

Science and Technology Group

Annual Report FY 2025

Name: Xinying Jia

Position: Science and Technology Associate

1. Introduction

In FY2025, our research examined how social learning, institutional incentives, and psychological traits shape long-term social behavior. Using evolutionary game theory, agent-based modeling, and adaptive dynamics, we studied how punishment systems, imitation processes, and emotional mechanisms (fear, shame, guilt) influence the spread of cooperation and harmful strategies.

2. Activities and Findings

Project 1 — Social Learning Enables Inferior Strategies to Spread under Severe-but-Rare Punishment

Collaborators: Isabelle Oberlin (former intern), Ulf Dieckmann

We modeled how agents imitate others based on observed short-term success. Even when risky behavior is inferior in the long run, it can spread through imitation when punishment is rare but severe.

Key findings:

- Severe-but-rare punishment can unintentionally promote the behavior it seeks to deter.
- Nonlinear imitation dynamics and skewed capital distributions amplify this effect.
- Effective deterrence requires frequent and visible punishment.

Project 2 — Evolutionary Dynamics of Fear in the Hawk–Dove Game

Collaborators: James Timothy White (former intern), Ulf Dieckmann

We incorporated fear as an evolving trait in the Hawk–Dove game. Fear introduces a psychological cost and changes strategic behavior, producing richer evolutionary outcomes.

Key findings:

- Fear resolves degeneracy in the classical model, enabling meaningful evolutionary dynamics.
- Fear-driven selection leads to evolutionary branching and coexistence of behavioral types.
- Fear acts as a regulatory mechanism shaping long-term population structure.

Project 3 — Severe-but-Rare Punishment and the Gordon-Gekko Effect

Collaborators: Kalle Parvinen (University of Turku, Finland), Ulf Dieckmann

We analyzed how institutional cost minimization and social learning interact. Cost-minimizing institutions often choose severe-but-rare punishment, which can backfire under social learning.

Key findings:

- Cost-minimizing institutions tend to implement rare but severe punishment.
- Under probabilistic imitation, this can amplify undesirable behaviors.
- A 'double temptation' arises when enforcement is costly and severe punishment is inexpensive.

Project 4 — Evolutionary Dynamics of Fear, Shame, and Guilt

Collaborators: Alejandra Campo Archbold (current intern), Ulf Dieckmann

We modeled the co-evolution of fear, shame, and guilt through adaptive dynamics. Emotional traits evolve in response to social learning, institutional structure, and cognitive costs.

Key findings:

- Prosocial emotions evolve only when selfish behavior is sufficiently constrained.
- Populations converge to a prosocial manifold before diverging into distinct emotional regimes.
- Depending on institutional conditions, fear-, shame-, or guilt-dominant cultures emerge.

3. Output and Outlook

Manuscripts from all projects are in advanced stages of preparation and will be finalized and submitted by June 2026. Beyond publication, we will consider whether to initiate behavioral experiments to test model predictions. These experiments may involve controlled economic games in which participants choose between cooperative and risk-taking behaviors under different punishment regimes. By measuring emotional responses and social learning dynamics, we may bridge theoretical predictions with empirical evidence.

