Problem B:
Punishing Infants

SCUDEM VIII 2023 - Team 1112

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Overview

- Problem
- Assumptions
- Basic model
- Modified model
- Conclusion

Problems

- How P effects other agents
- The long-term dynamics for different J based on different levels of punishment
- The change of populations of agents over time
- The long-term stability of a society
- What behaviors are more important and how do they compare to situations where punishment is the dominant reaction

Basic Model Assumption

Agent-based model:

- Agent
- Behaviors
- Interaction rules
- Stability
- Happiness

Agent 1

N: refer to population of normal People

Agent 2

J_n: refer to population of normal Joker (receives friendly warning OR punishment)

J_w: refer to population of worse Joker (receives punishment only)

Interactions:

J_w → N → J_n (100%)

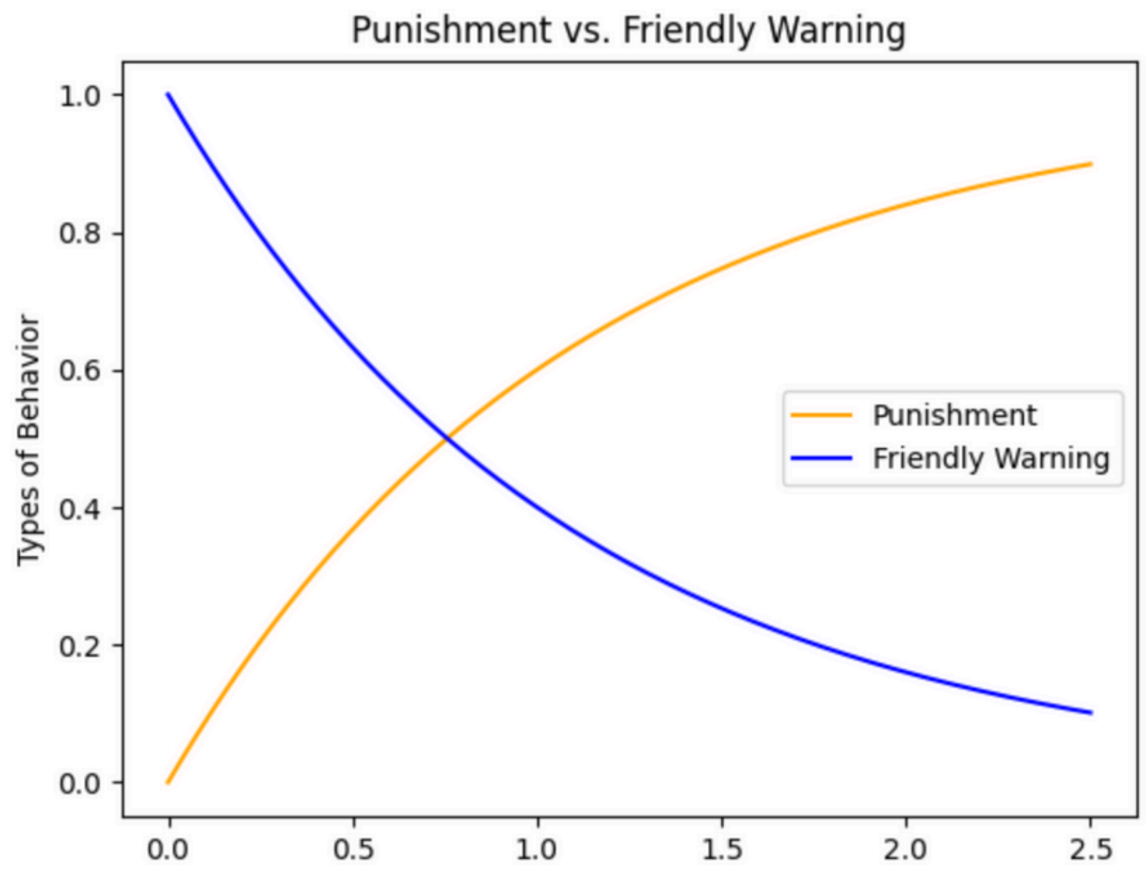
Agent 3

P: refer to population of Potential Batman

Assume that a P will only give a certain amount of friendly warning at first, then it will switch to only giving punishment.

Behaviors: (Scenario 1, where friendly warning is dominant first, and punishment is dominant later)

F_w: $F_w = \alpha^t$ The possibility of P giving friendly warnings over time.
P_n: $P_n = -F_w + 1$ The possibility of P giving punishments over time.
We set alpha is 0.4



Agent 3

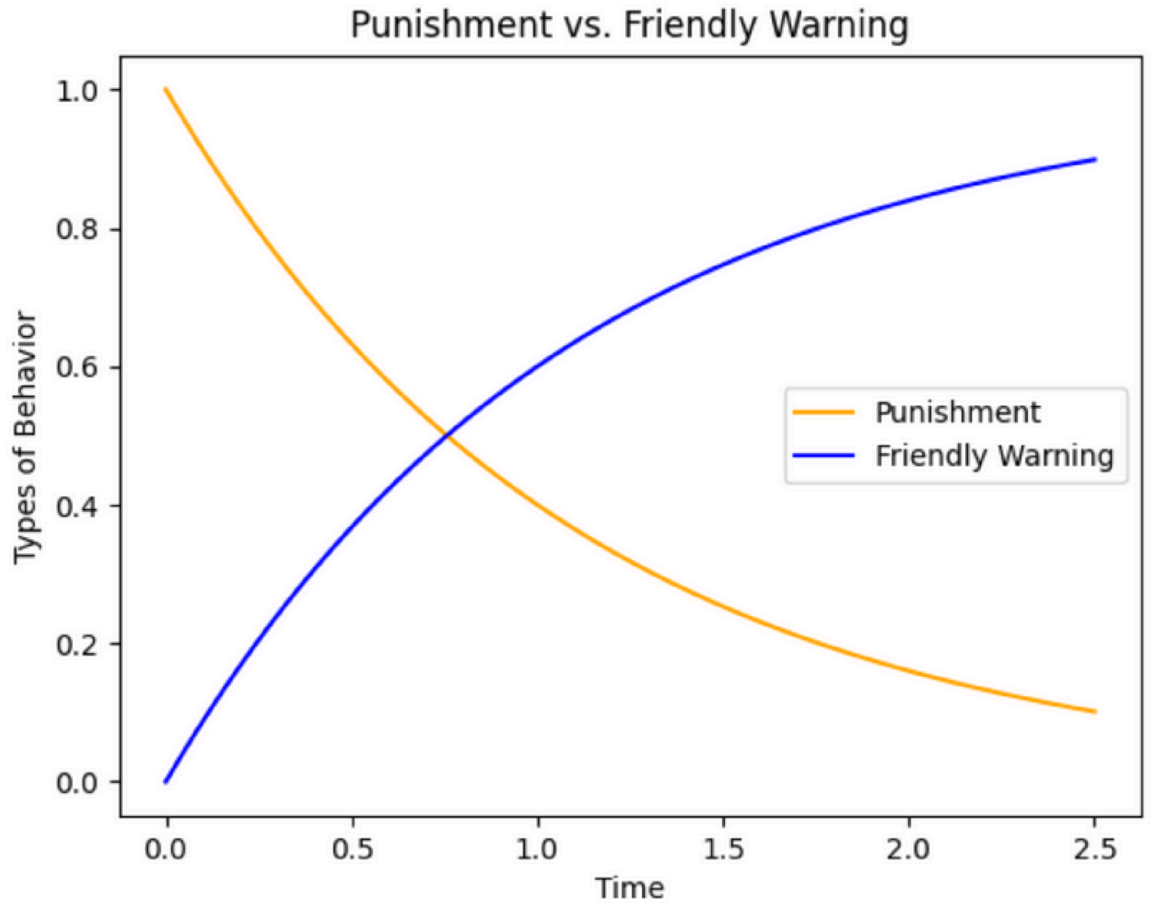
Assume that a P does specific enough times of punishment, he will only do friendly warning.

Behaviors: (Scenario 2, where punishment is dominant first, and friendly warning is dominant later)

P_n: $P_n = \alpha^t$ The possibility of P giving friendly warnings over time.

F_w: $F_w = -P_n + 1$ The possibility of P giving friendly warnings over time.

We set alpha to 0.4



Agent 3 (continued)

Interactions:

$P \xrightarrow{F_w} J_n \rightarrow N$ (with Fw x 100%) OR J_n (with 1-Fw x 100%)

$P \xrightarrow{P_n} J_n \rightarrow N$ (50%) OR J_w (50%)

$P \xrightarrow{P_n} J_w \rightarrow J_n$ (50%) OR J_w (50%)

Interaction Rules

Let's assume that the frequency of interactions (rate) is proportional to the product of the populations involved (following a mass-action principle common in chemistry). For example: $N J_w$ means the frequency of interactions between N and J_w.

Stability

The initial stability of the entire group is 0 at the start of the simulation.

If a J_n turns into a N, stability increases by 1.

If a J_w turns into a J_n, stability increases by 1.

If a N turns into a J_n, stability decreases by 1.

If a J_n turns into a J_w, stability decreases by 1.

Happiness:

Def: The rate of change of Stability (slope)

Up: Stability going up means that there are more positive interactions, which implies that the entire group become happier. 😁

Down: Stability going down means that there are more negative interactions, which implies that the entire group become unhappier. ☹️

Basic Model: Differential Equations

$$\frac{dN}{dt} = c * (-NJ_w + f_w J_n P + \frac{1}{2} P_n J_n P)$$

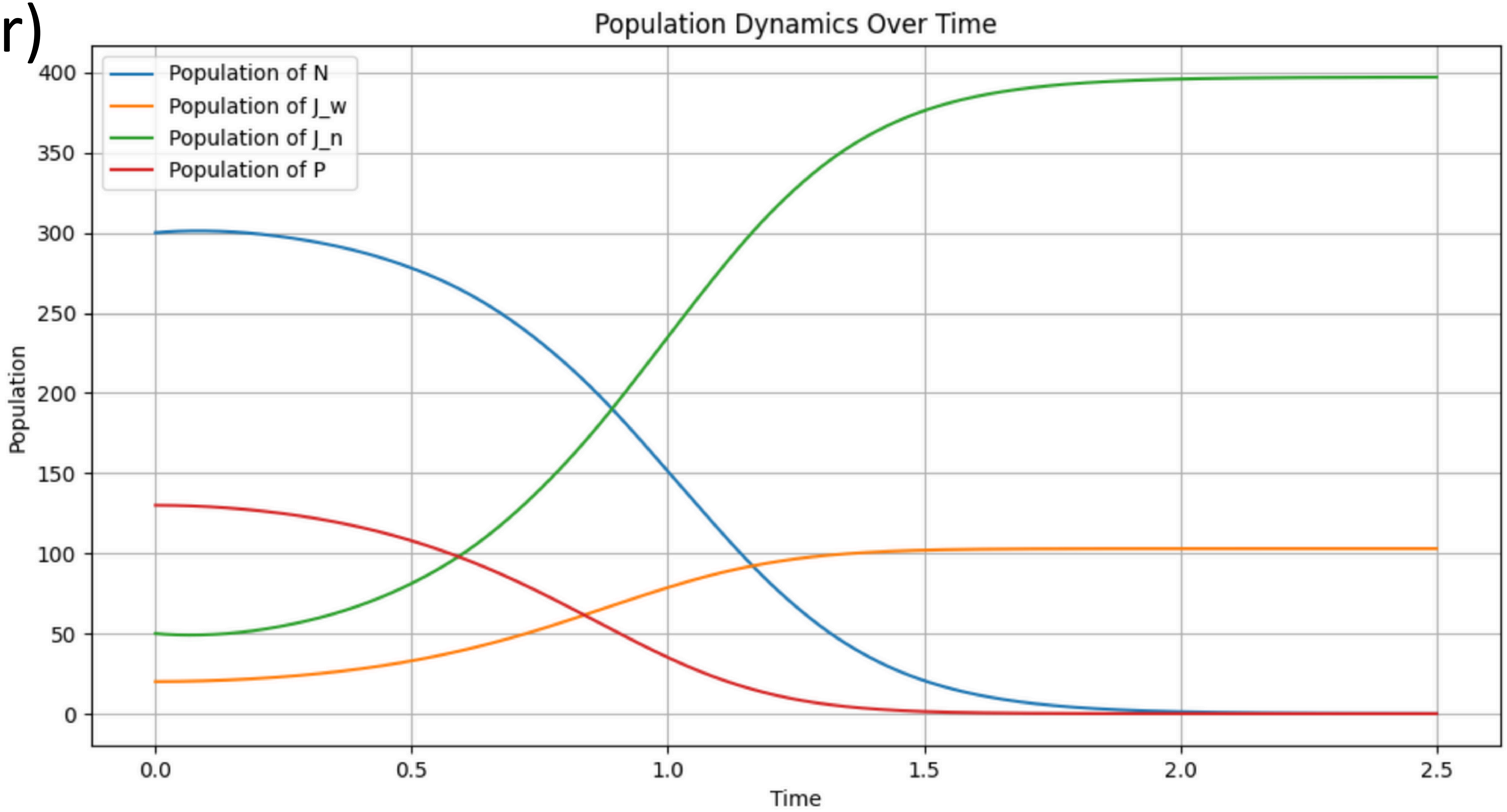
$$\frac{dJ_n}{dt} = c * (NJ_w - f_w J_n P - \frac{1}{2} P_n J_n P + \frac{1}{2} P_n J_w P)$$

$$\frac{dJ_w}{dt} = c * (\frac{1}{2} P_n J_n P - \frac{1}{2} P_n J_w P)$$

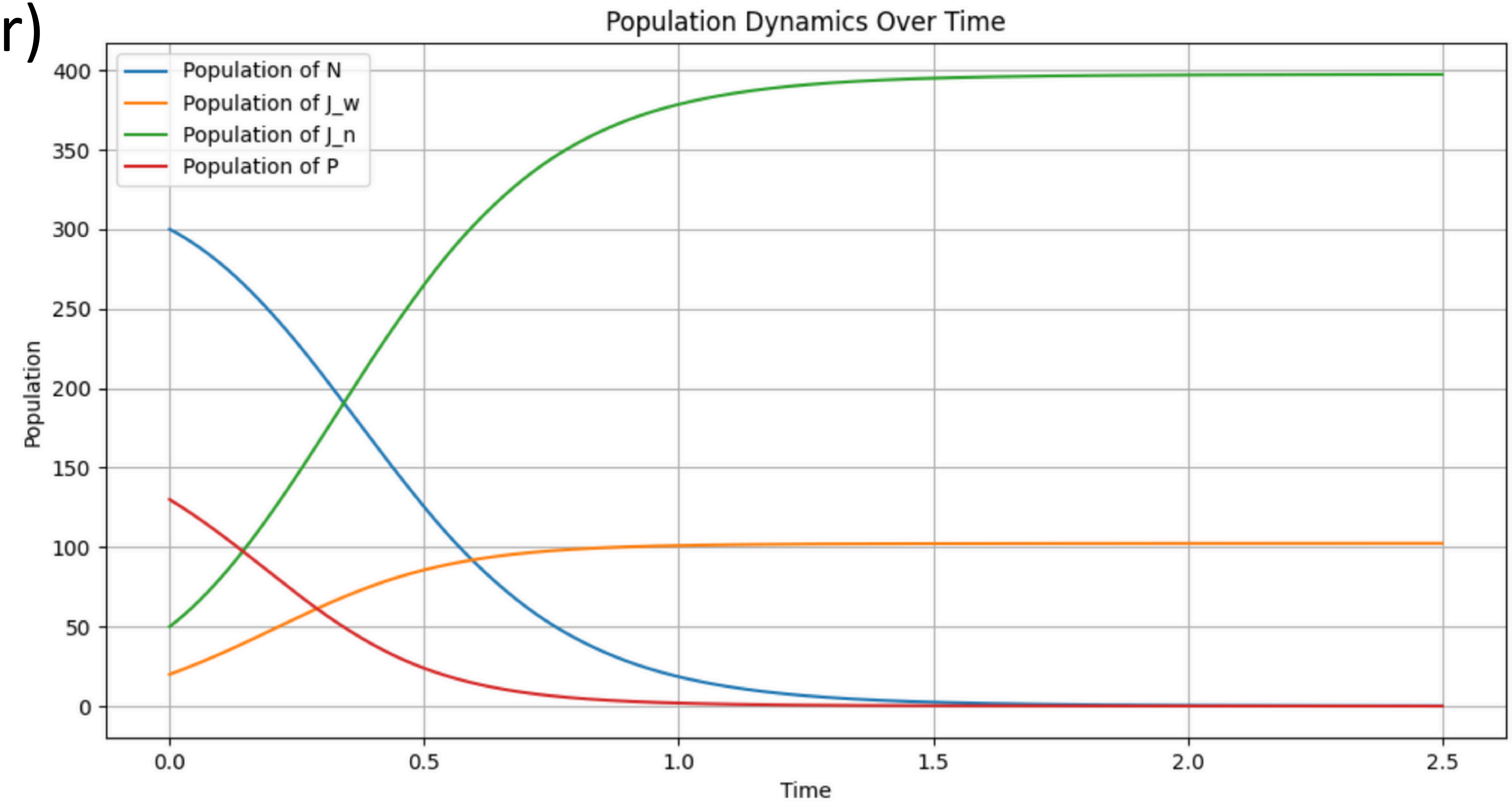
$$\frac{dP}{dt} = -(\frac{dJ_n}{dt} + \frac{dJ_w}{dt} + \frac{dN}{dt})$$

c = adjusting coefficient

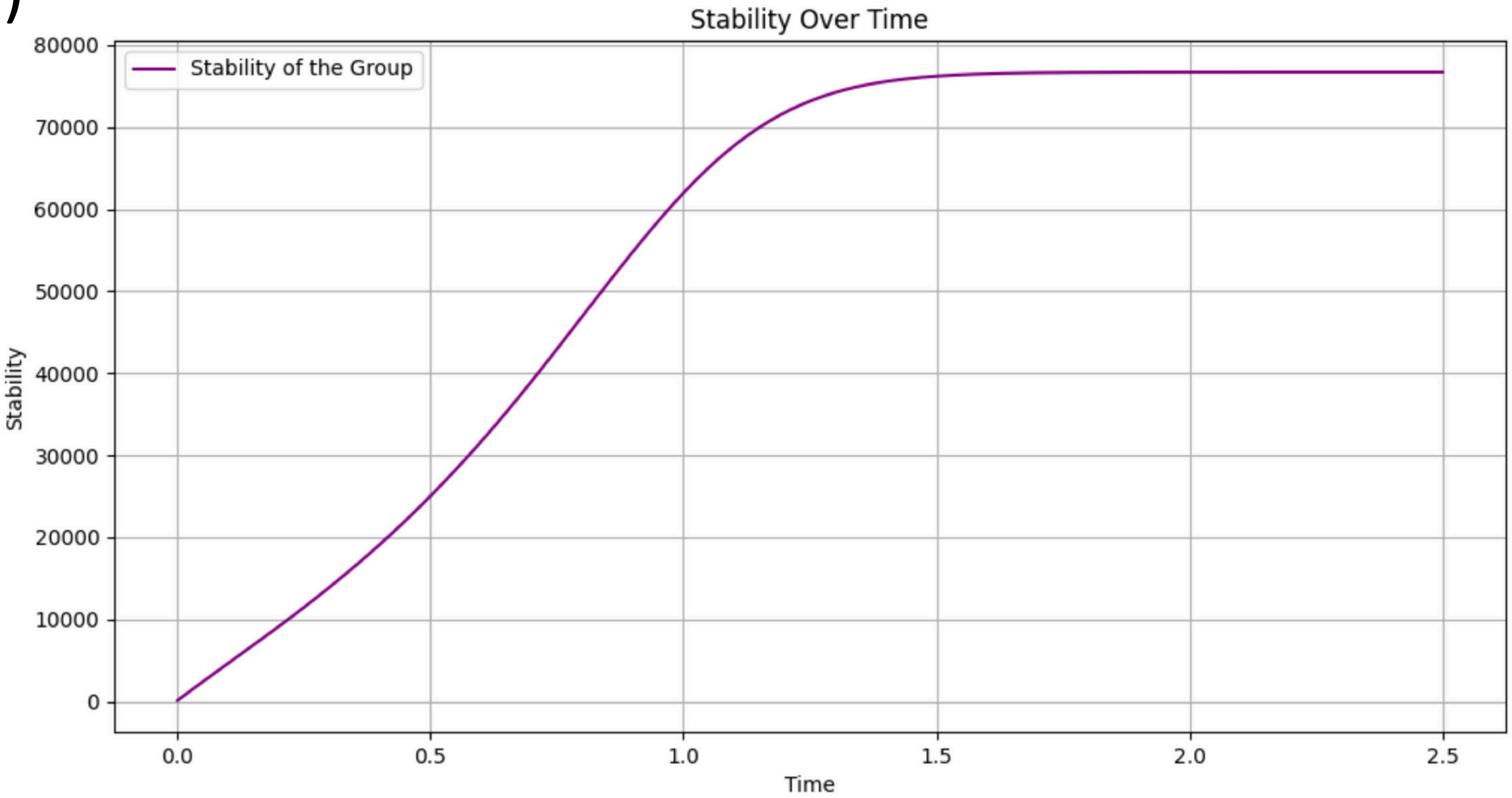
Basic Model: Solutions (Scenario 1, where friendly warning is dominant first, and punishment is dominant later)



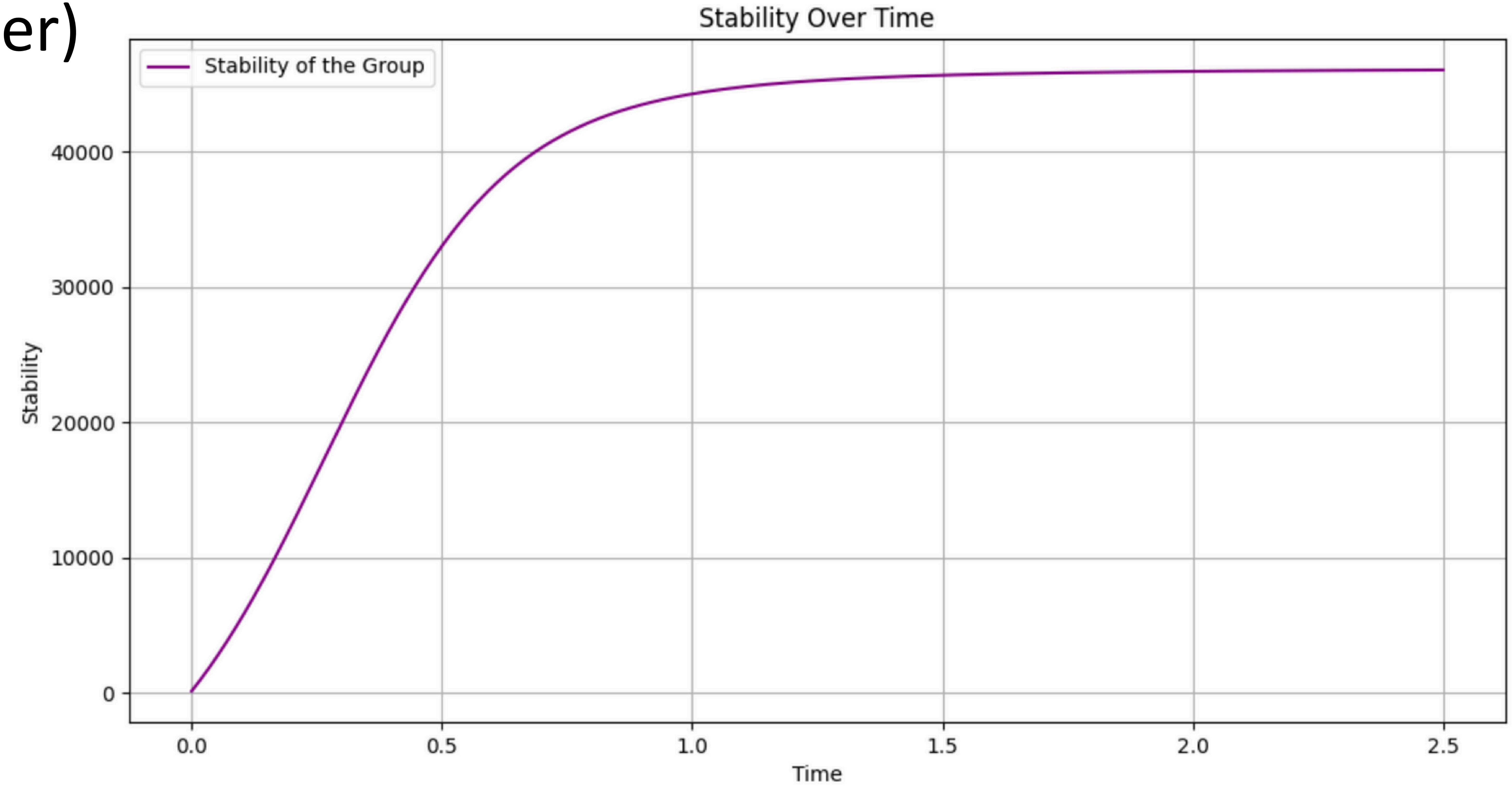
Basic Model: Solutions (Scenario 2, where punishment is dominant first, and friendly warning is dominant later)



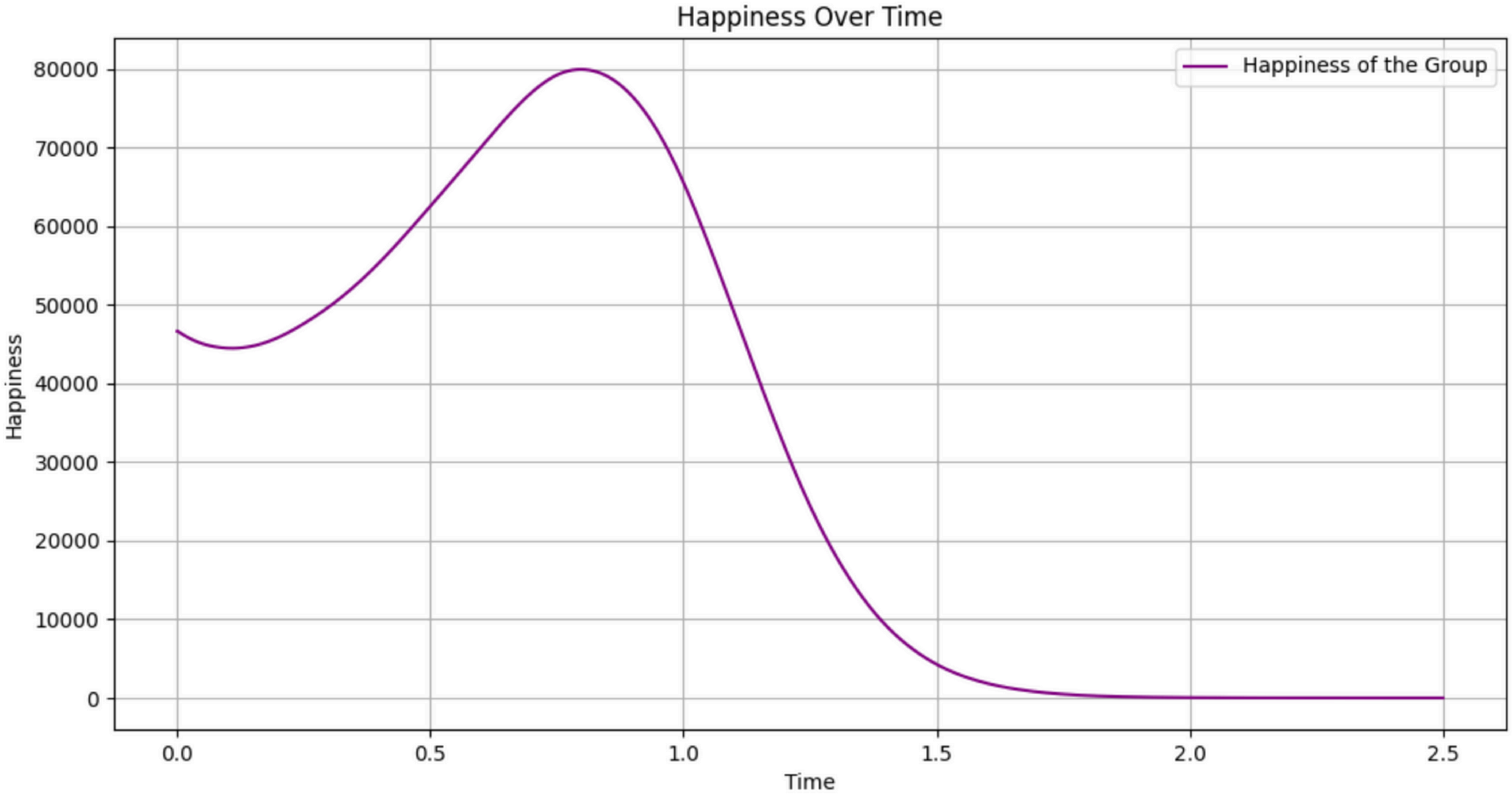
Basic Model: Solutions (Scenario 1, where friendly warning is dominant first, and punishment is dominant later)



Basic Model: Solutions (Scenario 2, where punishment is dominant first, and friendly warning is dominant later)



Basic Model: Solutions (Scenario 1, where friendly warning is dominant first, and punishment is dominant later)



Basic Model: Solutions (Scenario 2, where punishment is dominant first, and friendly warning is dominant later)

Observation:

- Scenario 2 is worse than Scenario 1 because N & P in Scenario 2 go extinct quicker.
- Having F_w dominant first makes N and P decrease slower
- If the P_n is dominant first and F_w is dominant later, it will still eventually converge to zero
- P_n contributes to the Stability most
- F_w contribute to happiness most

Disadvantage:

- Just having friendly warning and punishment leads N and P both converge to zero and creates more J
- Happiness converges to zero
- N turns into J too easily (J_w → N → J_n (100%))
- Difficult for J to turn into N

Modified Model Assumption

Agent-based model:

- Agent (Modified)
- Behaviors (Modified)
- Interaction rules
- Stability
- Happiness

Modified Agent 1

N_n: refer to population of normal People

N_h: refer to population of hurt People

Agent 2

J_n: refer to population of normal Joker (receives friendly warning OR punishment)

J_w: refer to population of worse Joker (receives punishment only)

Modified Interactions:

J_w → N_n → N_h (100%)

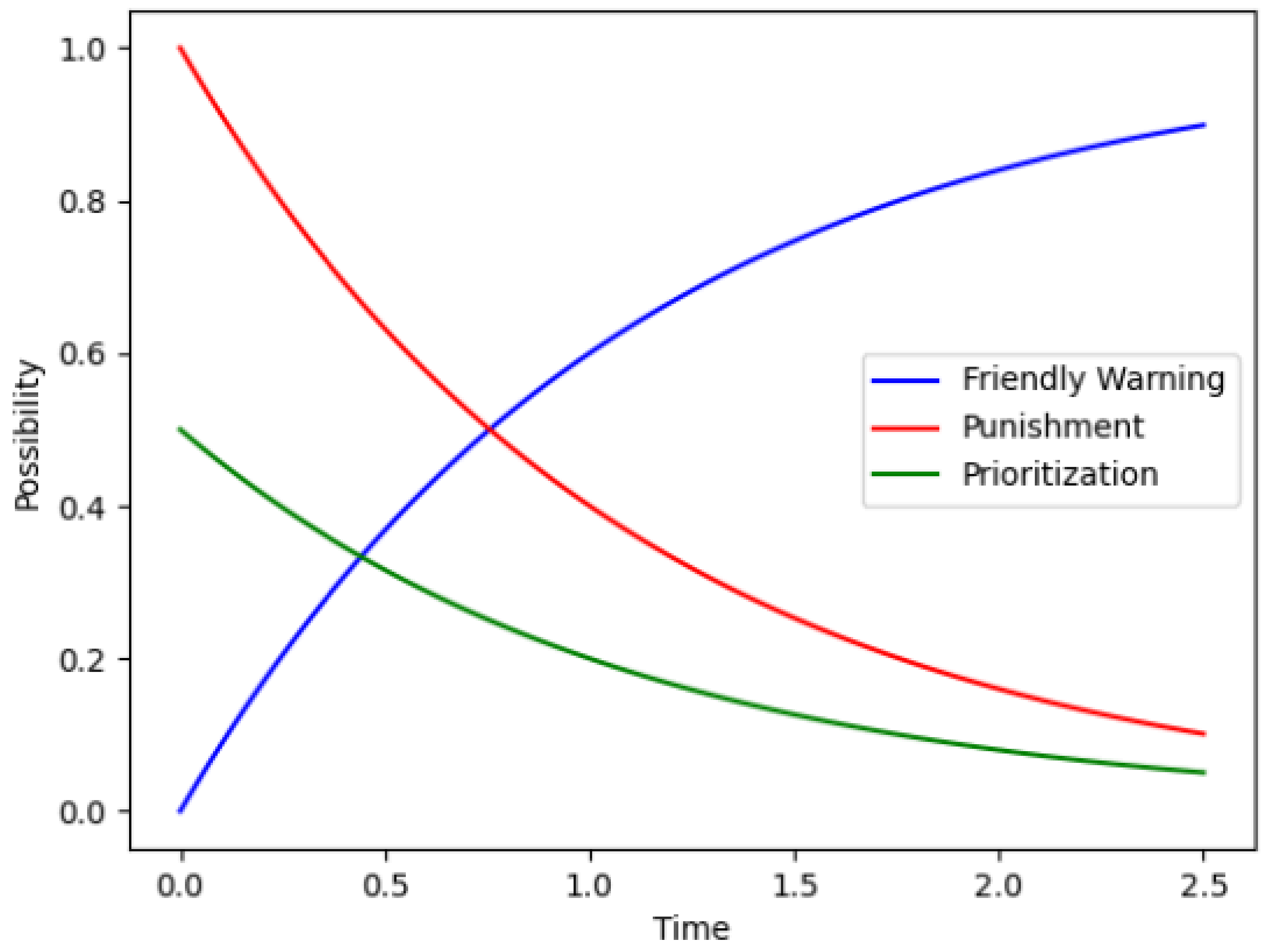
J_w → N_h → J_n (100%)

Agent 3

P: refer to population of Potential Batman (Constant in this case, since there are more needs for the group by P)

Adding Prioritization Behavior:

$$P_r = 1 - f_w - \frac{1}{2}P_n$$



Agent 3 (continued)

Modified Interactions:

$P \xrightarrow{P_r} N_h \rightarrow N_n$ (100%)

$P \xrightarrow{F_w} J_n \rightarrow$ N_n (with Fw x 100%) OR J_n (with 1-Fw x 100%)

$P \xrightarrow{P_n} J_n \rightarrow N_n$ (50%) OR J_w (50%)

$P \xrightarrow{P_n} J_w \rightarrow J_n$ (50%) OR J_w (50%)

Interaction Rules

Let's assume that the frequency of interactions is proportional to the product of the populations involved (following a mass-action principle common in chemistry and epidemiology).

For example: $-NJ_w$ means the frequency of interactions between N and J_w

Modified Stability

The initial Stability of the entire group is 0 at the start of the simulation

If a J_n turns into a N_n, Stability increase by 1.

If a N_h turns into a J_n, Stability decreases by 1.

If a N_h turns into a N_n, Stability increases by **1.5**.

If a N_n turns into a N_h, Stability decreases by 1.

If a J_n turns into a J_w, Stability decreases by 1.

If a J_w turns into a J_n, Stability increases by 1.

If a J_w turns into a J_n, Stability increases by 1.

Happiness:

Def: The rate of change of Stability

Up : stability goes up, which means that there are more positive interactions, which implies that the entire group become happier. 😁

Down : stability goes down, which means that there are more negative interactions, which implies that the entire group become unhappier. ☹️

Modified Model: Differential Equations

$$\frac{dN_h}{dt} = c * (N_n J_w - P_r N_h P - N_h J_w)$$

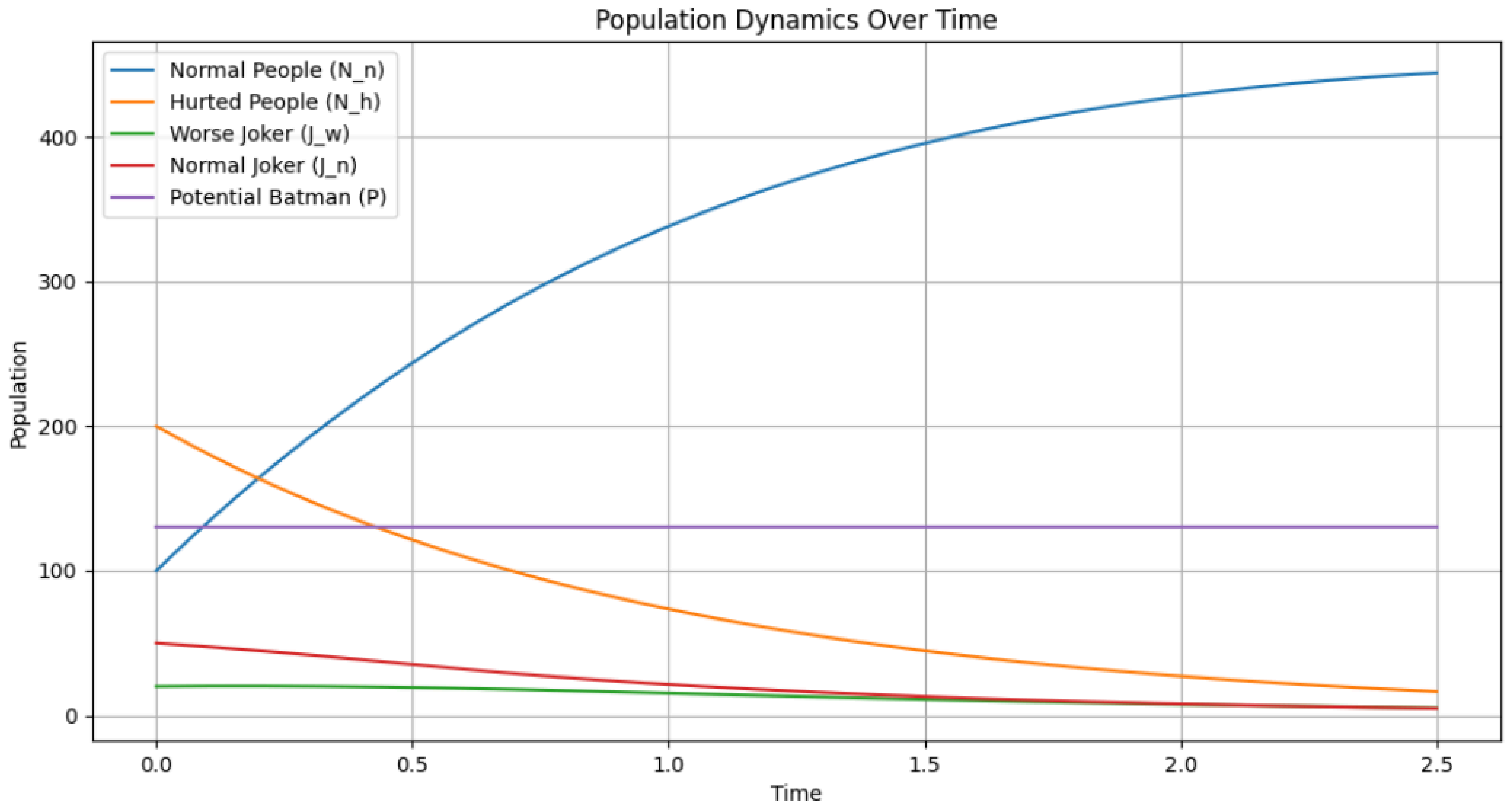
$$\frac{dN_n}{dt} = c * (F_w J_n P + P_r N_h P - N_n J_w + \frac{1}{2} P_n J_n P)$$

$$\frac{dJ_n}{dt} = c * (\frac{1}{2} P_n J_w P - F_w J_n P - \frac{1}{2} P_n J_n P + N_h J_w)$$

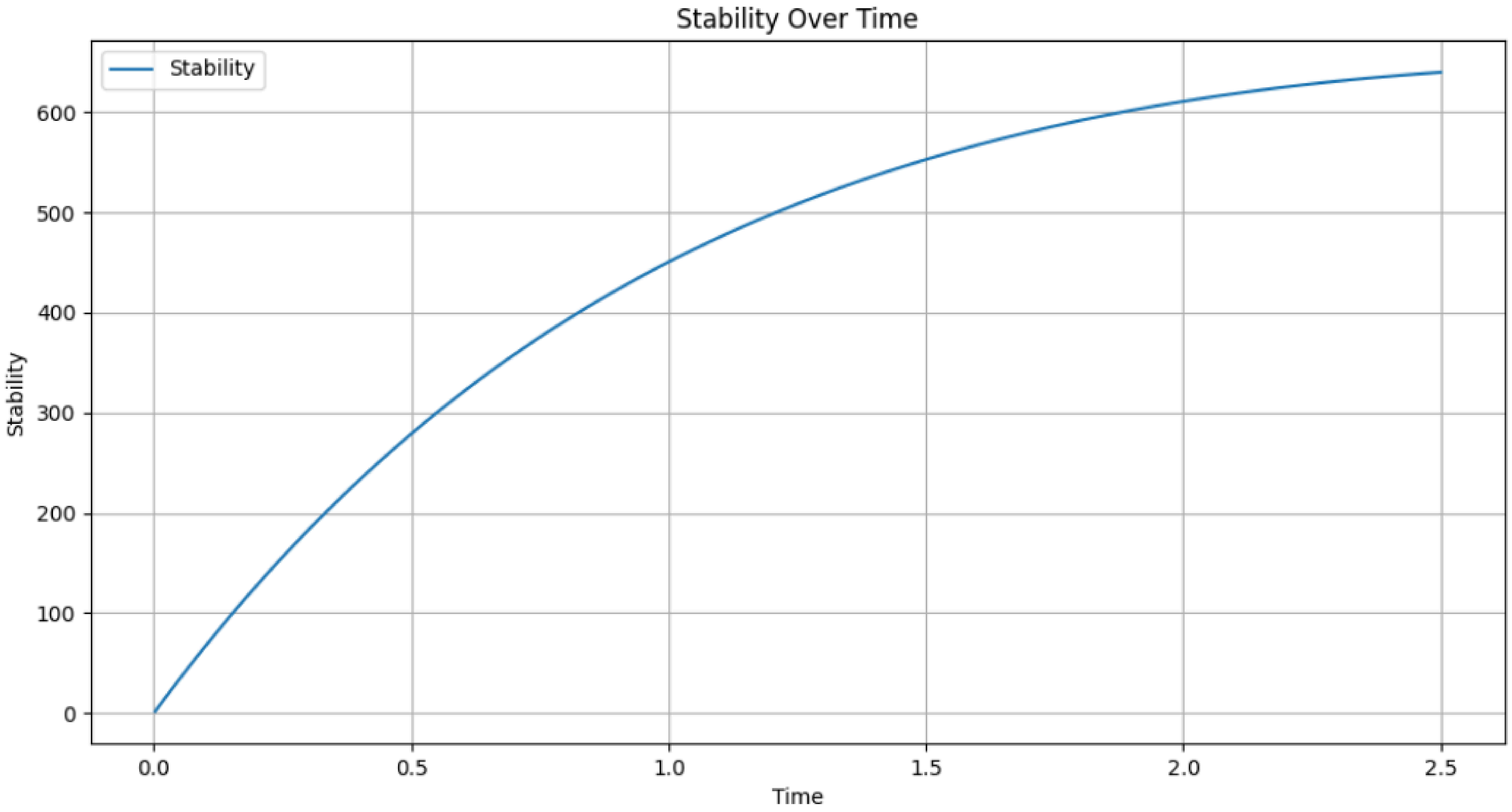
$$\frac{dJ_w}{dt} = c * (\frac{1}{2} P_n J_n P - \frac{1}{2} P_n J_w P)$$

c = adjusting coefficient

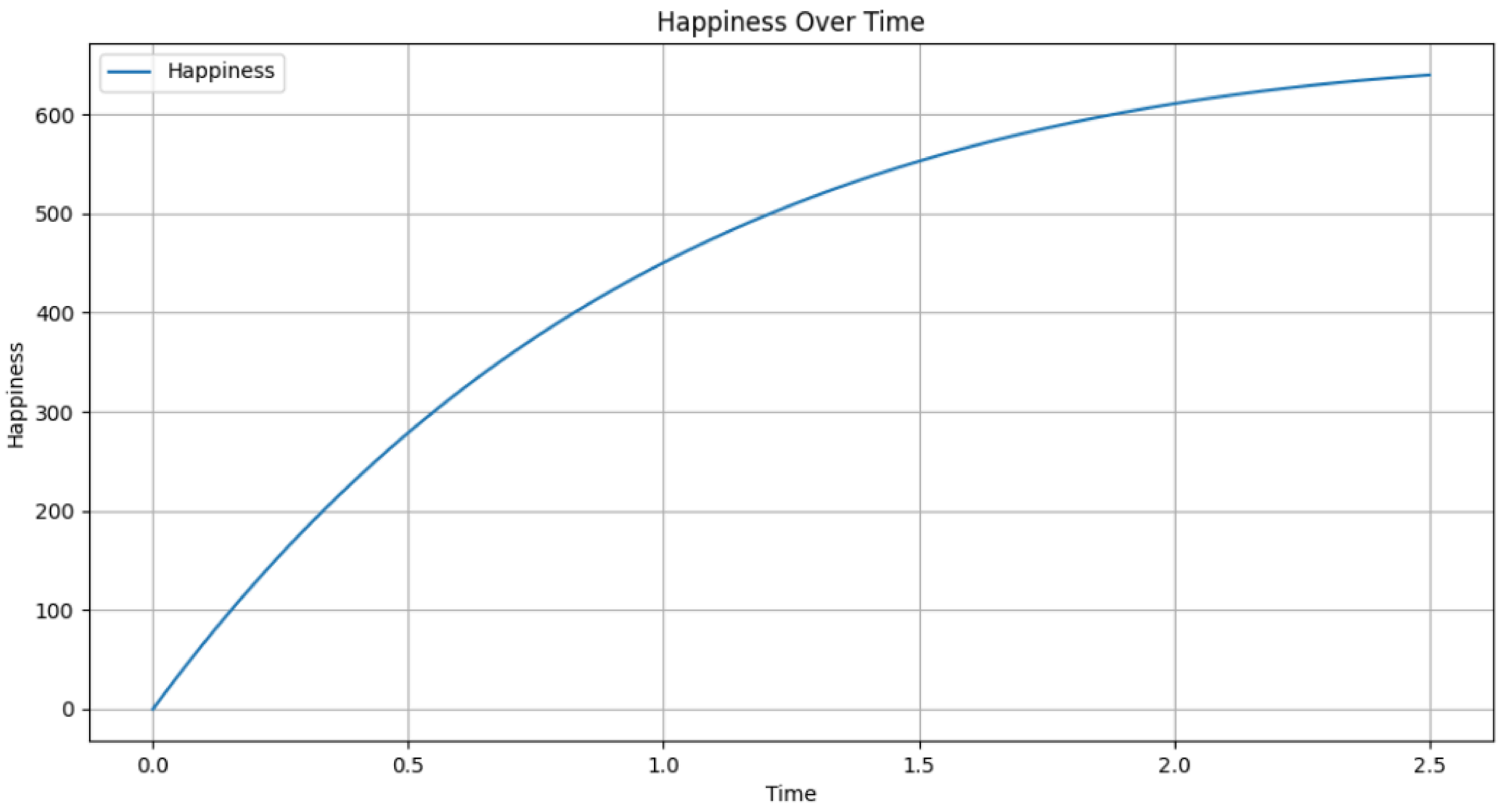
Modified Model: Solution (Scenario 2, where punishment is dominant first, and friendly warning is dominant later)



Modified Model: Solution (Scenario 2, where punishment is dominant first, and friendly warning is dominant later)



Modified Model: Solution (Scenario 2, where punishment is dominant first, and friendly warning is dominant later)



Conclusion:

- With the effect of Prioritization, N_n does not go extinct.
- Instead, J_n & J_w go extinct. And there are more and more hurt people get recovered.
- Although P_n is dominant at the beginning, the P_r still significantly turns all negative agents (N_h, J_n, J_w) to the neutral (N).
- The most important behavior to affect Stability & Happiness is P_r. (Although P_n is dominant and brings negative effects at the beginning, Stability & Happiness still increase.)

Limitation:

- Model significantly relies on the interaction rule.
- We neglect the order of behaviors of P.
- 50% is not rigorous

Further Direction:

- Set the order of P’s behaviors
- Model is more realistic and rigorous if we have a possibility function that is related to behaviors for Js who got punished, rather than just setting 50%
- Application in the medical situation by changing adjusting coefficient

Resource:

[1] Kanakogi, Y., Miyazaki, M., Takahashi, H. et al. 2022. Third-party punishment by preverbal infants. Nat Hum Behav 6, 1234–1242. https://doi.org/10.1038/s41562-022-01354-2 Last accessed 4 August 2023.