Tutorial: Analysis of a EGT paper

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The paper

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Evolutionary dynamics in finite populations can explain the full range of cooperative behaviors observed in the centipede game

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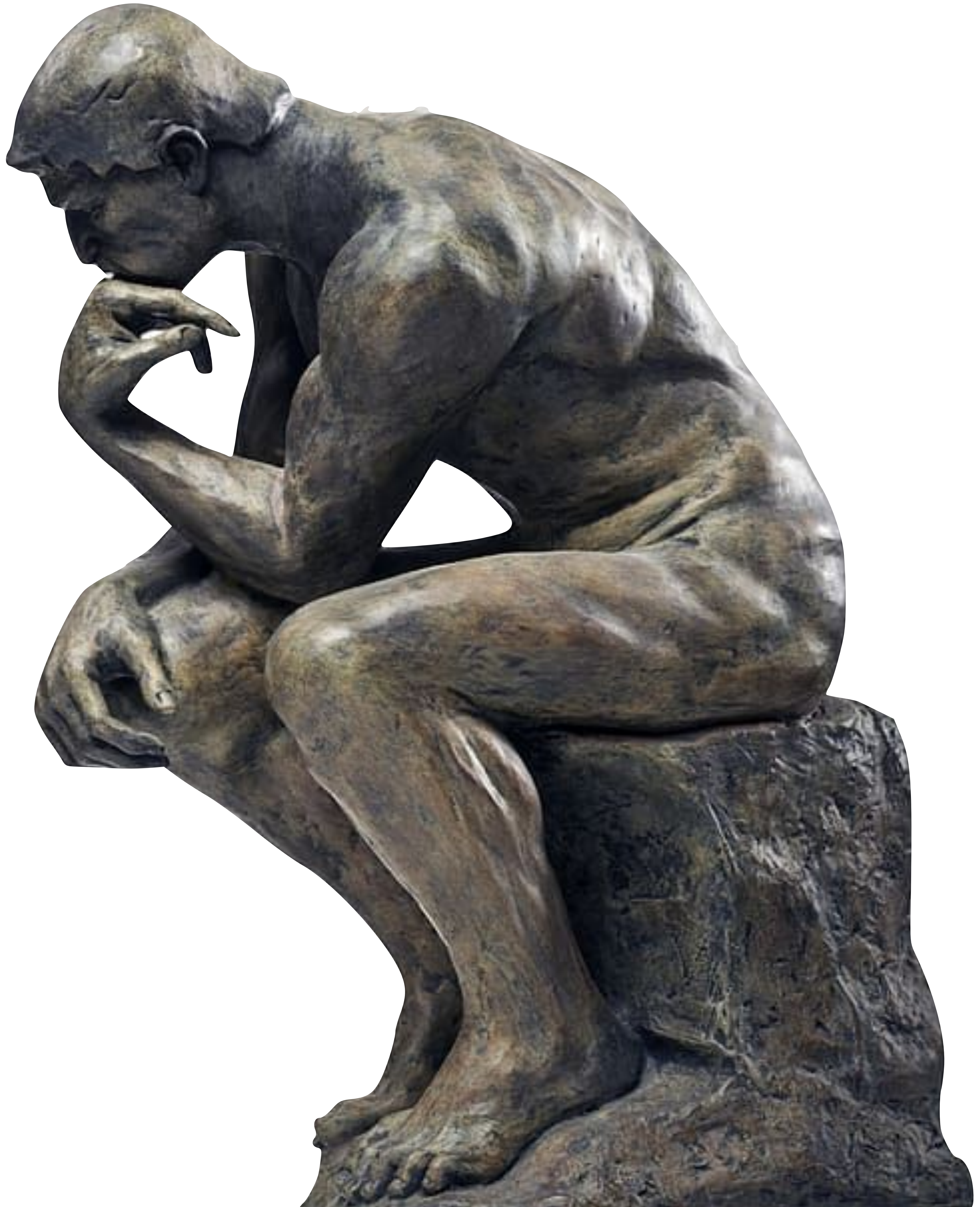
ABSTRACT

Classical economic models make behavioral predictions based on the assumption that people are fully rational and care only about maximizing their own payoffs. Although this approach successfully explains human behavior in many situations, there is a wealth of experimental evidence demonstrating conditions where people deviate from the predictions of these models. One setting that has received particular attention is fixed length repeated games. Iterating a social dilemma can promote cooperation through direct reciprocity, even if it is common knowledge that all players are rational and self-interested. However, this is not the case if the length of the game is known to the players. In the final round, a rational player will defect, because there is no future to be concerned with. But if you know the other player will defect in the last round, then you should defect in the second to last round, and so on. This logic of backwards induction leads to immediate defection as the only rational (sub-game perfect Nash equilibrium) strategy. When people actually play such games, however, immediate defection is rare. Here we use evolutionary dynamics in finite populations to study the centipede game, which is designed to explore this issue of backwards induction. We make the following observation: since full cooperation can risk-dominate immediate defection in the centipede game, stochastic evolutionary dynamics can favor both delayed defection and even full cooperation. Furthermore, our evolutionary model can quantitatively reproduce human behavior from two experiments by fitting a single free parameter, which is the product of population size and selection intensity. Thus we provide evidence that people's cooperative behavior in fixed length games, which is often called 'irrational', may in fact be the favored outcome of natural selection.

Motivation

Mismatch between predictions of rational self-interest models and actual human behavior



The perfect example

The Centipede Game

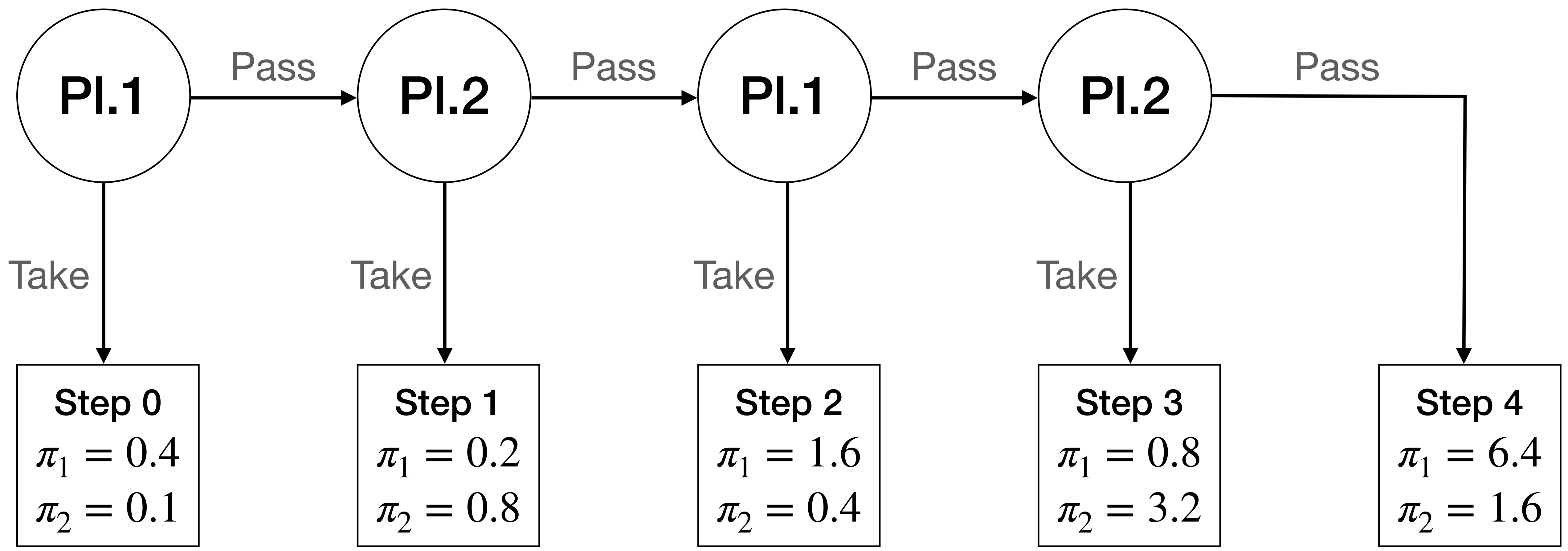
Sequential game

2 Players (>2 is also possible)

Finite number of rounds

Certain (**immediate**) gain vs higher uncertain (**future**) gain

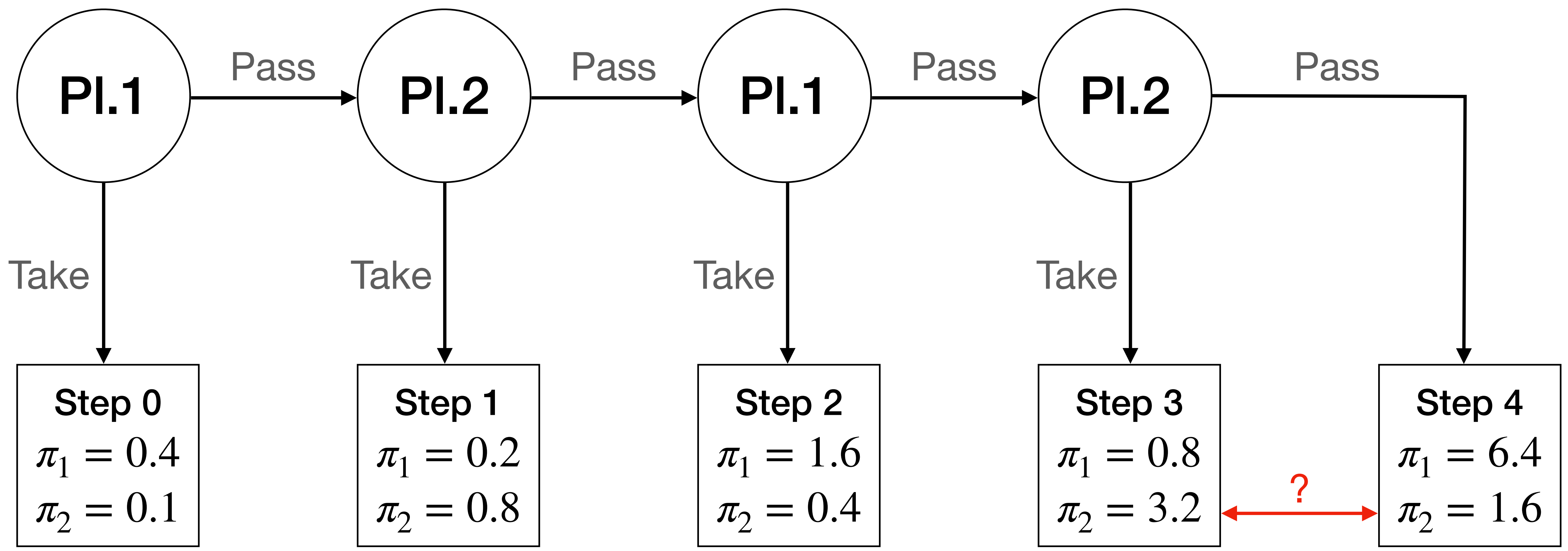
Here the resource to be shared **doubles** at each step



The perfect example

Backward Induction

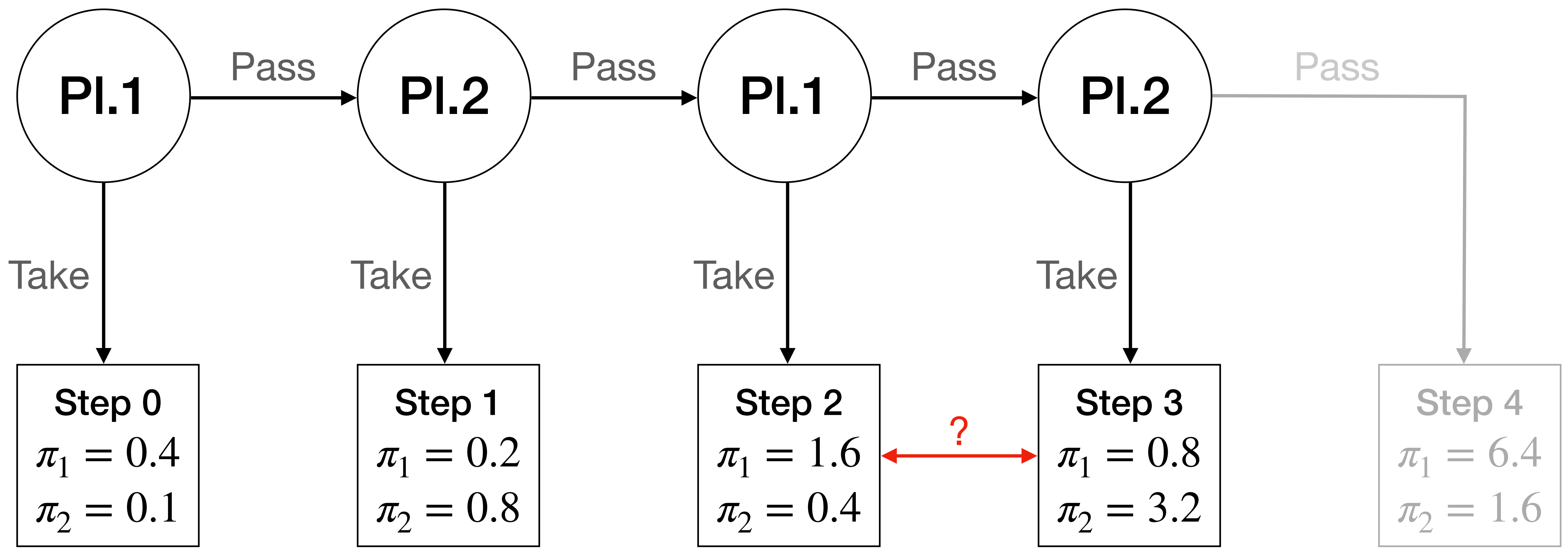
- At the last turn Player 2 would take at Step 3 because 3.2 > 1.6



The perfect example

Backward Induction

- At the last turn Player 2 would take at Step 3 because 3.2 > 1.6
- Player 1 knows it so they would take at Step 2 because 1.6 > 0.8



The perfect example

Backward Induction

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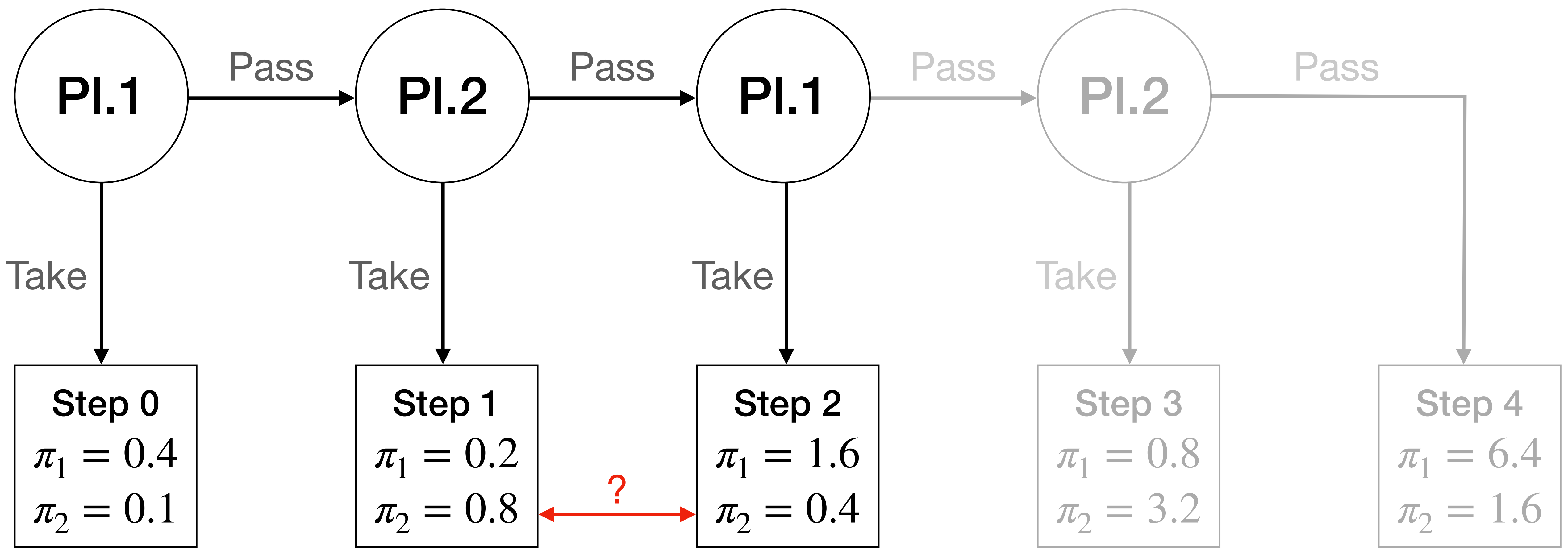

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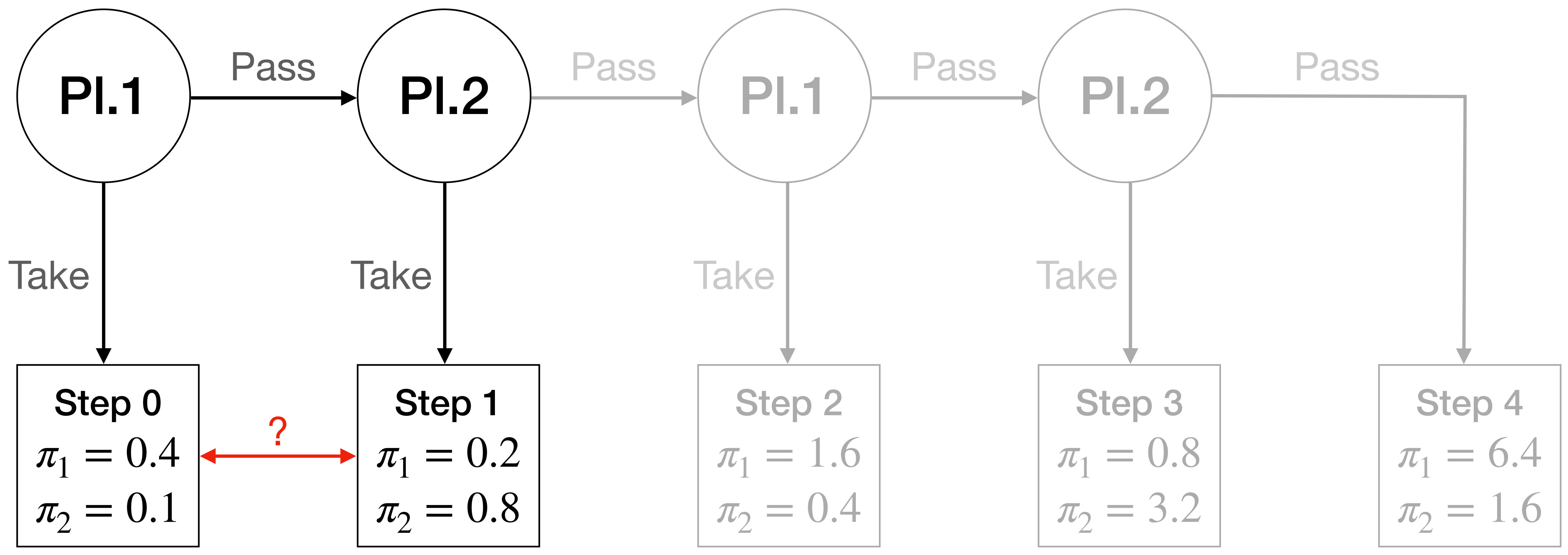

The perfect example

Backward Induction

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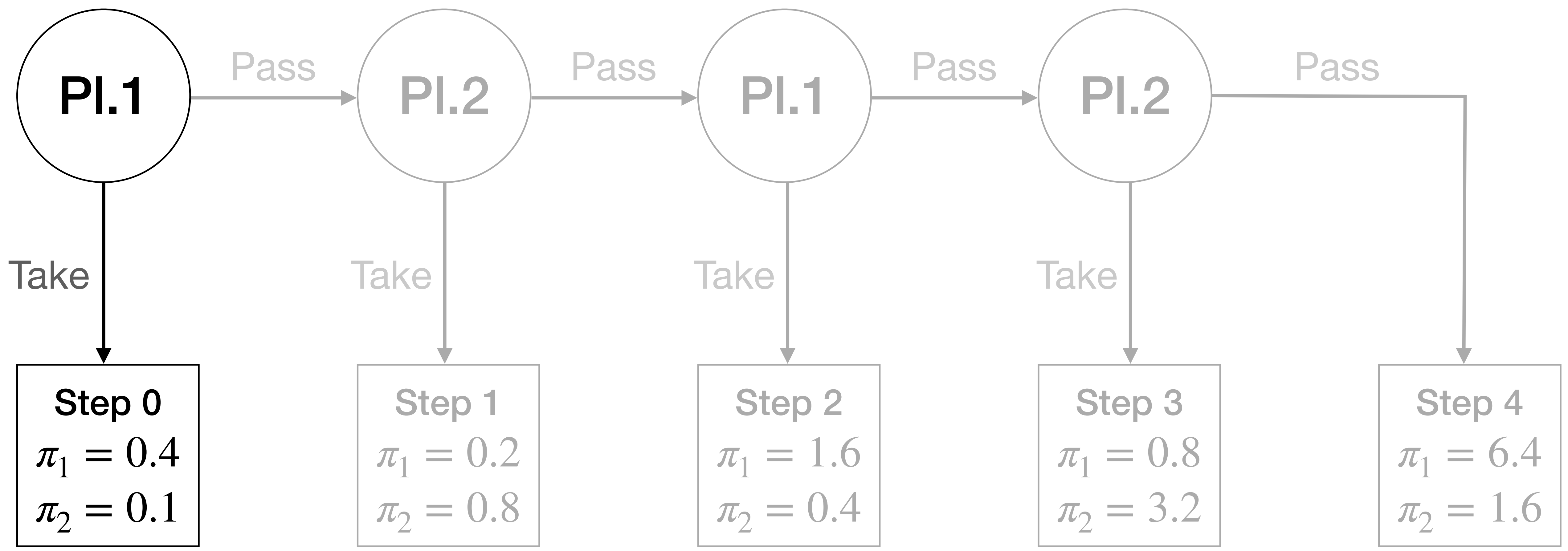
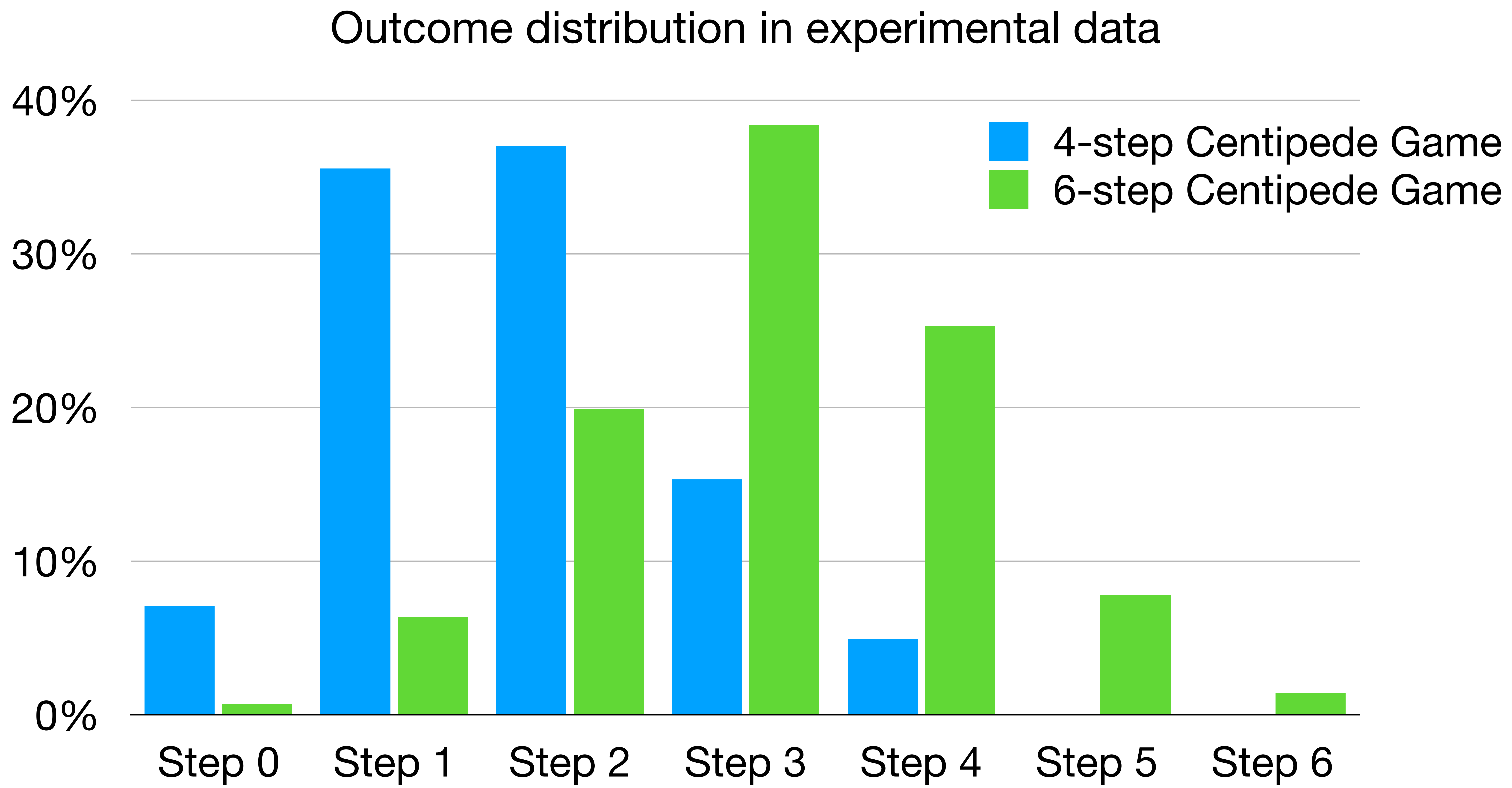
- Player 1 knows it so they would take at Step 2 because 1.6 > 0.8
- …
- Solution via backward induction: **Take ASAP**



The perfect example

How do people actually play?



McKelvey & Palfrey (1992)

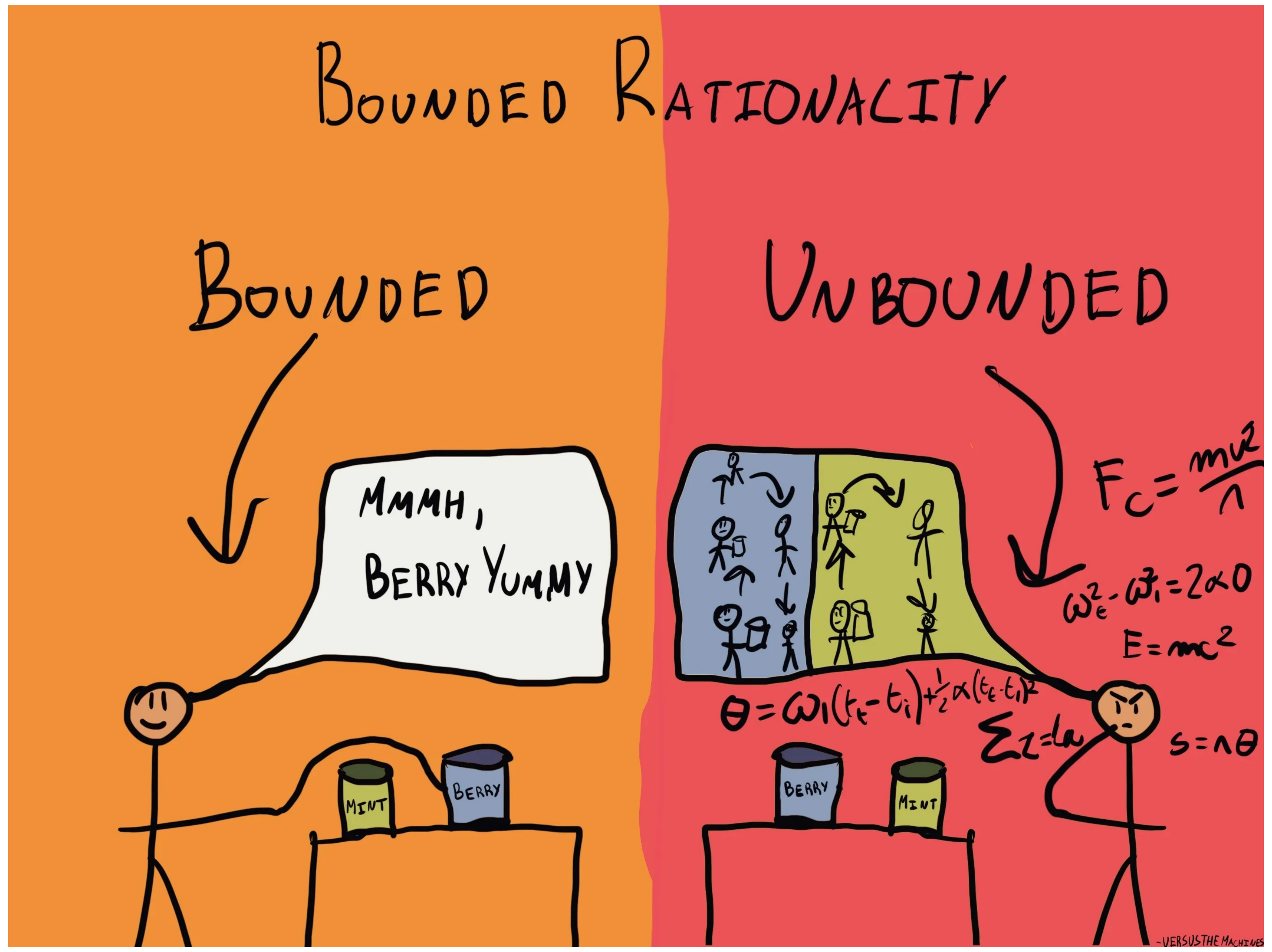
The *Paradox of Backward Induction*

Why can't classical game theory explain human behavior?

Possible explanations

1. **Bounded rationality**: humans might not use full backward induction

2. Altruistic players

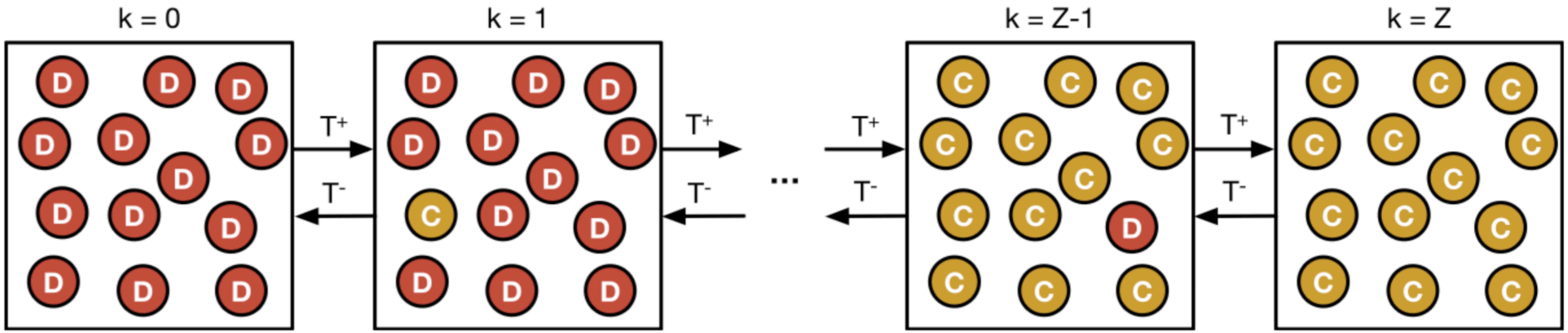


https://thedecisionlab.com/biases/bounded-rationality

One possible solution

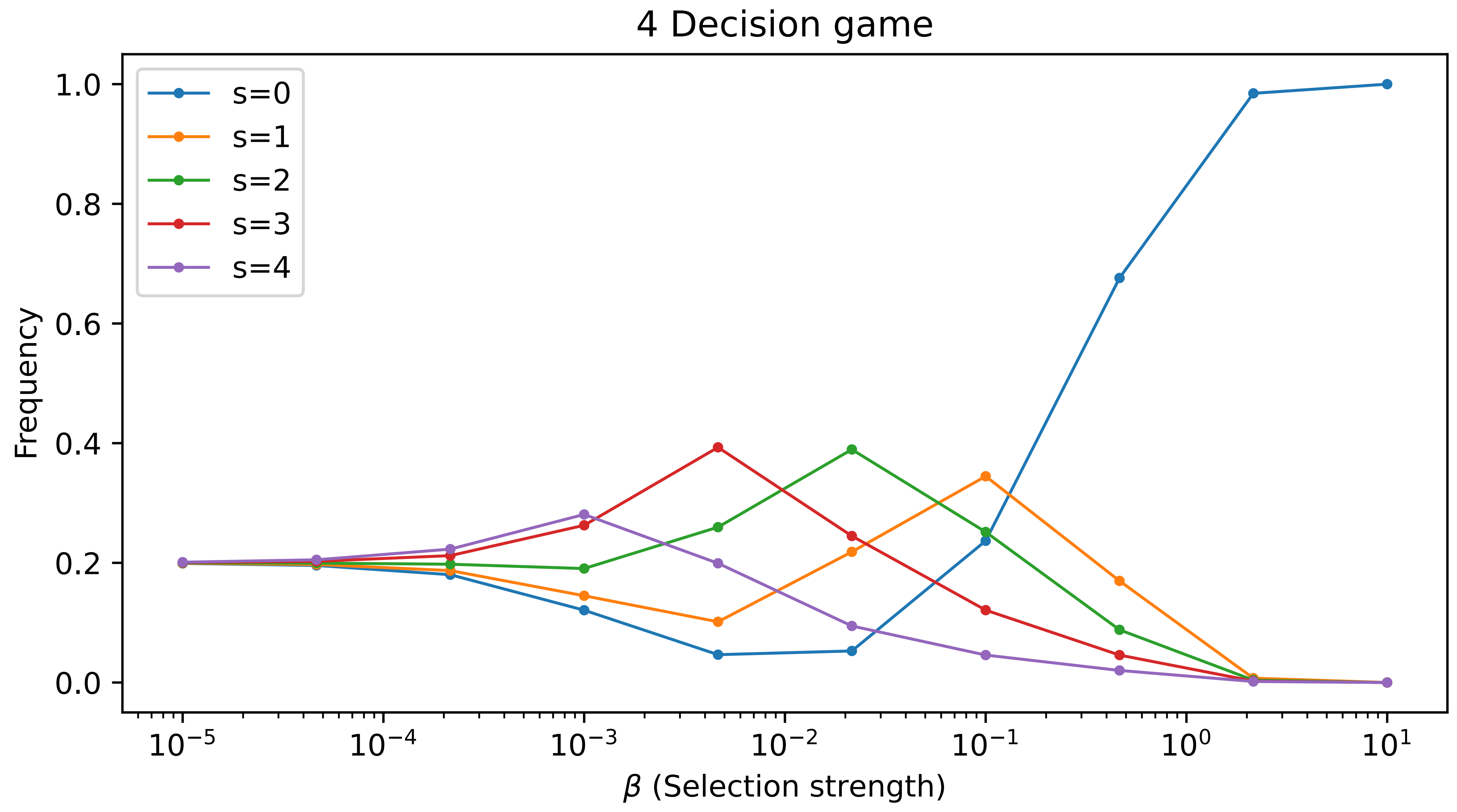
Evolutionary Game Theory (EGT)

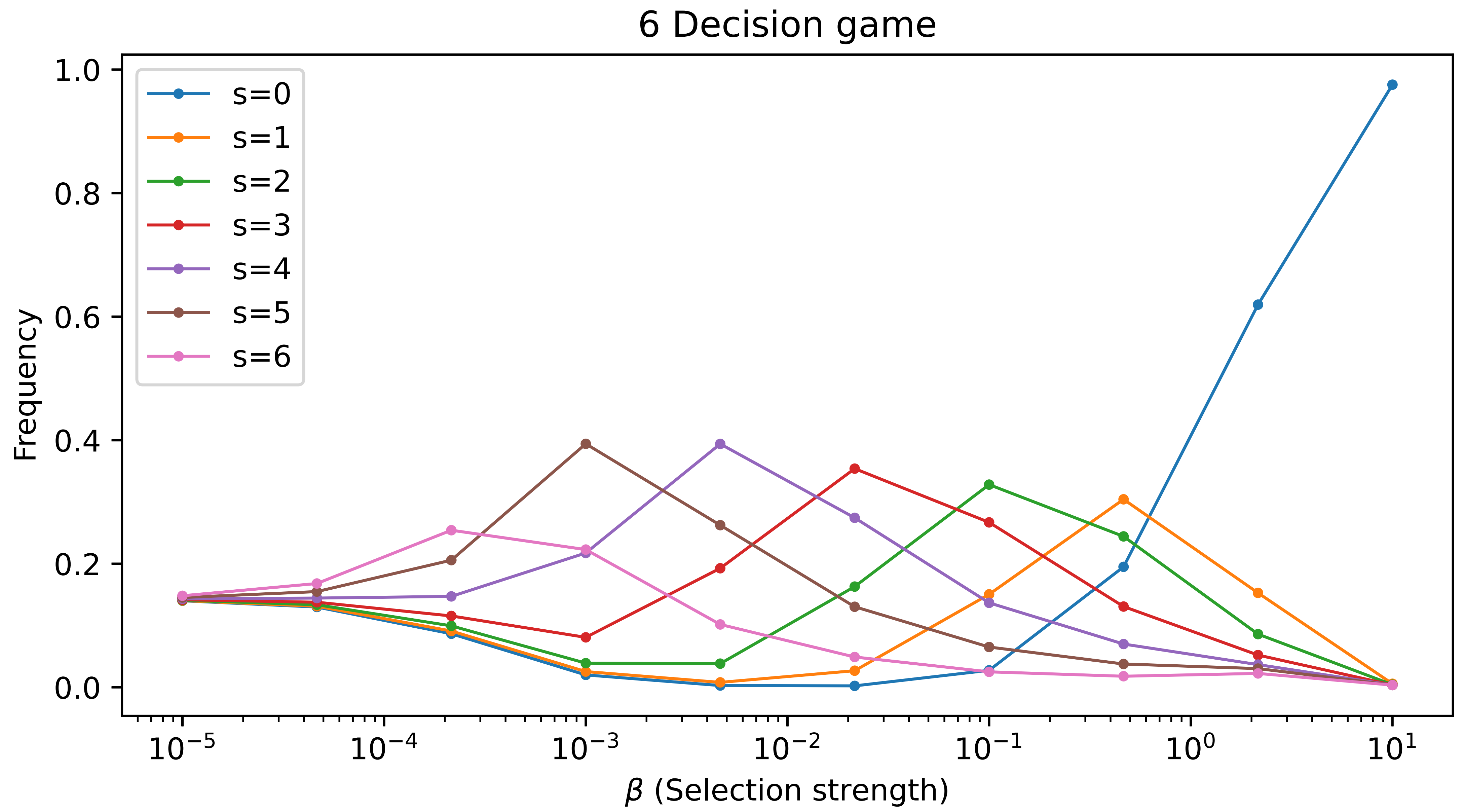
- In EGT, a player's payoff is associated with a **fitness** (biological advantage)
- The fittest individuals are more likely to produce offspring
- Stochastic birth-death process (parameters: population size Z & selection strength β)



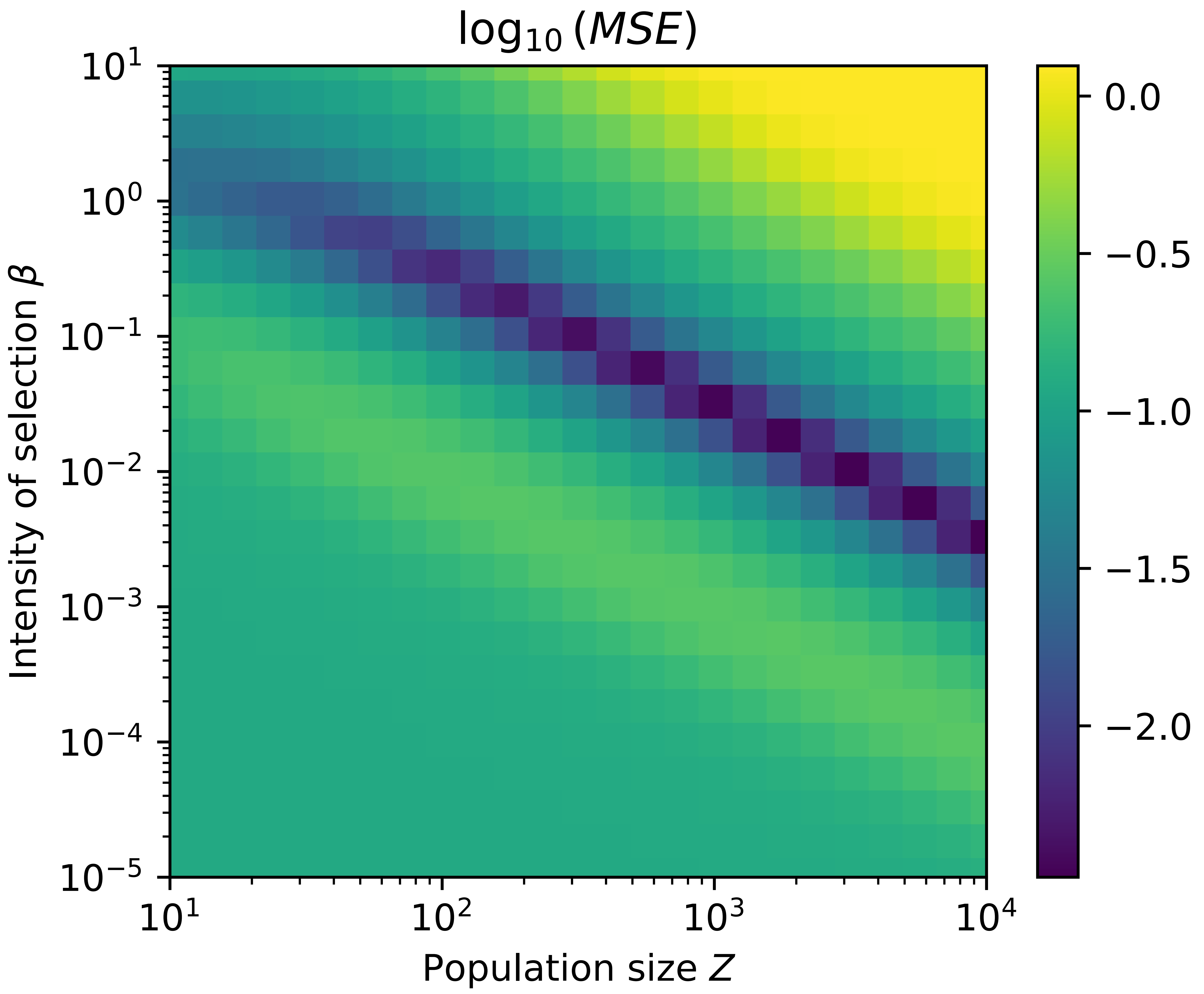
Domingos, Santos, & Lenaerts, (2023)

Decreasing the selection strength favors increasingly cooperative strategies

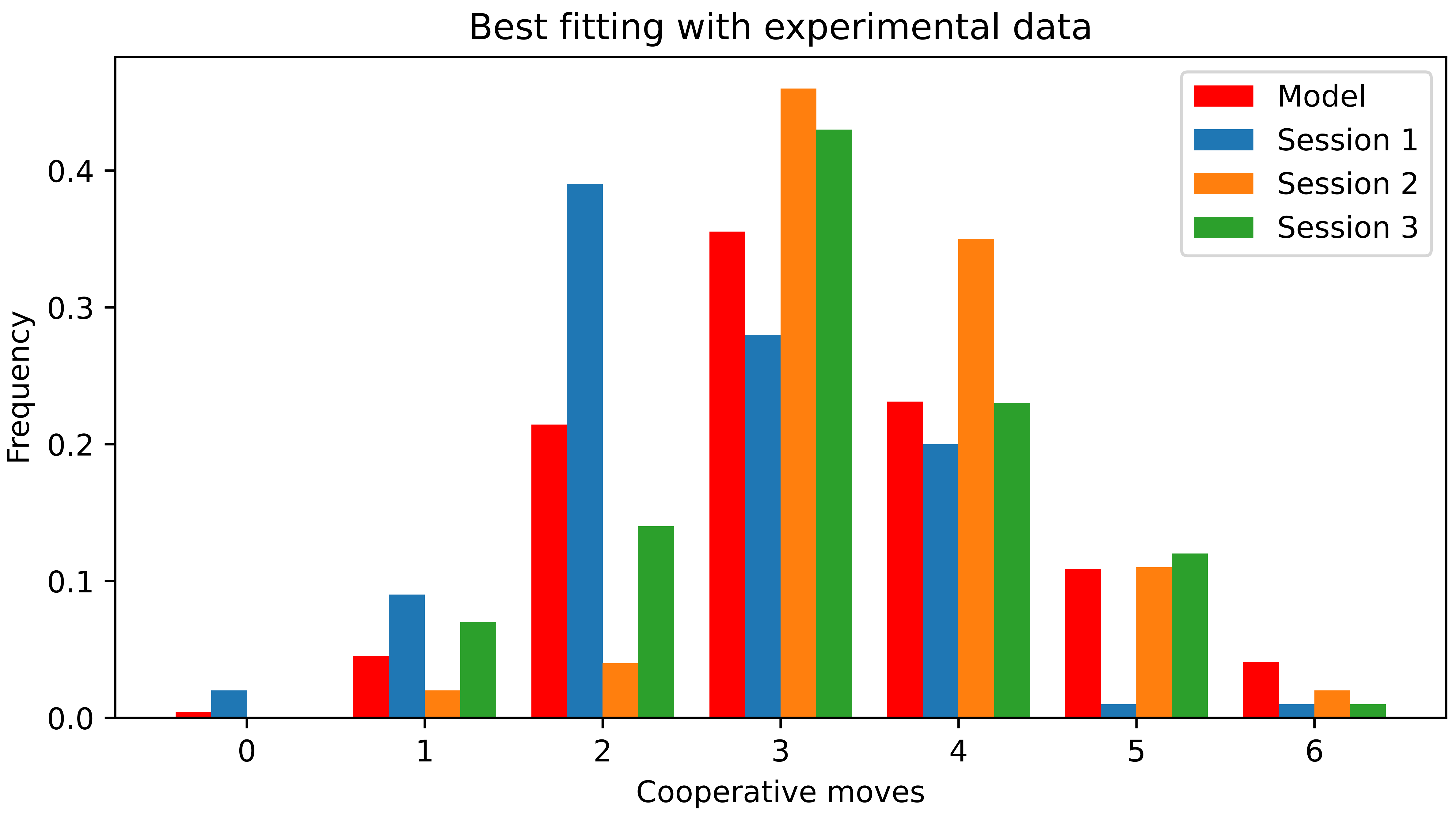




The model can reproduce the frequency observed in the behavioral experiments when $Z \cdot \beta \approx 30$



Example with $Z = 1000$ and $\beta = 0.03$



Conclusions

- Natural selection can favor both full cooperation as well as partial cooperation, without assumptions about other-regarding preferences or cognitive limitations
- A strategy which does best in a perfectly precise world does not necessarily triumph in the presence of stochastic effects
- The evolutionary model quantitatively reproduces the behavior of humans from two behavioral experiments

Discussion

- Are C*ooperation* and D*efection* suitable terms to describe players' actions?
- What are the differences between our analysis and the paper?
- What happens for large population size?
- How can the model be expanded or improved?

Thank you!



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