Understanding Strategic Decision-Making: A Study of the Prisoner's Dilemma

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Introduction to Prisoner's Dilemma

Game theory is the analysis of strategies when dealing with competitive situations where the outcome depends on the participant's choice. In the broad concepts and problems of game theory, the Prisoner’s Dilemma is a simplified concept that sheds light on strategic decision-making and cooperation among rational individuals. This concept was created by the RAND Corporation, an American nonprofit global policy think tank that provided experiments to follow this concept (Kuhn, 2019). Basically, the problem of the prisoner dilemma gives two people two decisions, giving a total of 2*2=4 outcomes. The problem concept is described as follows (THE INVESTOPEDIA TEAM, 2024):

> The basic Prisoner’s Dilemma scenario is between two robbers, Sam and Bob, who robbed a bank a week ago. The police know that Sam and Bob were the robbers, but they do not have any evidence to prove that, so the only way to convict them is if one confesses. The police take each one to a separate room and give them three options. If both confess to their robbery, they will serve a three-year sentence. If one person confesses and the other doesn't, the person who confessed will get a one-year sentence, while the other person will get a 10-year sentence. If they both deny it, they both get a two-year sentence.

So, in total, three scenarios with their respective sentences will be carried out. To visualize these sentences, there is a payoff matrix in the realm of game theory.

For this prompt, the payoff matrix will look like this:

Outcome	Sam Confesses	Sam Defects
Bob Confesses	(3,3)	(1,10)
Bob Defects	(10,1)	(2,2)

At first glance, confessing is a player's best option when participating in a Prisoners Dilemma game. When the player confesses, the only two sentences they can get are one or three years, depending on the other player's picks. However, this is only when the player acts in an interest to be safe. Nevertheless, if both players act in pure self-interest, they will likely defect to maximize their individual payoff. However, this leads to a suboptimal outcome compared to mutual cooperation, where both players could achieve a higher collective payoff, called a Nash equilibrium, where it reaches an optimal outcome. Nash equilibrium means they cannot improve their sentences unless both players change their decisions, proving they are in the best scenario. The best scenario in this case is confession for both players, as there is not much the player is gambling on based on the other player's decision. If the player denies it, there can be two options: one or ten years.

Iterated Prisoner's Dilemma

The Iterated Prisoner's Dilemma is the same as the classic Prisoner's Dilemma, except it introduces multiple rounds between the same people, allowing them to develop strategies throughout the dilemma. In a typical scenario of a Prisoner's Dilemma, the wisest choice is always to confess, as it ensures a lesser sentence. Players can adopt more nuanced strategies in the iterated version, strategically confessing or denying based on their assessment of previous and future rounds. This leads to a cycle of confession and denial as rather than the people looking for the best choice to achieve the lesser sentence, they can gamble on denying and try to get the least amount of punishment.

The most common strategies used in the Iterated Prisoners Dilemma are the tit-for-tat strategy and the Grim Trigger. The tit-for-tat is exactly like its name; a person will choose their strategy based on what the other player did in the previous round. While choosing their decision, the player looks back on the earlier rounds and thinks that if they have a history of cooperating, then that is the best choice, but if they have a history of denying, that is what they choose (THE INVESTOPEDIA TEAM, 2024). The Grim Trigger is a more straightforward strategy where a person cooperates till the other person denies it, which then changes their decision to always deny. They will work with the other person until they are betrayed(Kuhn, 2019). In essence, the Iterated Prisoner's Dilemma unveils the strategic depth of human decision-making under repeated interactions, showcasing the delicate balance between cooperation and self-preservation strategies in complex social dilemmas.

Real-world Applications

a. Economics

In Economics, the underlying concept behind the Prisoner's Dilemma is frequently used by firms in oligopolistic markets, where they face the dilemma of pricing strategies to compete with other markets. One prominent instance is the partnership between venture capitalists and newly established businesses, as mutual cooperation is essential for the company to expand. Startups often face the dilemma of whether to collaborate with venture capitalists for funding and support rather than pursue independent growth strategies.

Nevertheless, as Cable and Shane (1997) have noted, "Historically, these ventures have spent over $5 billion on research and development annually and have created approximately 230,000 jobs" (p. 142). Venture-backed businesses that collaborate well can quickly obtain funding and make connections within their industries. While the business itself has "working knowledge about combining intangible and tangible resources," venture capitalists contribute networks and reputation that the company would have to work hard for years to achieve (Cable and Shane, 1997, p. 144). Though each has a strength of its own, venture capitalists and entrepreneurs rely on one another and must make calculated decisions before entering a given market.

Such a situation mirrors the Prisoner's Dilemma, in which venture investors and startups must choose between acting independently for personal gain or cooperating for mutual advantage. In this sense, it also pertains to the venture capitalists and entrepreneurs' short- and long-term decisions. If a decision regarding a project is unclear, they are likely to defect from it. Nonetheless, their objective is to advance the company and foster a cooperative decision-making process more prominent in the commercial world than defecting. The Prisoner's Dilemma is

illustrated by the fact that various factors, including time constraints, project uncertainty, and profit motivation, can impact an individual's decision to cooperate or defect in economics (Cable & Shane, 1997) (p.154).

b. International Politics

In the realm of international politics, a prominent example that illustrates elements of the iterated Prisoner's Dilemma is the Cold War rivalry between the United States and the Soviet Union from the late 1940s to the 1990s. This war was a political rivalry over ideology and military tensions between both countries(Hankins, 2023). Relating to the Prisoner's Dilemma, the only difference between the regular and iterated prisoner's dilemma is that the countries competed against one another for several rounds; in this case, it was the proxy wars. Although it was not a direct application of cooperating or defecting, the underlying dynamics of strategic decision-making and mutual distrust resembled aspects of the dilemma.

First, the Cold War was not a direct war between the Soviet Union and the United States; instead, it was a proxy war in which these two countries were the superpowers behind them. They used a tit-for-tat strategy for these proxy wars, mirroring the opponent's previous move in subsequent interactions (Axelrod, 1980). An example of this was in the Cuban Missile Crisis in 1962 when the United States found that the Soviet Union was placing missiles in Cuba, threatening national safety. In response, the United States declared a naval blockade on Cuba, stopping any additional missiles from shipping. Although the Soviet Union initially denied the accusations, they eventually agreed to remove them if the United States would not invade Cuba and remove their missiles in Turkey. They both continued to make decisions to de-escalate the situation while engaging in similar strategies in the other proxy wars by constantly assessing the

different countries' decisions and influencing their moves. This shows the practical use of the Tit for Tat strategy in the iterated Prisoner's Dilemma.

Past Experimental Studies

Melvin Dresher and Merril Flood created the Prisoner's Dilemma during the Cold War to develop a solution to the strategic thinking involved in the Cold War. To test their hypotheses, they conducted a series of experiments with ordinary people to analyze their cognitive abilities. The first experiment's results helped improve the technique used in performing the second experiment. The first experiment had two players, either a junior or senior, with a partition between them, preventing them from speaking or seeing the other person.

They were given switches to either pick strategy one or strategy 2, which is the same as whether to confess or deny. When they selected a decision, they were shown to each other simultaneously. For the experiment, the motive was to make the most out of the six hundred fifty pennies given by the end of the game. They had one trial run with a hundred actual runs and then a final trial. During the experiment, they realized that the first trial run was to test that the players would not cooperate on the first run, but this spoiled the subsequent hundred runs as it ran similarly, and it was instead a game of need but one of liking. Realizing that the first experiment had flaws in terms of some players knowing each other and not properly explaining the problem also affected the results.

The second experiment involved either a first- or second-year student who was lured to play the game by offering that they may make a dollar and fifty cents. Reducing the number of trials for fairer play and increasing the depth of the instructions to understand allowed it to become an accountable experiment. After showing the payoff matrix to the players, in addition to asking what their decision was, they were also asked what they expected the other player to play and what would happen if the game was repeated. This game went on until a player lost all their money. When they analyzed their data, they relied heavily on the players' responses to the new

questions to review their analytical capabilities and to see if they saw a pattern in the gameplay. The experimenters split up the people who understood or did not, using three types of yes and no. The three types of yes include people who tried cooperation, people who do not have much opinion on the other person, and people who distrust the other person. Their results show that 23.6% of people who said no did not understand the game, while 76.4% understood the dilemma(Lave, 1960).

The results of these experiments shed light on the complexities of human decision-making in strategic settings. By analyzing participants' responses and categorizing their understanding levels, Dresher and Flood could discern patterns of cooperation, neutrality, and distrust, revealing insights into how individuals approach strategic dilemmas. Their findings, notably the 23.6% who did not grasp the game's dynamics, underscore the challenges in strategic thinking and the importance of clear communication and understanding in such scenarios. Overall, these experiments significantly contributed to studying cognitive abilities and decision-making processes, particularly in strategic contexts like those encountered during the Cold War.

Experiment Overview

To examine the Prisoner's Dilemma in real-time, an investigation was conducted of an in-person test of the Prisoner's Dilemma. Rather than giving them a jail sentence, they would receive candy in return for participating. As many people didn't come with another person, the experiment was conducted only with one person, where they were given two options: confess or deny and 6 other survey questions.

The prompt that was given:

> You and your friend were walking back from a candy shop with a bag of candy. You know both of you stole the candy bag with four pieces of candy, but the candy shop owner missed you in the act. However, the owner spotted you and your friend with the candy bag with no sticker that says paid on your way back and grew suspicious. The next day, you were stopped by the owner, who asked you to bring your friend along for questioning, as they suspected one of you stole from the shop. As you have no choice, you brought your friend. The owner took each of you into a different room and gave you three options:
>
> - Option 1: If you both confess, you both get banned from the candy shop, but you each get to keep only a single piece of candy.
> - Option 2: If you confess and your friend doesn't, you get to keep all the stolen candy, which is 4 pieces, but your friend gets banned from the shop.
> - Option 3: If you both deny it, the candy shop owner doesn't have enough evidence to punish either of you, so you both walk free with all the candy, which means two for each.

The survey questions were:

1. What year in college are you?
2. Do you have prior knowledge about the Prisoner's Dilemma?
3. Would you want to confess or deny?
4. How much do you trust your hypothetical partner in this scenario? (Low, Medium, High)
5. If the situation involved one of your loved ones, would you want them to deny or confess?
6. On a scale of 1 to 5, how risky do you perceive your choice in the scenario?
7. On a scale of 1 to 5, how likely do you think your decision will lead to negative outcomes in this scenario?
8. What were your motivations for your decision?

The experiment was performed as follows:

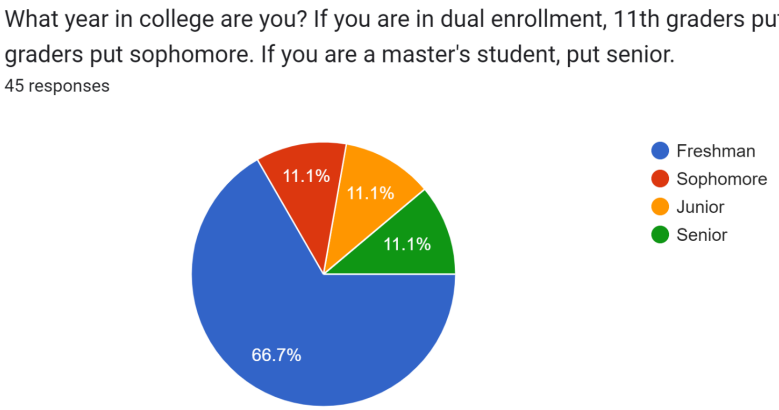
1. A willing participant was identified on the UCF campus and was informed they would receive some candy in return for participating.
2. The participant was told about the given prompt and was told they could confess or deny.
3. After telling their decision, they were given the rest of the survey questions to answer and received candy for participating in the experiment.

Experiment Data

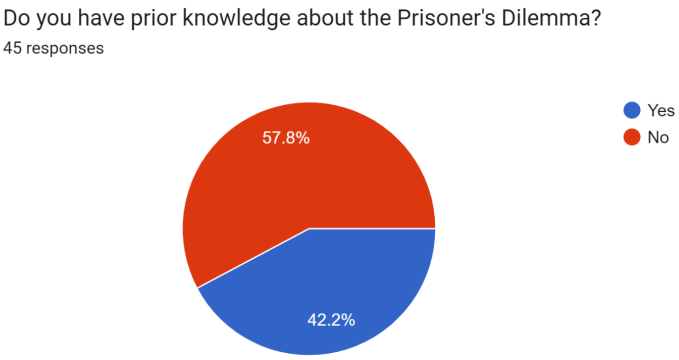
Results of the experiment:

There was a total of 45 participants.

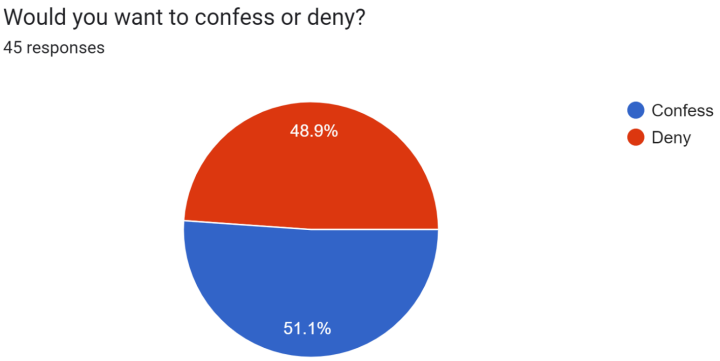
- 66.7% were Freshman, 11.1% were Sophomores, 11.1% were Juniors, and 11.1% were Seniors



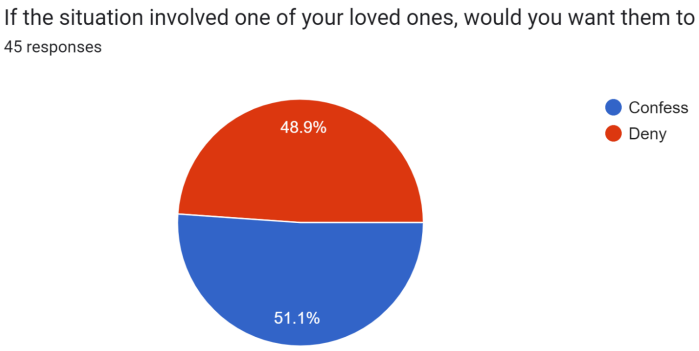
- 42.2% had prior knowledge about the Prisoner's Dilemma, 57.8% did not have prior knowledge about the Prisoner's Dilemma



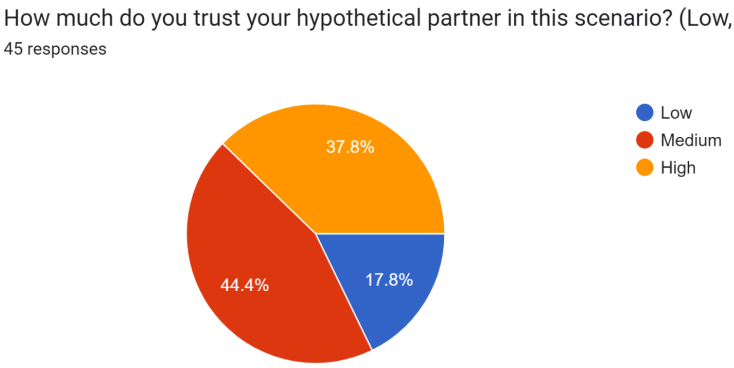
- 51.1% wanted to confess, while 48.9% wanted to deny.



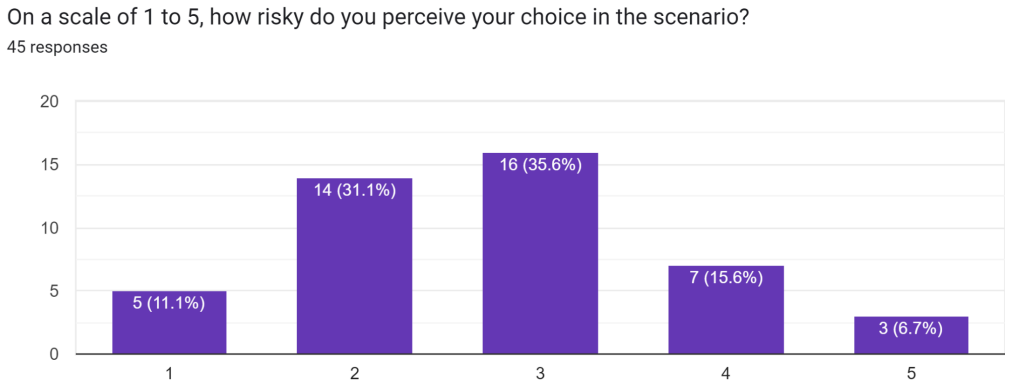
- 51% wanted their loved ones to confess, and 48.9% wanted their loved ones to deny



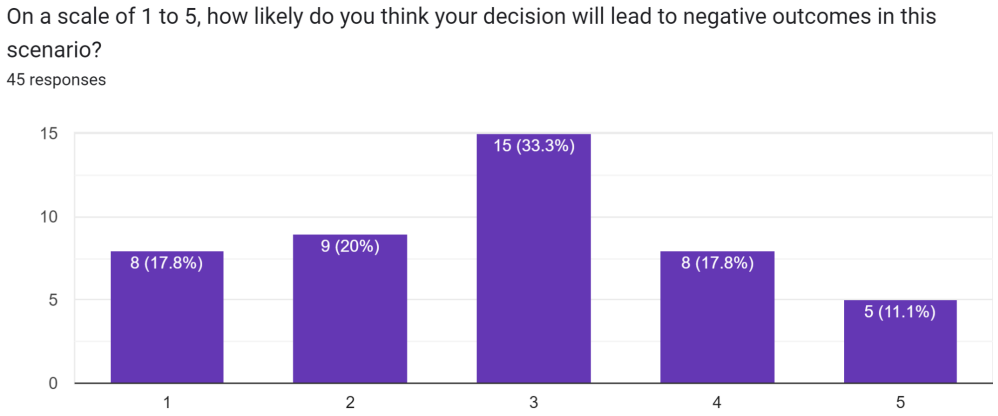
- 17.8% trusted their hypothetical partner low, 44.4% trusted their hypothetical partner medium, and 37.8% trusted their hypothetical partner high



- For the question: “On a scale of 1 to 5, how risky do you perceive your choice in the scenario?”



- For the question: “On a scale of 1 to 5, how likely do you think your decision will lead to negative outcomes in this scenario?”



Analysis

a. Analysis of the data

From the experimental data, the percentage between whether to confess or deny was split almost evenly, with twenty-five people confessing and twenty-four denying. Based on previous knowledge of the prisoner's dilemma, this is actually an accurate response from the public. If this was conducted where you would compare two people, you could earn variations of the candy, pushing people to choose how to get more candy no matter the risk. Most participants commented that the reason they decided to confess or deny depended on their hypothetical partner.

Of the 36 people who chose medium or high for their trust in their hypothetical partner, twenty-one decided to deny, showing that more than 50% of people who somewhat trusted that their partner wanted a higher reward. Of the nine people who chose low, eight confessed, matching their response that since they don't trust their partner, they will obviously confess being safe with either one or four candies. Trust played a pivotal role in guiding participants' decisions, yet it was not the sole influencer; their depth of understanding about the dilemma added a compelling layer to their choices.

Among the people who didn't know about the Prisoner's Dilemma, fourteen confessed, whereas twelve denied, and the people who knew about the problem, nine confessed and ten denied. Interestingly, participants familiar with the question were likelier to deny it, indicating a willingness to take a risk for a potentially higher gain. The participants answered that since they knew the problem, they could decide they wanted to get the most candy rather than picking the safest option. This reflects a common theme in decision-making scenarios where individuals weigh potential gains against potential losses, even at the expense of taking risks.

b. Mathematical Analysis of the data

In this prompt, the participant's goal is to get the most candy, while in the original prisoner's dilemma, it is to get the least amount of sentence.

Here are some constants that will be used to find the expected amount of candies:

A. Confession Reward: This reward is given to the person who confesses while the other denies. The reward is four candies.
B. Deny Reward: This reward is given if both deny. The reward is 2 candies.
C. Confession Punishment: This punishment is given if both confess. The reward is only one candy.
D. Deny Punishment: This punishment is for the person who denies it while the other person confesses. The reward is zero candy.

We can assign the following values: A=4, B=2, C=1, and D=0. As D is 0, it doesn't make much difference in an equation for the expected amount of candies, so it is not included. This is Nash Equilibrium, where A>B>C>D, where the participants know of their choices, and there is always a better choice than they pick. If the participant chooses to confess, the amount of candy they will get is between one and four, whereas if they choose to deny, it is between two or none.

To calculate the expected value of candies for each participant, we can create an equation to represent it. Let p be the probability that player one cooperates, and q be the probability that player two cooperates. So, the probability will be defined as one if they confess and zero if they deny. The first formula represents the expected score for player one, A, and the second one for player 2, B.

$$E(A) = p * q * C + p * (1 - q) * A + (1 - p) * (1 - q) * B$$

$$E(B) = p * q * C + q * (1 - p) * A + (1 - p) * (1 - q) * B$$

Each player's formula is quite the same, except that the places where p and q are opposite each other as we determine the number of candies for each, which may not be the same.

To test the equations:

p=0 and q=0 E(A)=B=2 E(B)=B=2	p=1 and q=0 E(A)=A=4 E(B)=D=0
p=0 and q=1 E(A)=D=0 E(B)=A=4	p=1 and q=1 E(A)=C=1 E(B)=C=1

Conclusions

The Prisoner’s Dilemma is a hypothetical scenario that accurately explains trust and risk perception, how they play into decision-making, and the interplay between individual choices and collective outcomes. Although the survey may not be able to give exact results of a real-life dilemma scenario, it provides a valid conclusion on the participants' thought processes. While the most optimal outcome for Nash equilibrium is to confess, everyone has a human consciousness where we are greedy. This is why, in this survey, almost half of the people chose to deny it, as they can gamble for more candy than be safe, and technically, they don’t lose anything.

However, if this scenario happened when two people stole candy and were put in the spot to either confess or deny, the better choice is to acknowledge and be able to get a lesser punishment, but the pressure they felt to make the right choice is not shown in this survey. Unless there is an environment where people will lose something, it is better to take the risk and get more if possible; otherwise, they try next time. In essence, the prisoner's dilemma is an important model for testing outcomes in the real world and making calculated decisions according to the circumstances.

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