Science and Technology Group

Annual Report FY 2024
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1. Introduction

Our previous game-theoretical agent-based model revealed an unexpected finding:
when punishment is **infrequent but severe**, a long-term inferior strategy may still be learned and imitated by others.

This result has strong real-world relevance to **deterrence theory**. Historically—and continuing today—many societies have employed extremely harsh punishments to deter unwanted "crimes." In the field of **penology**, scholars and lawmakers have long sought to understand how punishment affects future deviant behavior.

Whether through laboratory experiments or statistical analysis of real-world case studies, qualitative results have consistently aligned with our findings.
To **quantitatively** understand the underlying mechanisms, we conducted further studies based on insights from our earlier agent-based modeling work.

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2. Activities and Findings

Two studies were conducted in collaboration with:

- Prof. Kalle Parvinen (Turku University, Finland)
- Prof. Ulf Dieckmann (OIST)
- James White (Intern of OIST)

Project 1: Off with Their Heads — The Tragic Double Temptation of Severe but Rare Punishment

In collaboration with Prof. Parvinen, we used **mathematical analysis** to identify the conditions under which the phenomenon of severe-but-rare punishment arises.

Main findings:

- Severe-but-rare punishment maximizes the **Gordon-Gekko effect** (where short-term gains dominate long-term stability).

- **Institutional cost minimization** promotes severe-but-rare punishment strategies.
- **Institutional effect maximization** can trigger the Gordon-Gekko effect.
- Institutional cost minimization leads to the Gordon-Gekko effect particularly when:
  - Imitation is sufficiently **probabilistic**,
  - **Detection** of deviant behavior is **costly**,
  - Severe punishment itself is **relatively inexpensive**.

The first draft of the research paper is currently in preparation.

Project 2: The Evolutionary Dynamics of Fear in the Hawk-Dove Game

In this project, we investigated how **fear** influences the evolution of social behaviors, using the classical **Hawk-Dove game** as a base model.

In the standard game, individuals either fight (Hawk strategy) or avoid conflict (Dove strategy) when competing for resources. The outcome depends on the **benefits of winning** and the **costs of injury**, typically leading to a stable mix of Hawks and Doves when fighting is costly.

We extended the model by introducing **fear** as an evolutionary trait, implemented in two ways:

1. Adjusting the likelihood of adopting Hawk or Dove strategies based on fear sensitivity,
2. Adding a **direct fitness cost** associated with experiencing fear (e.g., health impacts, lost opportunities).

These adjustments better capture real-world dynamics, where fear can have direct biological and social costs.

Using **adaptive dynamics**, we demonstrated that fear alters evolutionary outcomes:

- Instead of a simple stable mix, populations often **split** into two distinct types:
  - Highly aggressive individuals (low fear, mostly Hawks),
  - Highly passive individuals (high fear, mostly Doves).

This phenomenon, known as **evolutionary branching**, is not possible in the classical Hawk-Dove model without fear.

Main findings:

- Introducing fear creates a novel framework for studying the evolution of cooperation and conflict.
- Fear-driven selection can trigger **evolutionary branching**, fostering greater **behavioral diversity**.
- Fear promotes the **coexistence** of both prosocial (Dove-like) and antisocial (Hawk-like) strategies within social groups.

Overall, these results show how incorporating fear into evolutionary models helps explain the emergence and maintenance of **personality diversity** in social systems.

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3. Collaborations

Collaborators:

- Ulf Dieckmann (OIST)
- Kalle Parvinen (Turku University)
- James White (Intern, OIST)

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4. Output

- Poster presentation at **Science Appreciation Month**, June 2024.