

# **PRINCIPLES OF BEHAVIORAL ECONOMICS**

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**Lecture 52**

Hello everyone, this is Lecture 52 of the course on Principles of Behavioral Economics. We have started discussing analytical game theory under the broad topic of strategic interactions. So in the previous module, we introduced the basic concepts related to game theory and also talked about how we derive the Nash equilibrium. Now, we are going to talk about another kind of game, a very popular kind of game known as the Prisoner's Dilemma. Similar to the Battle of the Sexes, I would also like to mention here that the Prisoner's Dilemma, of course, will be a classic case.

But then. From that classic example of the prisoner's dilemma, now the prisoner's dilemma has actually become a type of game that does not necessarily always imply that prisoners are involved. It's depending on the distribution of payoffs; certain games are now categorized as the Battle of the Sexes, the Prisoner's Dilemma, or the Stag Hunt, and so on. So here, let us talk about the classical example which gave birth to the concept or the idea of the Prisoner's Dilemma games.

Two criminals are arrested on suspicion of two separate crimes. The prosecutor has sufficient evidence to convict the two on the minor charge but not the major one. If the two criminals cooperate with each other and stay mum, they will be convicted on the minor charge and serve two years in jail. First of all, the criminals are arrested on suspicion of two separate crimes. One is a major one, another is a minor one. Now we are saying that there are two strategies.

The first one is cooperation with each other, where both of them will just stay mum or say, 'No, I have not done it,' and that's it. So they will not be able to be convicted of the major one only for the minor one they will serve two years in jail. The prosecutor offers each one of them a reduced sentence if they defect, that is, testify against the other. So here is the situation of defection that we defined in the previous

module, where one can defect and then get a benefit at the cost of the other. So here, defection implies that one prisoner or one criminal would say that I have not done it, but the other fellow has done it. So just because he has testified against the other criminal, the other criminal will get actually 20 years in jail, while the person who defects says that I have not done, but the other one has done, actually goes free. So if one prisoner defects but the other one cooperates—while one prisoner is saying the other one is guilty,

the other one is saying, 'No, I have not done it.' So then the defector goes free, whereas the cooperator serves 20 years in jail. If both defect—that is, both of them say that the other one has done it but I have not—both get convicted on the major charge. But as a reward for testifying, they only serve 10 years in jail. Assume that each prisoner cares about nothing but the number of years he himself spends in jail.

So there is no empathy or sympathy for the other one. You just think about yourself, and then let us see what the Nash equilibrium would be in this case. So, first of all, what is the payoff matrix? And then, what is the Nash equilibrium? If I mention the years in jail as a negative payoff and when someone is set free, the payoff is zero, we we can have any kind of numbers in this situation we can have also positive numbers instead of zero when someone is set free. Then, this can be considered as a payoff matrix where when both players are cooperating

That is, if both of them keep quiet, then they are serving jail terms just for the minor complaint. So, two years of jail for a minor crime. So, two years of jail. But suppose Player One keeps quiet while Player Two defects, then Player Two goes free and Player One serves a jail term of 20 years. Similarly, if Player Two keeps quiet and Player One says,

the other fellow has done it, I have not done it, then Player 1 goes free while Player 2 serves a jail term of 20 years. And if both of them say, 'I have not done it, but the other one has done it,' then both of them serve a jail term of 10 years. So, minus 10, minus 10. And how do we obtain the Nash equilibrium? As you can see, if Player 1 cooperates, then Player 2 is better off by defecting.

If player 1 defects, then by comparing -20 and -10, again player 2 is better off by defecting. When player 1 cooperates, then player 2 cooperates, then player 1 is better off by defecting because I am now comparing -2 with 0. And when player 2 defects, then again by comparing -20 and -10, player 1 is better off by defecting. So, defect-defect is the Nash equilibrium.

Now here we talk about something called a dominant strategy. A strategy X is said to strictly dominate another strategy Y if choosing X is better than choosing Y, no matter what the other player does. So here you can see that for each strategy of player 1, player 2 is better off by defecting. Player 2 is better off by defecting: -2 and 0, -20 and -10. So, defect is the dominant strategy for player 2.

For each strategy of player 2, you can see that -20, -2, -20 for each strategy of player 2. So for cooperate, this is like -2 and 0, so 0, and for defect, -2 and -10, so -10. So again, defect is the dominant strategy for player 1. In the prisoner's dilemma, defection strictly dominates cooperation, so cooperation can be eliminated altogether.

No rational player will cooperate, and both will defect. Pareto dominant outcome or strategy in this context is defined as an outcome X. that is say to Pareto dominate another y if all players weakly prefer x to y and at least one player strictly prefers x to y and the related concept is that of Pareto optimal outcome or strategy and outcome is Pareto optimal if it is not Pareto dominated by any other outcome. Alternatively,

an outcome is Pareto optimal if it is a Pareto dominant strategy. In the Prisoner's Dilemma, the cooperative outcome C, C Pareto dominates the Nash equilibrium D, D because you can see that the Nash equilibrium is minus 10, 10. Defect-defect are definitely dominant strategy, but they are not Pareto optimal outcome or Pareto optimal strategy. Because Pareto optimal outcome is an outcome where both of them would be better off. So cooperative outcome Pareto dominates the Nash equilibrium DD.

This that's why at times consider to refute Adam Smith's insight that the rational pursuit of individual self-interest leads to socially desirable outcomes. individual pursuits are leading to a dominant strategy of defect defect and this is the outcome while the socially desirable that is both of them together would have been benefited by an outcome like or strategy profile like cooperate-cooperate and outcome like minus 2-2. So this is a situation where Adam Smith's insight that the rational pursuit of individual self-interest leads to socially desirable outcome is refuted. As I probably mentioned in the beginning of the strategic interactions that it has been actually observed that in the context of analytical game, it need not be always true.

Now we talk about a game with no Nash equilibrium in pure strategy. Suppose you want to study in the library or in the department but don't want to run into your bestie. However, your bestie would like to study with you. So you want to study alone while your best friend wants to study with you. Now there is a conflict of interest. Let's see what happens. Suppose

a player gets a utility of 1 whenever his or her goal is attained and 0 otherwise. So your goal is to study alone. If you get to study alone, then you would get a utility of 1.

Your bestie's goal is to study with you. And if she gets to study with you, then she will get a utility of 1. In case you don't get to study alone, your utility or payoff would be 0. And if she does not get to study with you, then her payoff or utility would be 0. So this is how we construct the payoff matrix.

We are measuring—or this is player 1, and bestie is player two. The two options are where to study library or department for both of you library or department so if you happen to be in library and your best friend is also in library so basically you two are studying together. Your goal is not fulfilled; you are getting a utility of zero. Your best friend is getting a utility of one because that's what she wanted to do. But if you are in the library and she is in the department—or your best friend, he is in the department—then you are getting your goal fulfilled.

You are in two different places, and you are getting a utility of 1 while she is getting 0. In a similar fashion, you can understand that when you two are in different places, you are happy getting a utility of 1 and she is getting 0. When you two are at the same place, then you are not happy, getting a utility of 0, and she is getting a payoff of 1. So what is the Nash equilibrium here? Now you can see that if we try to find out the Nash equilibrium,

When you are in the library, it is best for her to be in the library. I am comparing 1 and 0. When you are in the department, then it is best for her to be in the department. When she is in the department, then it is best for you (by comparing these two) to be in the department. When she is in the department, then again, it is in your best interest to be in the library.

So, we do not have any Nash equilibrium here. Understandably, because what is best for you is not judged to be best for her by herself. so there is no Nash equilibrium in this game these games are also known as matching pennies where two players flip two coins If both get heads or tails, player one wins; otherwise, player two wins. So, in case both of them toss a coin and if both of them get the same thing— either head or tails- then it is for player one to win if they get

Different things like one gets heads, another gets tails, or one gets tails, the other gets heads. Then, this is for Player 2 to win. So again, there is a conflict of interest. Only one of these two can happen. Both of them cannot happen together.

So in one situation, one wins. In the other situation, the other fellow wins. So these games are pretty close to what is known as a zero-sum game. Ideally, a zero-sum game should have payoffs like -1, 1 and 1, -1. So that in each and every cell, the payoffs sum up to zero.

But what it implies is that there is a conflict of interest. What is good for you is not good for the other fellow. What is good for the other fellow is not good for you. So from that perspective, these are also zero-sum games or pretty close to the type of zero-sum game. A zero-sum game is a game in which the gains and losses of the individuals

sum to zero for all combinations of strategies they might pursue. Okay, so what we have seen is that some games have no Nash equilibria in pure strategies, but that does not mean that they do not have Nash equilibrium. Pure strategies are like when you are choosing one or more of the strategies that appear to be the best possible strategy for you, but mixed strategies are essentially when you are combining the pure strategies with certain probabilities. In the study example, as we saw, the game didn't have any Nash equilibrium. The game does, however, have a Nash equilibrium in mixed strategies.

Suppose that you figure out where to go by flipping a coin and that your bestie does the same. Given that you have 50% chance of ending up at the library and a 50% chance of ending up at department, your bestie is indifferent between library and department and can do no better than flipping a coin Basically, since both of you do not have any idea about where the other person is going, you are actually indifferent between the two locations. So you can decide just by flipping a coin where to go. And given that your bestie has a 50% chance of ending up at library and a 50% chance of ending up at department,

you are indifferent between library and department and can do no better than flipping a coin. The two of you are in a Nash equilibrium, though you are playing mixed rather than pure strategy. So here the two strategies are library and department, library and department for both of you. And since you are flipping a coin to decide where to go, we say that you are using a mixed strategy with each strategy having a 50% chance of occurrence. In a game like this, the mixed strategy equilibrium is easy to find.

In other games, it can be more tricky. Now, let us consider the game of Battle of the Sexes. Assume that the wife has a probability of  $P$  going to the concert and  $1 - P$  of going to the theater. So, the wife goes to the concert with a probability of  $P$  and to the theater with  $1 - P$ . The probabilities for the husband are  $Q$  and  $1 - Q$ , respectively. The players must be indifferent between the two strategies. Again, the strategies themselves do not tell you anything,

so when they are indifferent between the two strategies, which means that the utility from the concert is equal to the utility from the theater. So,  $U(\text{concert})$  is equal to  $U(\text{theater})$  for both of them. Now, equating  $U(\text{concert})$  with  $U(\text{theater})$ , the values of  $P$  and  $Q$  can be estimated. How? The expected payoff of Player 1 for each strategy is the expected value of  $U(\text{concert})$ , that is, the expected payoff of Player 1 for each strategy. So, let us consider the first strategy: concert.

So, the expected payoff from the concert is: if she goes to the concert, then what are the probabilities of getting these payoffs? The probability is  $Q$ , and the probability is  $1 - Q$ . So, she gets 2 utils of utility with the probability of  $Q$  and 0 utils of utility with the probability of  $1 - Q$ . Similarly, the expected payoff from the theater is 0 with the probability of  $Q$  and 1 with the probability of  $1 - Q$ . Now, since we say that these two are equal, we equalize these two:  $2Q + 0 = 1 - Q$ , which is basically  $2Q = 1 - Q$ . This is again  $0 = 1 - 3Q$ , and this gives me  $Q = 1/3$ .

So, equating them, we obtain  $Q = 1/3$ . In a similar fashion,  $P$  can be calculated as  $2/3$ . So in order to get  $P$  value what we do for each strategy of husband. The husband will see that he can get 1 with the probability of  $p$  and 0 with the probability of  $1 - p$  so he writes  $p + 0 = 1 - p$  which is basically  $0 = 1 - 2p$ . The utility from concert for the husband is equal to 0 into  $p$  and 2 into  $1 - p$ .

so again  $0 = p$  and  $2 = 1 - p$  which implies  $P = 2/3$ . I take  $2P$  to the other side. So this is how we calculate  $P$ . There is a Nash equilibrium in mixed strategies in which player 1 chooses a concerted probability of  $2/3$  and player 2 chooses a concerted probability of  $1/3$ . In the mixed strategy equilibrium, player 1 gets a payoff which is  $U_C = U_T = 2Q$ , and then that is  $2/3$ .

Player 2 gets a payoff again equal to  $2/3$ . This example shows that games with pure strategy equilibria may also have mixed equilibria. Now, let us take an example: what will be the NEs in the following games or Nash equilibrium? So, if we consider pure strategy Nash equilibrium, then you can see that for  $U$ , player 2 chooses  $L$ ; for  $D$ , player 2 chooses  $R$ . When player 2 chooses  $R$  or for the strategy of  $L$ , player 1 chooses  $U$ . When 2 chooses  $R$ , player 1 chooses 2.

So,  $U, L$  and  $D, R$  are the two Nash equilibria. We can also, in a similar fashion, calculate the mixed strategy equilibrium. The mixed strategy equilibrium would be calculated as  $Q$

equals 1 upon 5 and P equals 4 upon 5. This is another game. Now, you see here: if 1 goes for U, 2 goes for L. If 1 goes for D, then 2 is indifferent between L and R. If 2 goes for L, then 1 is better off by going for U. If 2 goes for R, then 1 would be indifferent between U and D. So, here you can see that U, L and D, R are again the two Nash equilibria. But if you try to calculate a mixed strategy equilibrium, you understandably can find none because most of the payoffs are zero. So, let us talk about pure versus mixed equilibria. Although mixed strategy equilibrium may at first seem like an artificial construct of mainly academic interest, mixed strategies are important and common in a wide variety of strategic interactions. Even if you are a tennis player with a killer cross-court shot, it would be unwise to hit the cross-court shot every time, or your opponent will learn to expect it.

Every so often, you must hit the ball down the line. In games like this, in order to keep your opponent guessing, you must mix it up a bit. This analysis shows that it is not a mistake but necessary every so often to hit your weaker shot. So basically, even though you have a very clear Nash equilibrium of playing the best shot you can, but then if you keep on playing that particular shot, you'd be very easily guessed, and your opponent might have an upper hand.

And as a result, you need to play and actually make a strategy sometimes. There are certain probabilities that you would be playing certain shots. In games, the fact that a person chooses the inferior option from time to time does not mean that he or she is not playing an equilibrium strategy. According to the authors of the book *Spousonomics*, Paula Szuchman and Jenny Anderson, Economics is the surest logical solution to what can often seem like thorny, illogical, and highly emotional domestic disputes. Suppose that you are stuck in an equilibrium where you do the dishes, make the bed, and empty the cat litter while your spouse sits back and relaxes.

*Spousonomics* apparently teaches that you can turn your spouse into an acceptable partner by playing a mixed strategy, by sometimes doing the laundry, sometimes not; sometimes making the bed, sometimes not; and so on. Relaxing is the best strategy for you. In pure strategy, relaxing gives you the maximum Nash equilibrium payoff, and it's a pure strategy Nash equilibrium when you just relax and your wife does everything. But then that leads to a lot of conflict.

And in order to avoid that, you can always go for a mixed strategy, sometimes doing certain things so that there is less animosity between you and your spouse. Similarly, let us take the example of chess. Chess is a finite game. We know this because every player has a

finite number of moves to choose from at any point in the game, and because every game ends after a finite number of moves. Because it is a finite game, Nash's theorem establishes that it has an equilibrium.

This suggests that chess should be uninteresting, at least when played by experienced players. Assuming player 1 plays the equilibrium strategy, player 2 can do no better than playing the equilibrium strategy and vice versa, and they are very much predictable, as a result of which the game becomes uninteresting. Thus, we should expect experienced players to implement their equilibrium strategies every time and the outcome to be familiar and predictable. Yet, Nash's theorem only establishes the existence of an equilibrium.

It does not reveal what the equilibrium strategies are. As of yet, no computer is powerful enough to figure out what they are. And even if we knew what the strategies were, they might be too complex for human beings to implement. Thus, chess is likely to remain interesting for a good long time. And finally, we talk about Nash's theorem.

So what Nash's theorem says is that every finite game, that is, every game in which all players have a finite number of strategies, has a Nash equilibrium. Given this theorem, the search for Nash equilibria is not futile. As long as the number of pure strategies available to each player is finite, and whether this condition is satisfied is fairly easy to determine, we know that the game has at least one Nash equilibrium in pure or mixed strategies.

That is neat. So, I conclude this module with this note. Next, we will briefly introduce the extensive form game and discuss the types of games. These are the references for this module. Thank you.