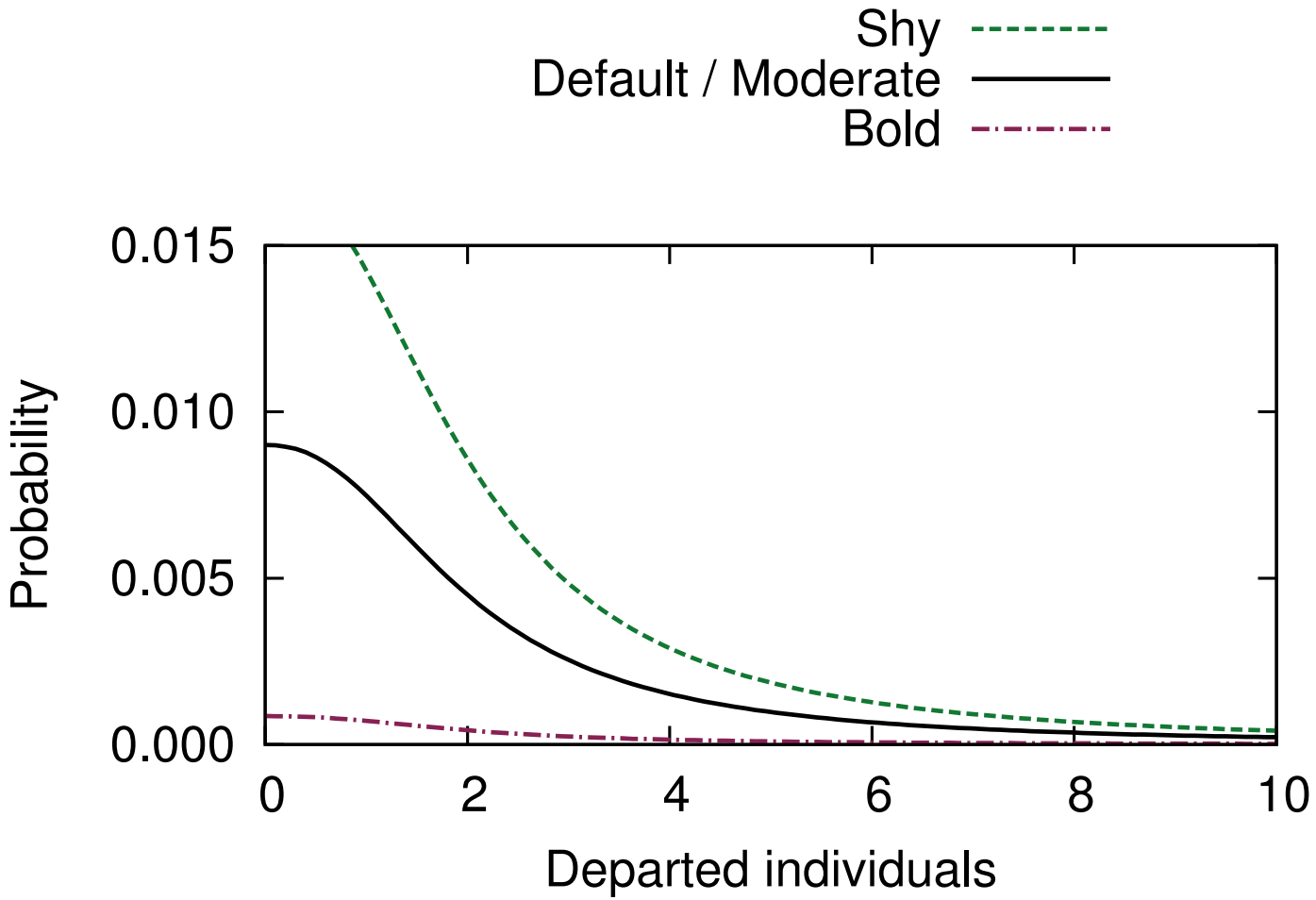
Default Decision Probabilities



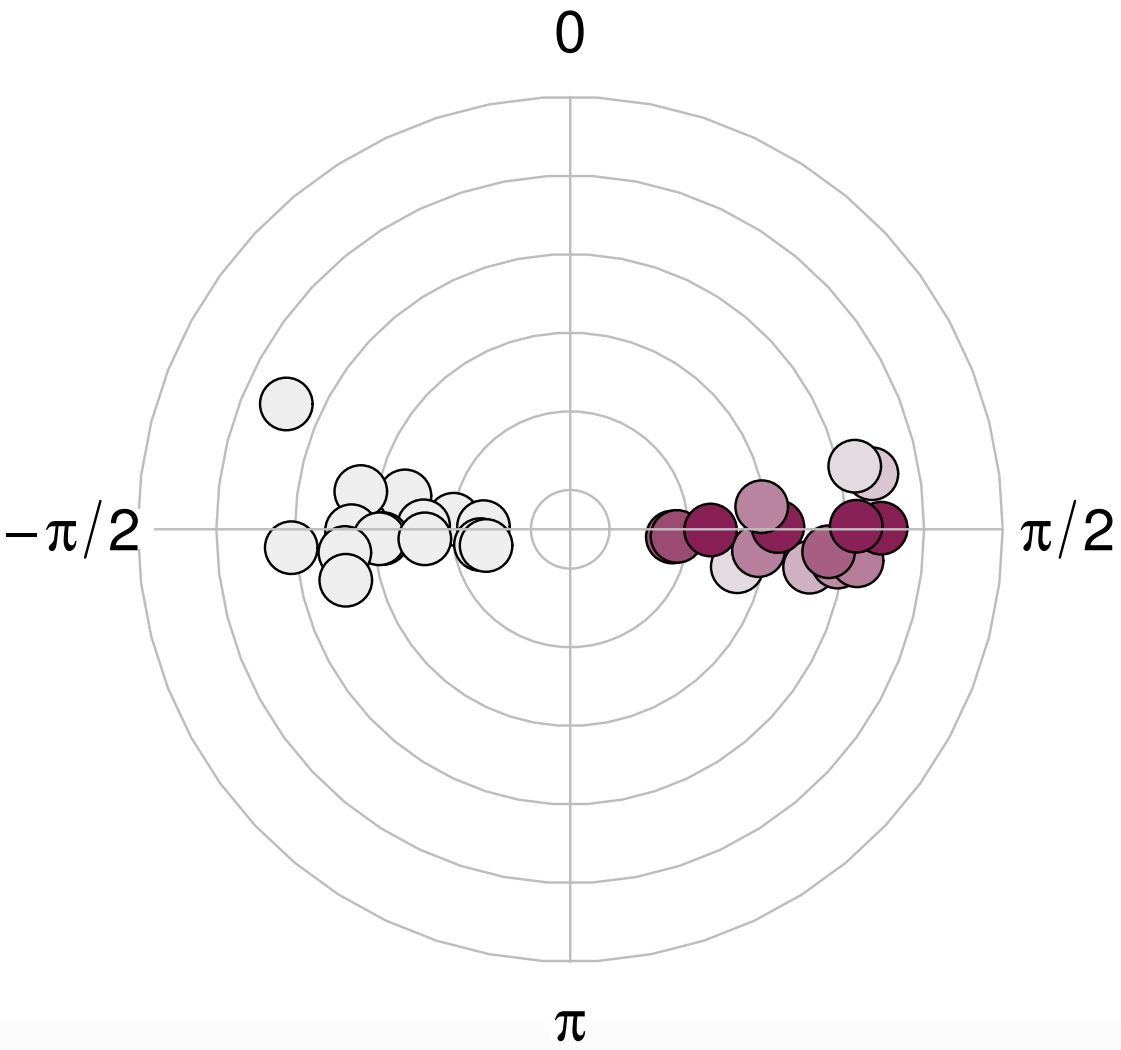
Effects of Personality on Following



Effects of Personality on Cancelling

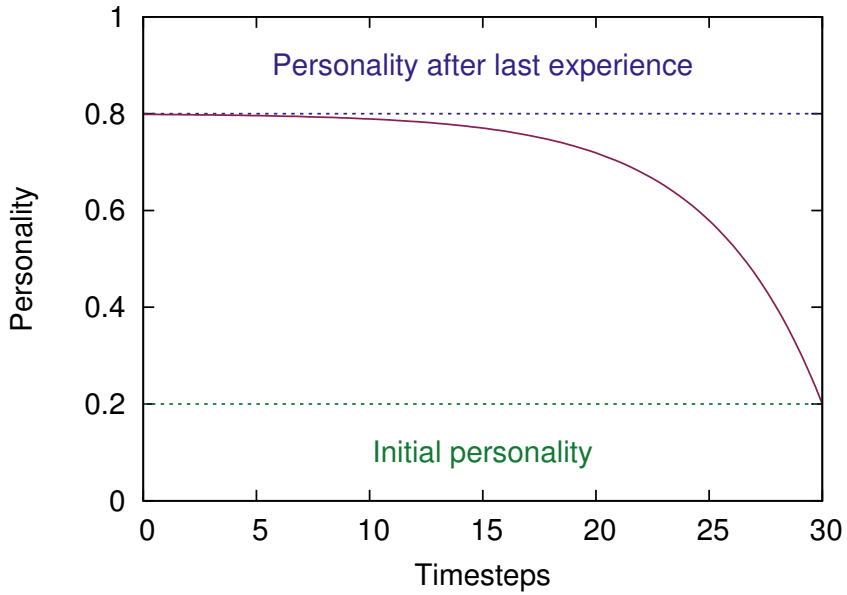


Preferred Directions



Short-term Winner and Loser Effects

- Effects decay as last experience becomes older
- Momentum decay - ”reverse” exponential
- Chosen because of its slow initial decay rate



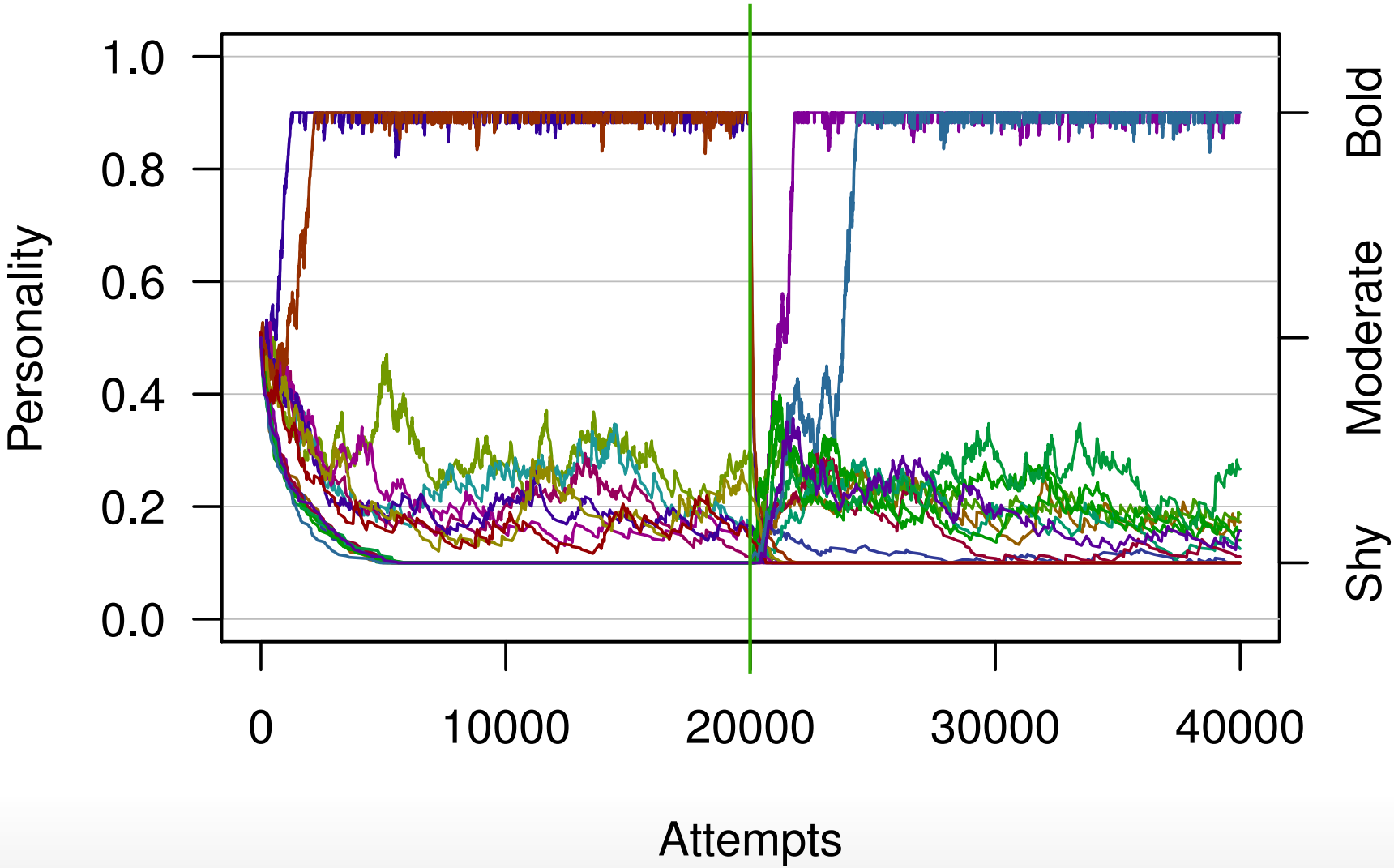
Numerical Treatments

- Initial personalities:
  - Shy ($p = 0.2$)
  - Moderate ($p = 0.5$)
  - Bold ($p = 0.8$)
- Group sizes of 20–50
- 50 evaluations
- $2000 \times N$ simulations per evaluation

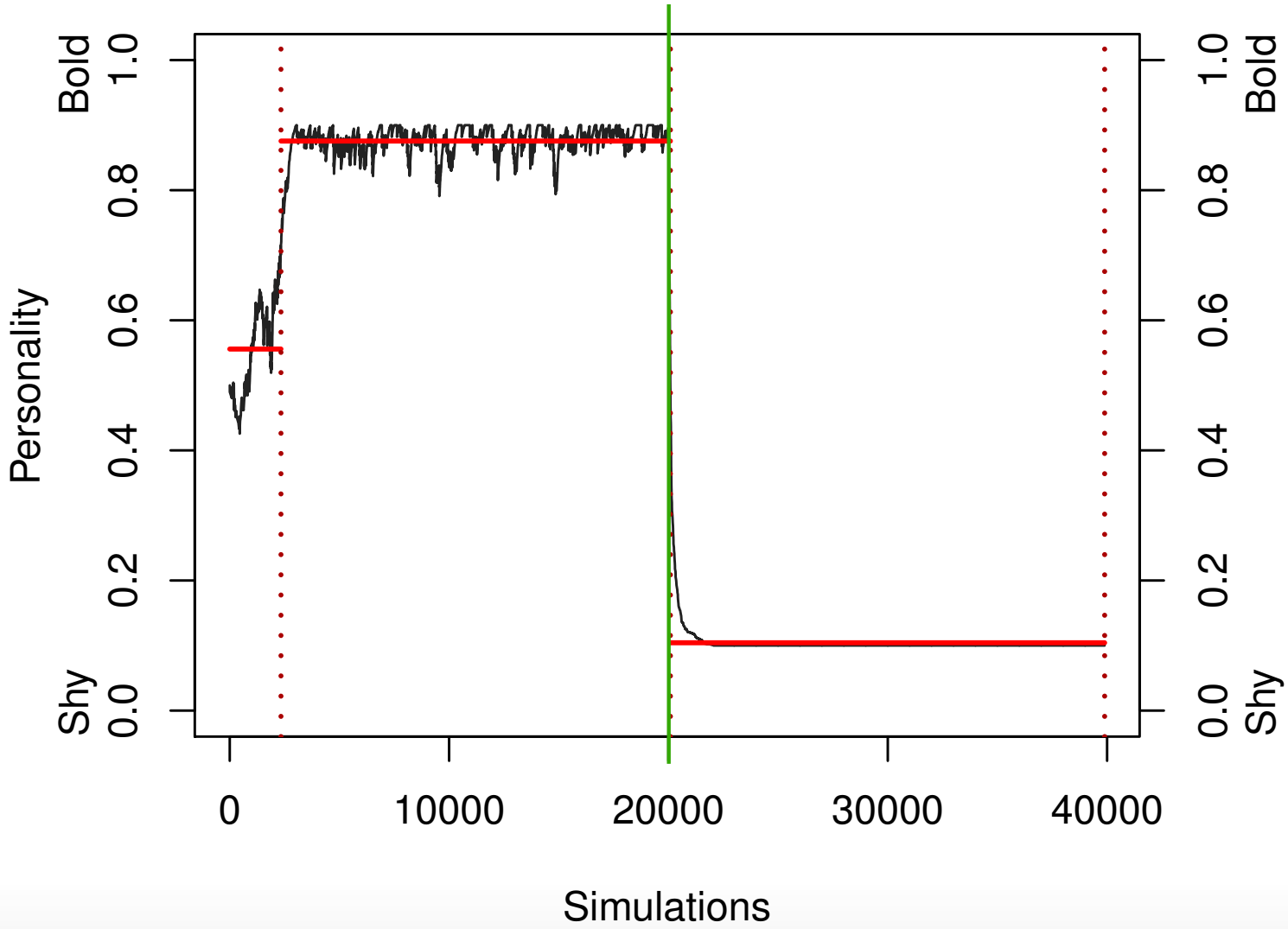
Source available at

https://github.com/snucsne/bio-inspired-leadership

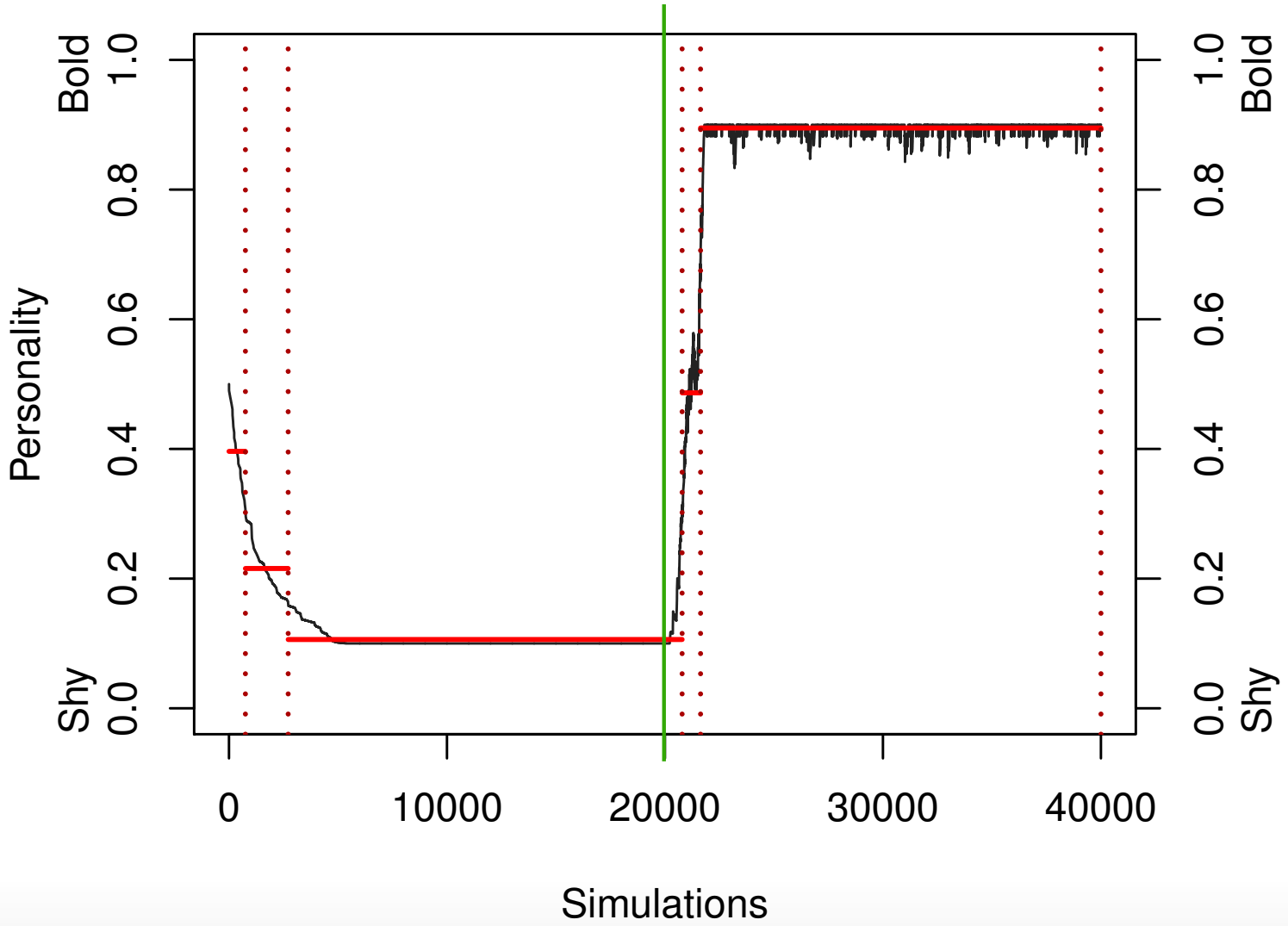
Direction Change: All Personalities ($N = 20$)



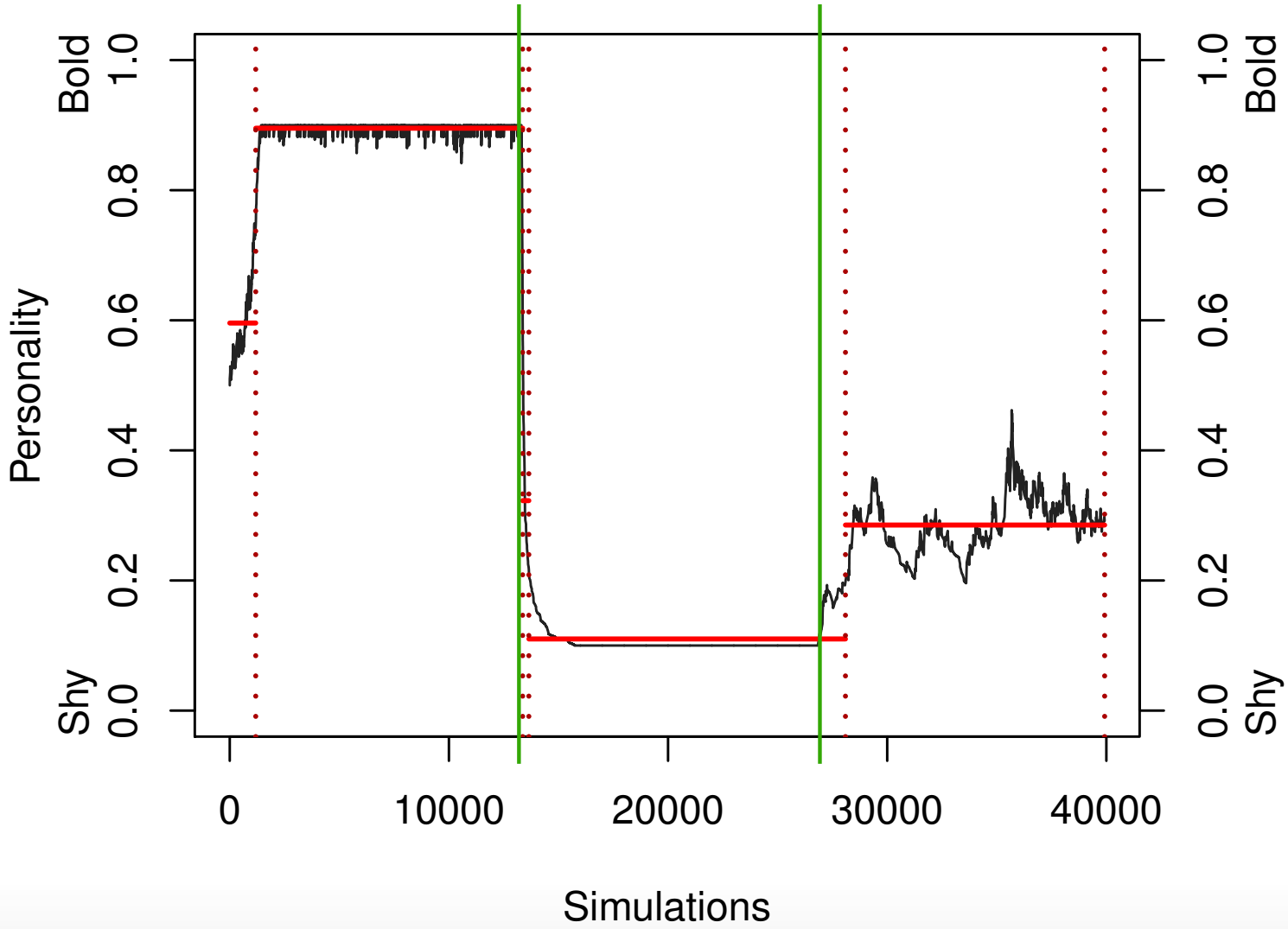
Direction Change: Once Effective Leader



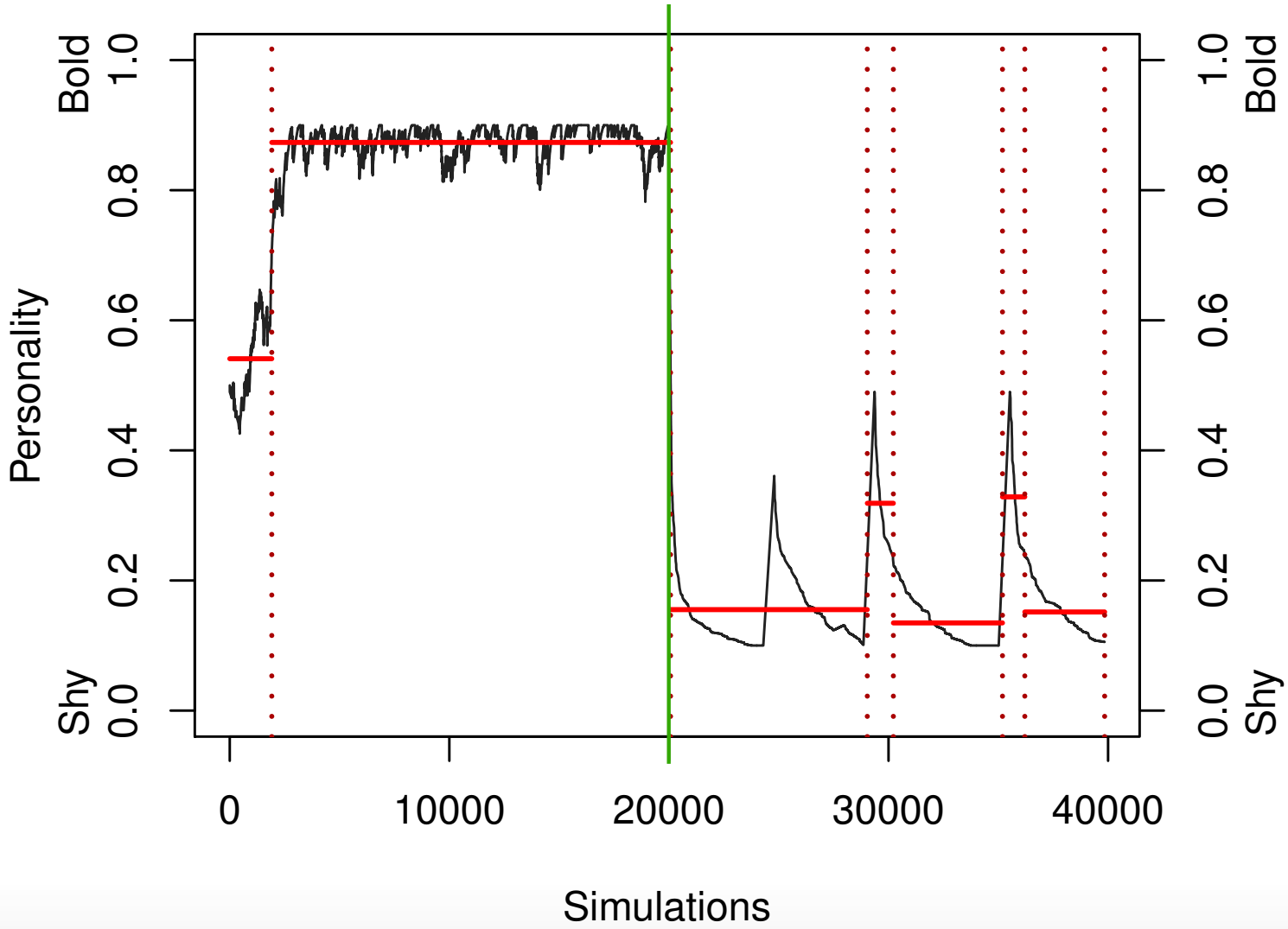
Direction Change: New Leader



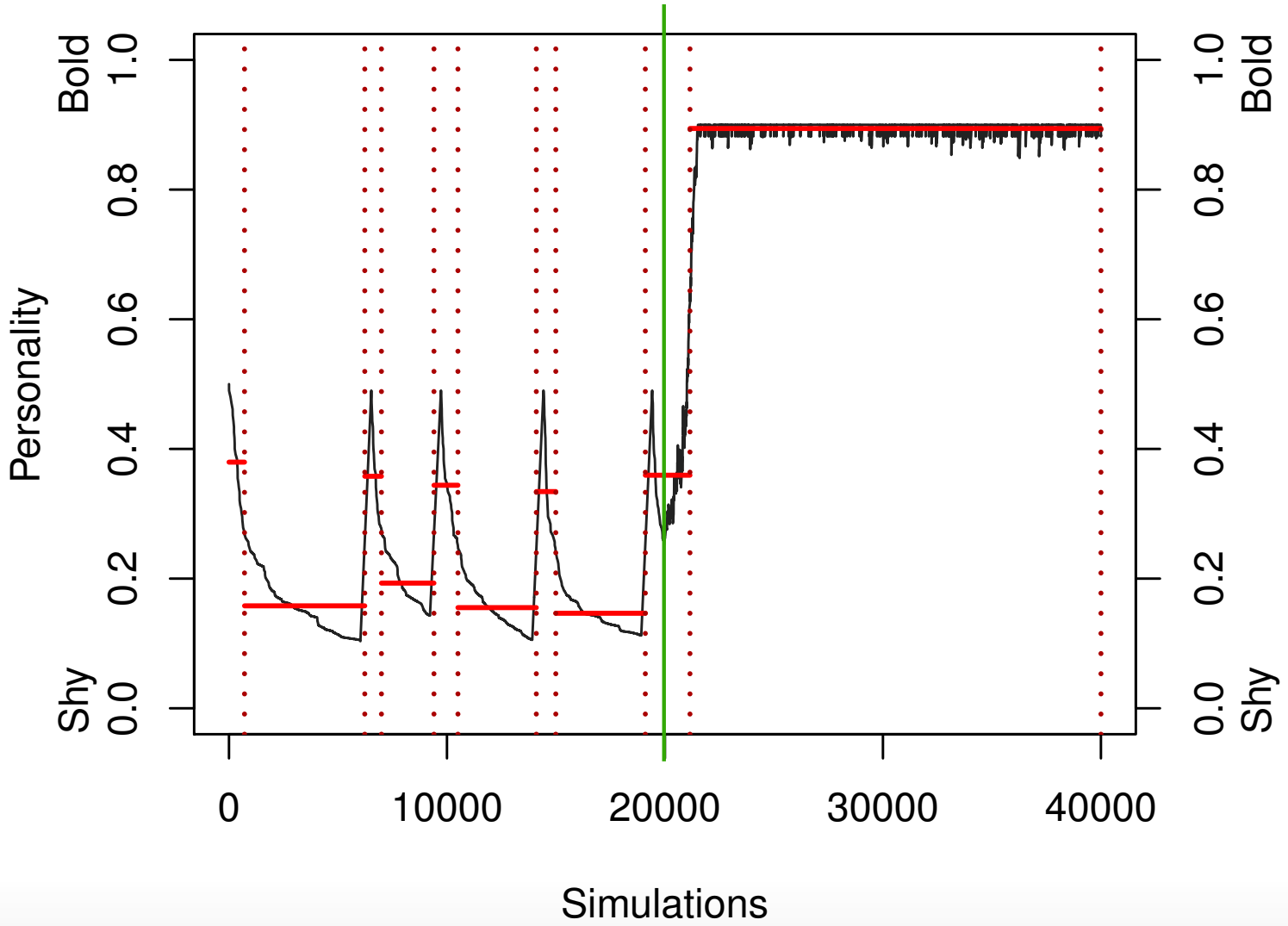
Direction Change & Change Back



Direction Change: Personality Decay



Direction Change: Personality Decay



Conclusions

- Personalities adapt to success and failure
  - Fixed environment (previous)
  - Recently changed (dynamic)
- Decay promotes faster adaptation
  - Provides personality “boost”
  - Gain up-to-date information
- Initial personality affects success (especially with decay)
  - Initially bold $\rightarrow$ no differentiation
  - Initially shy $\rightarrow$ differentiation

Future Work

- Incorporate results for actual movement
- Investigate better balance between personality decay benefits and detriments
- Search for quicker methods of adaptation

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Questions?

Source code can be found at:

github.com/snucsne/bio-inspired-leadership

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Supplemental

Decision Event Equations

Initiation

$$k_i / \tau_o \tag{1}$$

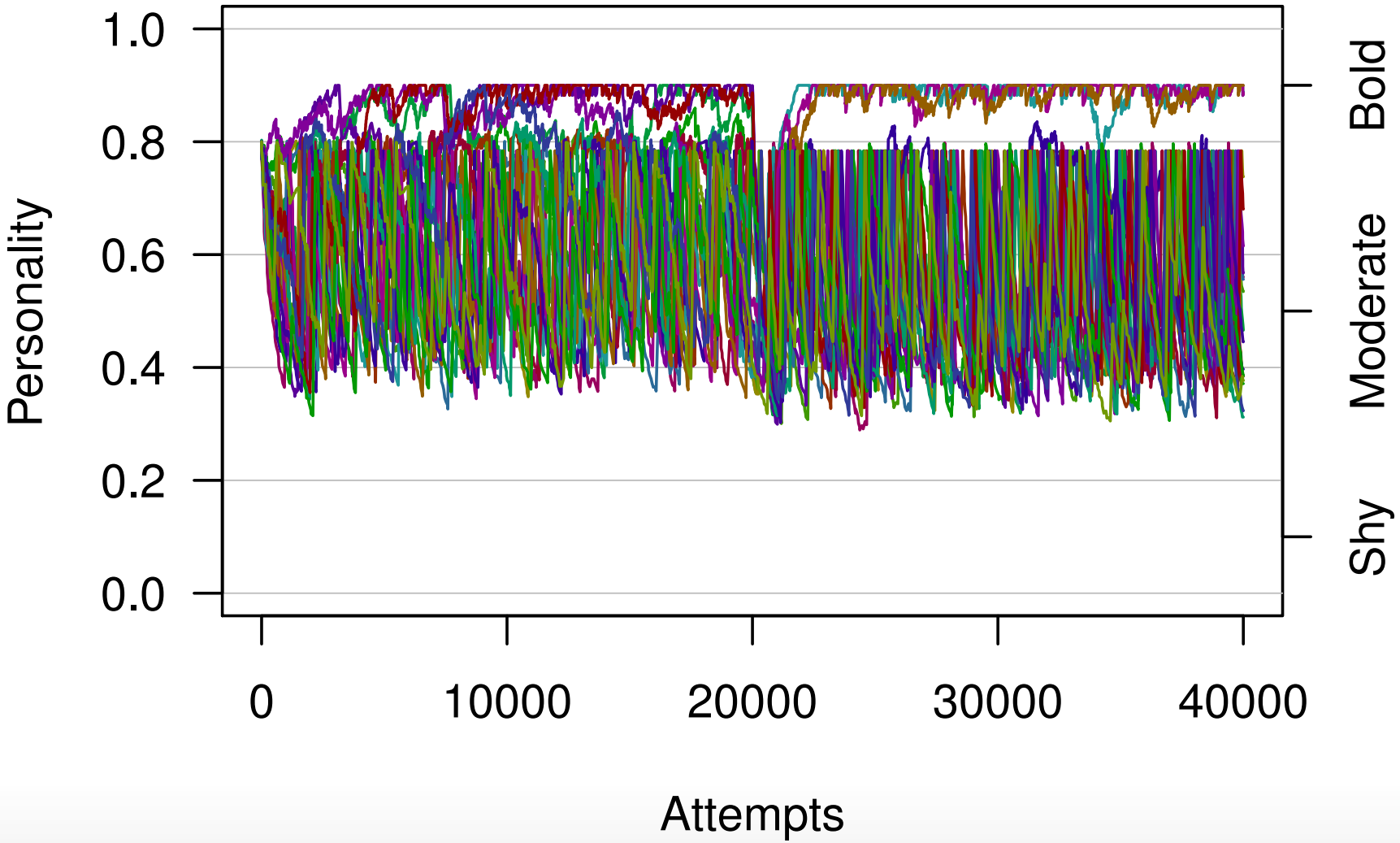
Following

$$\tau_r = \frac{1}{k_i} \left(\alpha_f + \beta_f \frac{N - r}{r} \right) \tag{2}$$

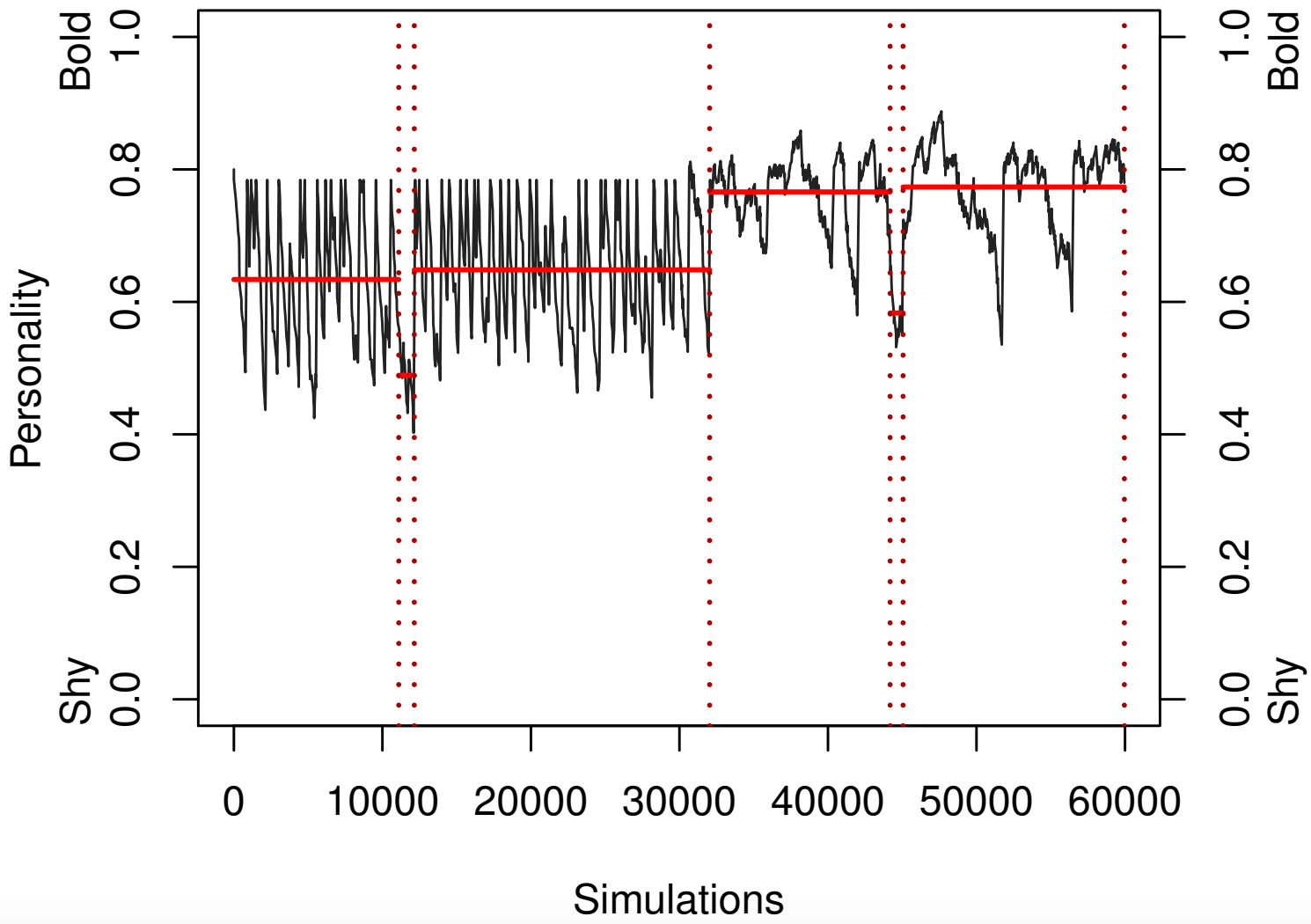
Canceling

$$C_r = k_i \left(\frac{\alpha_c}{1 + (r/\gamma_c)^{\varepsilon_c}} \right) \tag{3}$$

Destructive Personality Decay



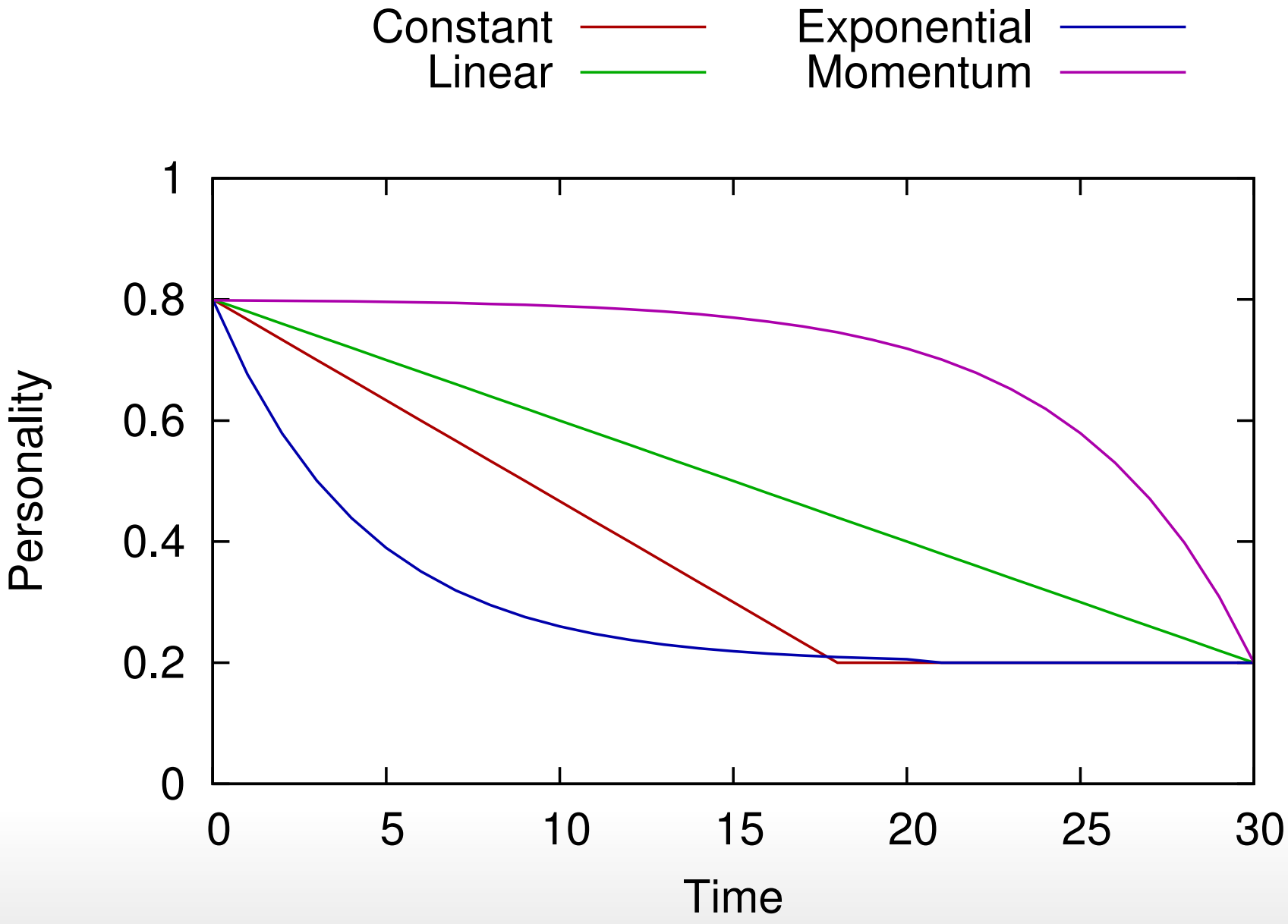
Destructive Personality Decay



Statistical Analysis

Group Size	Adaptation	Bold statistic	Without decay			With decay		
20	Change	Simulations	2503.6	±2663.2		2222.1	±2861.2	*
		Simulations (first)	1470.1	±431.3		1198.6	±438.6	*
30	Change	Initiations	387.7	±212.3		334.1	±228.8	*
		Initiations (first)	210.9	±37.3		158.6	±40.1	*
		Simulations	5613.0	±5213.0		5608.5	±6523.2	*
		Simulations (first)	1791.9	±416.3		1254.9	±472.1	*
40	Initial	Initiations	238.5	±152.4	*	262.5	±163.4	
		Simulations	4946.9	±5023.5	*	7002.5	±8112.0	
	Change	Initiations	391.2	±212.1		305.8	±185.4	*
		Initiations (first)	194.2	±29.1		130.4	±31.9	*
		Simulations	8983.4	±8321.4		8790.1	±9145.3	*
		Simulations (first)	2364.6	±432.7		1680.2	±435.9	*
50	Initial	Simulations	6824.6	±7155.9	*	8869.4	±10034.7	
	Change	Initiations	357.1	±169.9		307.5	±188.4	*
		Initiations (first)	180.3	±20.7		119.6	±17.4	*
		Simulations	11320.3	±9725.8	*	11479.1	±11256.1	
		Simulations (first)	2812.4	±450.6		2176.8	±366.2	*

Decay Graphs



Decay Equations

- Constant decay:

$$p_{t+1} = \begin{cases} p_l - \Delta t d_t & \text{if } p > p_i, \\ p_l + \Delta t d_t & \text{if } p < p_i. \end{cases} \tag{4}$$

- Linear decay:

$$p_{t+1} = p_l + \Delta t \frac{p_i - p_l}{d_t} \tag{5}$$

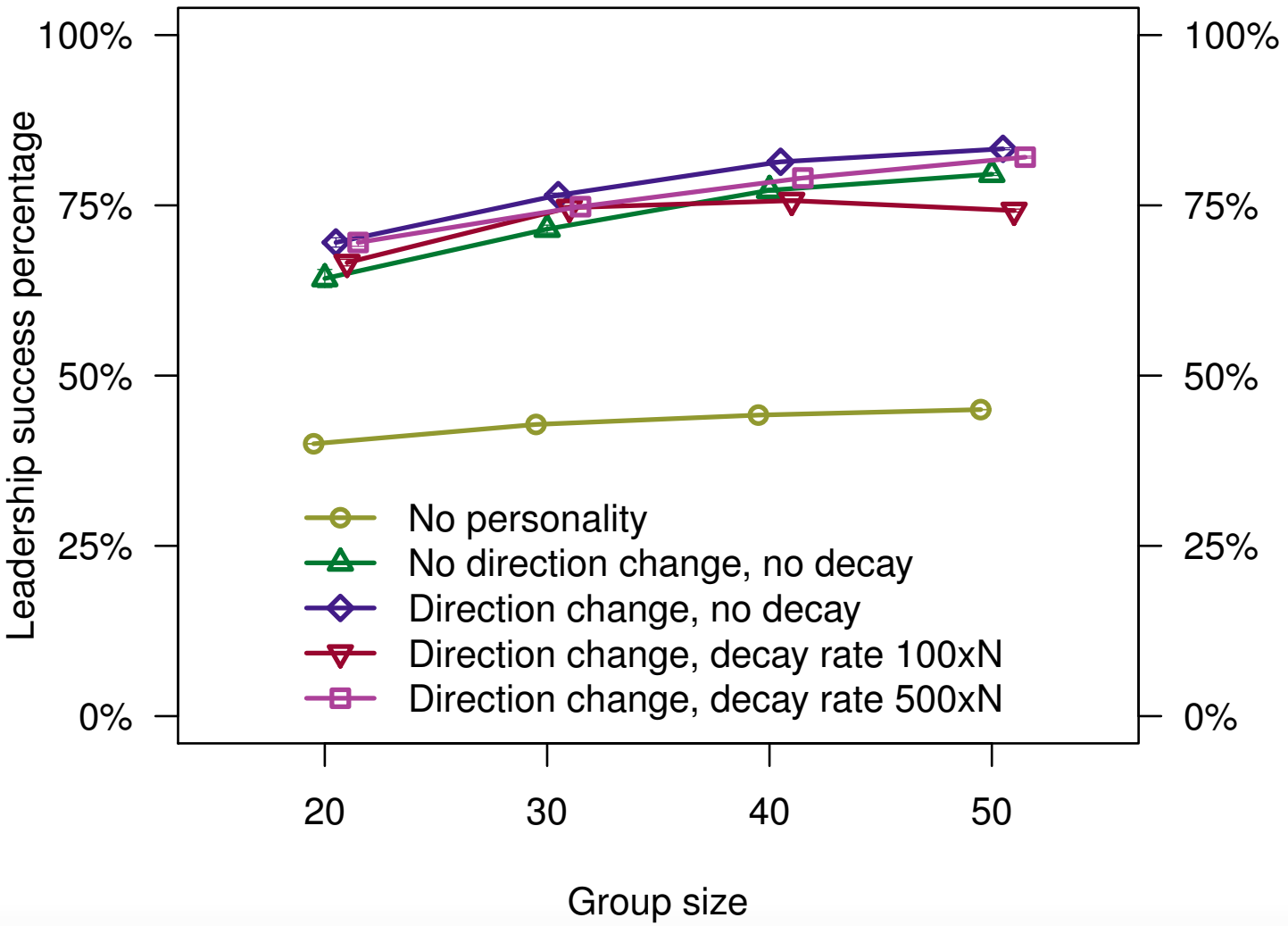
- Exponential decay:

$$p_{t+1} = (p_l - p_i)\left(e^{(\Delta t - d_t)/5}\right) + p_i \tag{6}$$

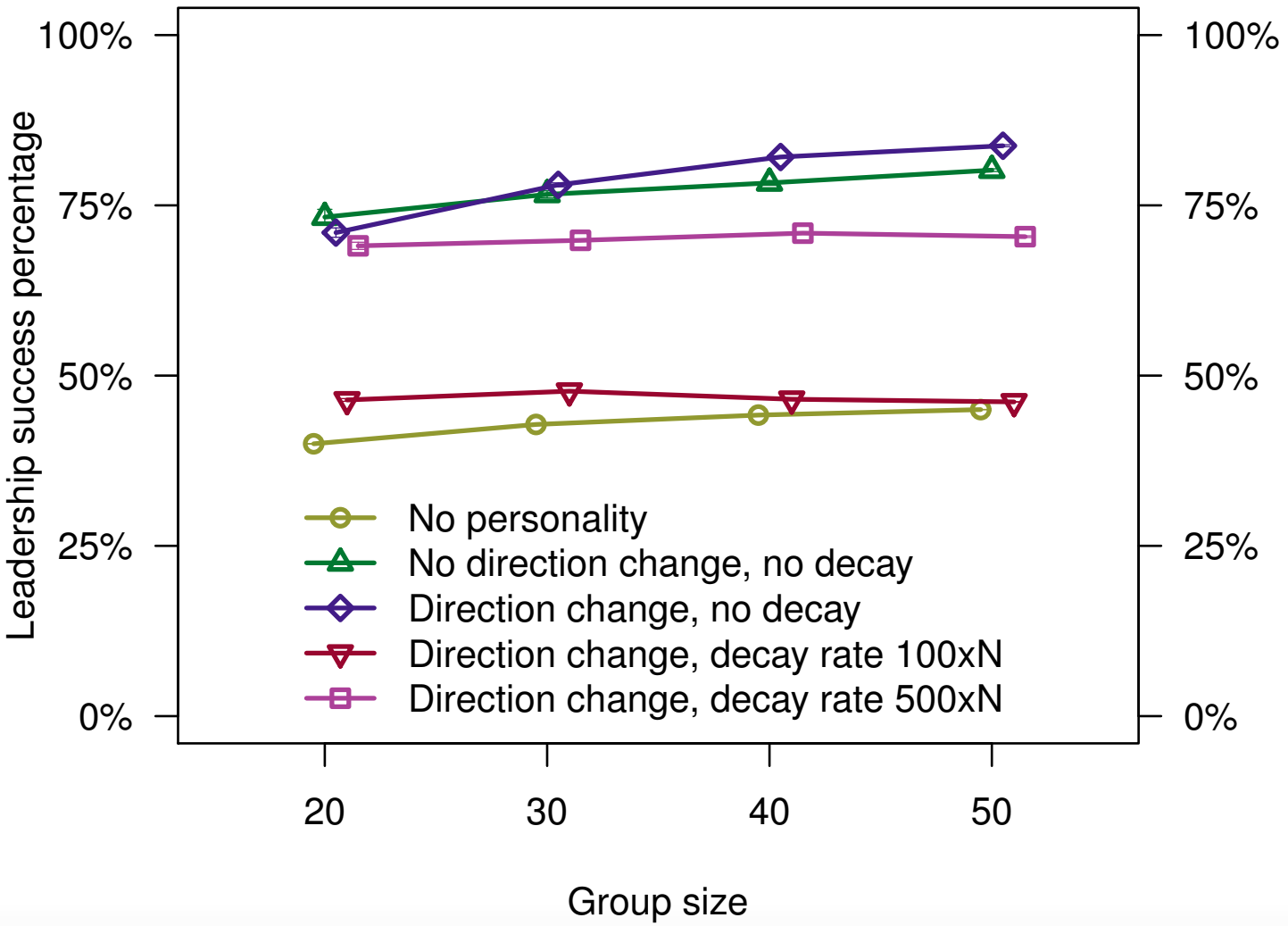
- Momentum decay:

$$p_{t+1} = (p_l - p_i)\left(1 - e^{(\Delta t - d_t)/5}\right) + p_i \tag{7}$$

Initiation success ($p = 0.2$)



Initiation success ($p = 0.5$)



Initiation success ($p = 0.8$)