Teaching Prospect Theory with the *Deal or No Deal* Game Show

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Summary
Recent evidence indicates that decision makers are more sensitive to potential losses than gains. Loss aversion psychology has led behavioural economists to look beyond expected utility by developing *prospect theory*. We demonstrate this theory using the *Deal or No Deal* game show.

◆ INTRODUCTION ◆

Individuals, groups, businesses and governments make decisions all the time, but why? Simply put, we make decisions because we have choices. Decisions and the associated choices can range from simple, such as what to eat for lunch, to complex, such as which job to take, which house to buy, which stock to invest in, which horse to gamble on or which presidential candidate to vote for. Simple decisions are typically based on intuition or common sense since the questions are 'easy' and the answers are 'obvious.' However, in complex decision-making situations, common sense is unreliable, and something more objective is needed in order to become an effective problem solver. This is where decision theory can help us. Decision theory is the study of human decision making through the use of statistical reasoning techniques. In the classroom, decision theory can be used to illustrate how statistics is applied to real problems in order to model human decision-making behaviour.

In decision theory, choices are referred to as alternatives or actions. Each alternative brings with it potential consequences which we call outcomes. For example, let's say that you are trying to decide which home to buy. One outcome that you might consider for each house (i.e. alternative) would be the resale value (i.e. high, medium or low) based on the house's location, description, age etc. Outcomes help us weigh the pros and cons of the alternative in order to make the best decision. In decision theory, these outcomes can be weighted according to the likelihood (i.e. probability) of the outcome occurring. For example, we can use the probability that the resale value will be high, medium or low in, say, 5 years in order to help us make a decision. Ask your students to describe some decisions that they have made today and the potential outcomes of their decisions. Did they consciously or subconsciously apply weights to the outcomes? If so, how did that help them make the decision?

◆ THE CONCEPT OF UTILITY ◆

Decision making has been studied since at least the 1700s, when Nicholas Bernoulli proposed a perplexing statistical problem referred to as the St. Petersburg Paradox (Savage 1967; Plous 1993). His cousin Danielle Bernoulli attempted to solve the paradox by describing the utility of money (Bernoulli 1738/1954). Bernoulli's concept of utility stated that a person's current financial frame of reference would greatly affect their decision when faced with a risky gamble (i.e. choices involving winning or losing money based on specific probabilities). In other words, a player with very few financial resources would consider a small monetary gain to be large, whereas someone who is wealthier would consider the same small gain to be inconsequential, simply because of their different frames of reference (i.e. utility). For example, ask your students if the difference between \$100 and \$200 is a lot of money to them. Next, ask if they think that the difference between \$1100 and \$1200 is a lot of money. Even though the difference between these two sets of values is the same (\$100), most people view the difference between \$100 and \$200 to be greater. This is because the utility of money is greater when we have less of it. In other words, the more money that a person has, the less valuable fixed incremental increases in monetary value will be to that person (c.f. Schoemaker 1982). Thus, as wealth increases incrementally, utility decreases.

◆ PROSPECT THEORY ◆

In an attempt to improve upon Bernoulli's concept of utility, von Neumann and Morgenstern (1953) took into account the risk/reward ratio associated with a decision. Ideally, this ratio would be small, indicating a low risk associated with a high gain or reward. However, realistically, we must expect to pay a price for a favourable risk/reward ratio, which is typically the case as illustrated by von Neumann and Morgenstern (1953) in their groundbreaking work in game theory. Their work also led to another groundbreaking decision theory referred to as *prospect theory*, which was first proposed by Kahneman and Tversky in 1979.

After presenting subjects with risky gambles called prospects, Kahneman and Tversky (1979) observed that when the prospect was presented in terms of a gain, people tended to be loss averse. That is, they typically chose to play it safe and avoid any potential loss. This discovery illustrated an interesting aspect of human behaviour—when people perceive that they stand to gain something compared to their current financial position, they become risk averse and will often refuse to take even a small risk to better their current financial position. Further, Kahneman and Tversky observed that the opposite behaviour occurred when the prospect was presented in terms of a loss. When this occurs, people seek out risk, preferring the possibility of recouping any loss even if it means taking foolish risks to avoid incurring what they perceive as a loss.

We now illustrate decision-making behaviour as predicted under prospect theory. To illustrate loss-averse behaviour, consider the following prospect: which alternative would you rather choose, an 80% chance of gaining \$400, or gaining \$300 for certain? This prospect can be represented as:

A: (\$400, 0.80; \$0, 0.20)
B: (\$300, 1.0)

Note that there is no risk involved in choosing alternative B (you will get \$300 no matter what), but there is a 20% chance that you will get nothing if you choose alternative A. Even though you would expect on average to gain more by choosing alternative A (expected value = (\$400 × 0.8) + (\$0 × 0.20) = \$320), most people would rather avoid the small chance of gaining nothing and instead go with the certainty of gaining \$300. Ask your own students which alternative they would prefer. It is very likely that the majority of students will be risk averse with respect to monetary gain. In other words, they won't want to risk getting less money.

Does this decision-making behaviour hold when the prospect is presented in terms of a loss instead of a gain? To illustrate risk-seeking behaviour, consider the following prospect:

A': (–\$400, 0.80; \$0, 0.20)
B': (–\$300, 1.0)

Now the question is: would you rather entertain the certainty of losing \$300 or take an 80% chance of losing \$400? No one wants to lose any amount of money if possible, so most people would recognize that the first alternative A' provides a way out—a 20% chance of losing nothing—and so would choose that over the sure loss. This represents risk-seeking behaviour since losing \$300 for certain is less than the expected loss of \$320 for alternative A' (expected value = (–\$400 × 0.8) + (\$0 × 0.20) = –\$320). In other words, since the prospect is presented in terms of a loss, most people would rather take the risk of losing nothing over the certainty of losing something, even if it meant losing more in the long run. Again, ask your students which alternative they would prefer. They may be amazed by their risk-seeking behaviour.

◆ EXCEPTIONS TO BEHAVIOUR PREDICTED BY PROSPECT THEORY ◆

No single theory can explain all decision-making behaviour and there are certainly some exceptions to the behaviour predicted by prospect theory. For example, prospect theory does not hold with respect to insurance premiums. In this case, most people would gladly pay an annual or monthly insurance premium (a certain monetary loss) on their car or house rather than risk losing more if, for example, they wreck their car or their house is destroyed by a fire, even if the chances of these things happening are very small. This type of behaviour is contrary to prospect theory. The lottery is another counterexample to prospect theory. Why would anyone pay any amount of money for the chance to win millions of dollars when the probability of winning is so small (e.g. 1 in 195,249,054 for Powerball; see http://powerball.com/powerball/pb_prizes.asp)? Perhaps it is the prospect of winning a life-changing amount of money for such a small monetary contribution. This would make an interesting discussion on risk-seeking behaviour, but regardless of why people gamble, this behaviour is also contrary to prospect theory. Still another exception to the behaviour predicted by prospect theory is behaviour on television game shows.

◆ *DEAL OR NO DEAL* ◆

In game shows such as *Deal or No Deal*, players also exhibit risk-seeking behaviour that is contrary to that predicted by prospect theory. This game provides an interesting study in decision-making behaviour that can be modelled and discussed in a classroom setting. (The particulars below concern the US version of the show. See, for example, http://en.wikipedia.org/wiki/DEAL_OR_NO_DEAL_UK for a description of the version televised in the UK.) Let's start with a description of the game strategy.

In *Deal or No Deal*, 26 monetary amounts ranging from $0.01 to $1,000,000 (see the first column of table 1) are randomly assigned by a third party to 26 cases. To begin the game, the player randomly chooses one case, which will remain unopened until the end of the game. The player continues the game by randomly choosing cases to be opened in each round according to the following schedule: six cases are opened in round 1, five in round 2, four in round 3, three in round 4, two in round 5 and one case in each of the remaining four rounds. After the appropriate cases have been opened in each round, an anonymous 'Banker' makes a monetary offer (based in part on the dollar amount of the cases left in play). At this point, the player must either choose to keep the Banker's offer (i.e. 'Deal') thus ending the game, or refuse the offer (i.e. 'No Deal') and continue the game. If the player continues to the

Start	*After round 1*	*After round 2*	. . .	*After round 7*	*After round 8*	*After round 9*
0.01						
1	1	1				
5						
10	10					
25	25					
50						
75						
100	100	100		100	100	100
200	200	200				
300	300					
400	400	400				
500	500	500				
750	750	750				
1000	1000	1000				
5000	5000	5000				
10,000	10,000					
25,000						
50,000	50,000	50,000				
75,000	75,000	75,000				
100,000	100,000	100,000		100,000		
200,000	200,000	200,000		200,000	200,000	200,000
300,000	300,000					
400,000						
500,000	500,000	500,000				
750,000	750,000	750,000				
1,000,000	1,000,000	1,000,000		1,000,000	1,000,000	
Expected value	149,664.30	178,863.40	. . .	325,025.00	400,033.33	100,050.00
Banker's offer	49,389	51,870	. . .	159,926	212,201	74,037

Table 1. Monetary values, in dollars, of unopened cases in a single game of *Deal or No Deal* (. . . indicates that rounds 3 through 6 have been left out of the table)

end of round nine, then their originally chosen case is opened to reveal their prize in round 10.

Similar to Kahneman and Tversky's (1979) examples of risky prospects, the *Deal or No Deal* decision involves an alternative that can be obtained with certainty (the Banker's offer) and a risky alternative (winning the highest amount remaining in play). Now, prospect theory predicts that the player should accept the Banker's offer because, being risk averse with respect to gains, the player should prefer a certain monetary value to a risk. However, contrary to prospect theory, most players refuse the Banker's offer and seek out the risk in hopes of gaining more money. Unfortunately (and in line with the predictable probabilities involved), players seldom win a large prize, and most players end up with very little money because of their risky behaviour.

Students can experience this decision-making behaviour themselves by playing *Deal or No Deal* online (go to http://www.nbc.com/Deal_or_No_Deal/game/flash.shtml). To do this, simply instruct each student to play the game according to the rules and to try to win as much money as possible. That may mean taking the Banker's offer at whatever round that they deem appropriate, or playing until the final round. Instruct them to make the decision to 'Deal' or 'No Deal' based on their own preferences. The students may want to play one or two games to become comfortable with the interface before they play 'for real'.

During each round, after the appropriate number of cases has been opened, ask the students to calculate the expected value of the remaining cases by adding the values left in play and dividing by the number of unopened cases. Record the Banker's offer, the expected value of the unopened cases, and the students' decision for each round. For example, consider the following game played online. Keep in mind that this example is just one game and the expected values and Banker's offers will vary from game to game. Also keep in mind that the Banker's offer in the online game does not incorporate the player's psychological 'state of being' that the television game show Banker purports to use in calculating the offers.

In this example, the player starts by selecting one case that is set aside until the last round. After this, the player chooses to open six randomly selected cases. The remaining unopened cases are shown in table 1 (see table 1, the 'After round 1' column). From these cases, the expected value of about $150,000 may be calculated and compared to the Banker's offer of $49,389 (see table 1). Consistent with the disparity of these two values here, the Banker's offer is typically very low compared to the expected value in order to entice the player to stay in the game. Suppose the player rejects the offer. He or she then must choose five more cases to open in the next round.

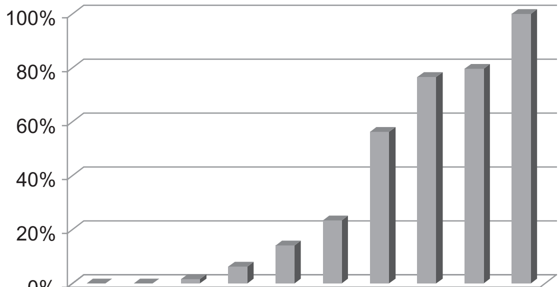
In round 2, the expected value of the unopened cases is more than three times larger than the Banker's offer (see table 1, 'After round 2'). Again, the Banker tries to entice the player to stay in the game at this point by offering a low amount to leave the game. Suppose the game continues with the player rejecting the offer and randomly choosing to open the designated number of cases in each round.

Now let's pick up the game in round 7. In this round the player must only open one case. The Banker's offer is considerably larger in this round because the $1,000,000 prize is still in play. At this point, the risk to the player increases as he or she has a 1/4 chance of opening the $1,000,000 case in the next round. Thus, according to prospect theory, when given the choice of a certain gain, the risk-averse player would choose to take the Deal. However, because of the excitement generated by playing the game (especially during the television show with the accompanying audience) and the desire to 'go for broke,' the player often decides to take the risk and refuse the Deal, as is the case in this example.

In round 8, one more case is opened, leaving the $1,000,000 case still in play (see table 1, 'After round 8'). Now the Banker's offer increases to 53% of the expected value of the remaining cases and the player has a 1/3 chance of opening the $1,000,000 case in the next round. Logically, this is the time to take the Deal. Prospect theory predicts that the player would take the offer because the gain obtained with certainty in this round is large compared to the risk of choosing the $1,000,000 case in the next round and being offered less than the next highest value (in this case, less than $200,000). But again, contrary to prospect theory, the player typically chooses the risk and continues to the next round.

Unfortunately, this time the player opens the $1,000,000 case (see table 1, 'After round 9'). As a result, the Banker's offer drops dramatically below the expected value of the remaining cases. At this point the player may continue playing simply because he or she feels that there is nothing to lose or the player may choose to take the Deal and at least leave with something. In this example, the player chooses to continue. Now the case originally chosen at the beginning of the game is opened to reveal the prize of either $100 or $200,000. This time the player's luck holds and the case is opened to reveal $200,000. However, players are often not that lucky and therefore walk away with very little.

This example of decision-making behaviour for several players can be illustrated with your students' data using a cumulative frequency chart based on those players who took the Banker's offer within each round. For example, consider figure 1, which shows the cumulative relative frequency chart based on data from a recent study of 64 *Deal or No Deal* players from the first two seasons of the American version of the game show.



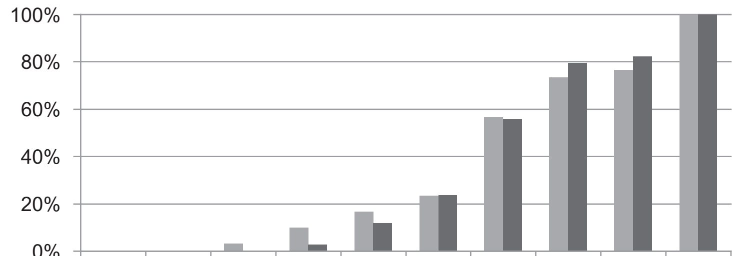
	1	2	3	4	5	6	7	8	9	10
Cum. RF (%)	0	0	2	6	14	23	56	77	80	100

Fig 1. Cumulative relative frequency (Cum. RF) of players who took the Banker's offer in the specified round

The cumulative relative frequency chart in figure 1 illustrates risk-seeking behaviour because none of the players accepted the Banker's offer in rounds 1 and 2, and only a few (14%) accepted it by round 6. However, by round 7 the players tended to revert back to risk-averse behaviour, tending to accept the Banker's offer. By round 9, 80% of the players had accepted the offer and left the game while 20% remained risk seeking and stayed in until the end.

Interestingly, this trend is apparently different for male versus female players. Ask your students to see if there is a gender difference for your class data. Divide the data into the two gender groups, recalculate the frequencies and create a new cumulative relative frequency bar chart based on these gender groups (see figure 2 for an example based on the television show data).

Figure 2 shows that more male players opted to take the Banker's offer in rounds 4 and 5. However, more women than men had chosen to take the Banker's offer by rounds 8 and 9. This hints at an interesting trend in risk-seeking behaviour between males and females. To examine this further, look at the differences in winnings by round for male versus female players. You can see in figure 3, that because the women players were more risk averse in the later rounds (i.e. rounds 6 through 9), they actually won more money than the male players who preferred riskier behaviour.



	1	2	3	4	5	6	7	8	9	10
Cum. RF Males (%)	0	0	3	10	17	23	57	73	77	100
Cum. RF Females (%)	0	0	0	3	12	24	56	79	82	100

Fig 2. Cumulative relative frequency (Cum. RF) of players who took the Banker's offer in the specified round by gender

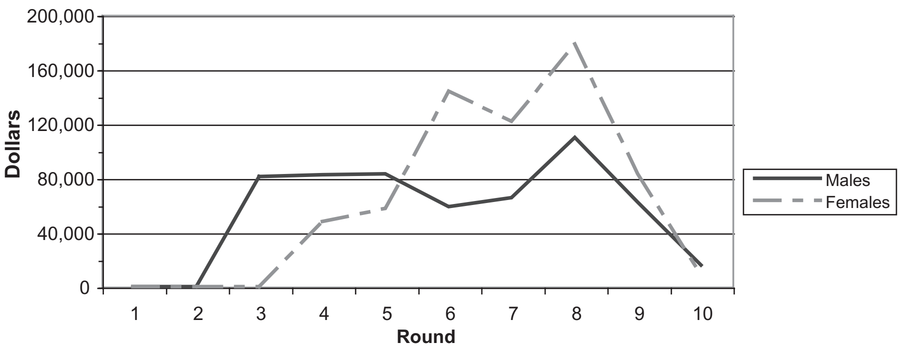


Fig 3. Average winnings by gender for each round

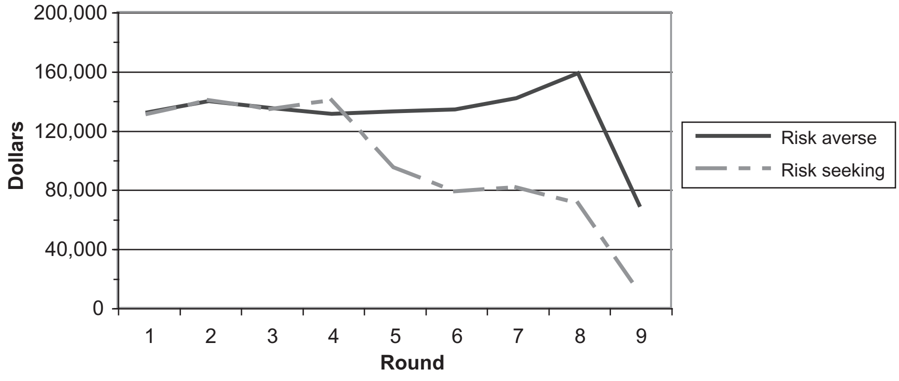


Fig 4. Comparison of expected value of remaining cases for risk-averse (players who took the Deal before round 10) and risk-seeking (players who stayed in until round 10) players

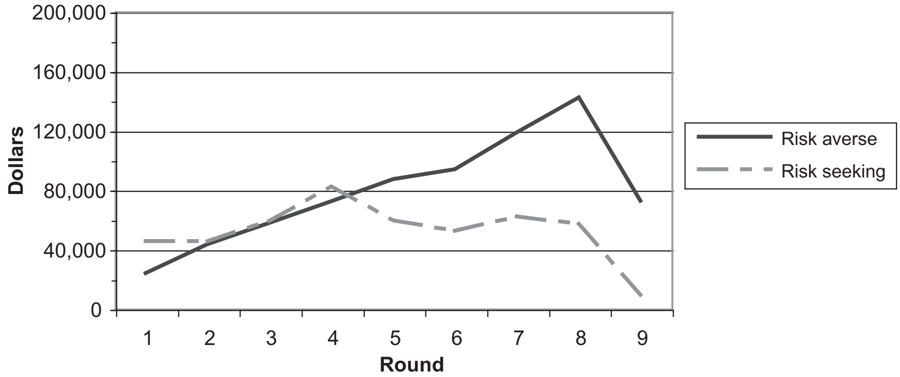


Fig 5. Comparison of average banker's offer for risk-averse (players who took the Deal before round 10) and risk-seeking (players who stayed in until round 10) players

Ask your students to verify this trend in the classroom data they collected. If it is not apparent, ask your students why the trends were not similar. One reason might be due to differences in using laboratory data (the students' data) versus real life data (from the actual *Deal or No Deal* TV show). This could lead to an interesting discussion of how research studies are conducted and how the results can affect us as consumers. Another reason might be due to the differences in sample sizes. This would also lead to an interesting discussion of how sample size can affect study results.

Now, consider the *Deal or No Deal* data from the perspective of two other groups: risk seeking (those players who stayed in the game until the very end) and risk averse (those players who accepted the Banker's offer any time before the final round). The expected values of the cases remaining in play were calculated for each round within each of these groups and are displayed in figure 4.

It is interesting to note that the risk-averse players had higher expected values than the risk-seeking players. This means that on the average, there were more high-dollar values left in play during each round for risk-averse players. This translated to higher offers from the Banker as illustrated in figure 5. This can be attributed to the fact that the 'devil' in the banker was trying to entice the risk-averse players into taking more risks.

Thus, even though the nature of *Deal or No Deal* promotes risk-seeking behaviour, risk-averse players actually won more money on average than risk-seeking players. Again, ask your students to verify this trend in their data. If this trend is not apparent, ask your students how outside influences (such as noise, cameras, stress, excitement, the audience, the supporters, the menacing Banker and other distractions) can affect a player's decisions. In addition, the student playing online has nothing to lose and so might be more risk seeking than a player on the show.

◆ CONCLUSION ◆

The *Deal or No Deal* game show provides a real-life opportunity to observe decision-making behaviour and opens the door to many discussions about decision theory, the decision-making process and statistics in general. Your students may be wondering why all these decision theories are important at all. To answer this, simply ask them how important it is for marketers to predict what consumers will buy. Just imagine that if you could accurately model decisions, you could predict consumer behaviour and become a market leader by presenting your product in such a way that it does not appear to be a risky venture. Therefore, the consumer would be more willing to try it. This is just one important application of decision theory. Can your students think of others that would be beneficial not only to businesses but to individuals as well?

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TECHNOLOGY TIP

This TECHNOLOGY TIP is a companion to that on p. 72 of this issue. We again examine the distribution of winnings when making *n* consecutive bets of £1 on red in roulette; this time we do so using Minitab code. We still assume that we have a roulette wheel with 18 red slots, 18 black slots and 2 green slots. A player in a particular £1 bet either wins £1 with chance 18/38 when red appears or loses £1 with chance 20/38 when red fails to appear.

With the two files below on your machine (be sure to have the correct path for the roulette.txt file inside the driver.txt file) run the command *execute 'driver.txt'* from the session window in Minitab. As with the R code in the TECHNOLOGY TIP on p. 72, this code will produce a histogram of 1000 (k4) replications of $n = 100$ (k3) consecutive £1 bets on red in roulette along with the fraction of times out of 1000 that we at least break even.

driver.txt:

```
set c1
-1 1
end
let k1 = 20/38
let k2 = 18/38
set c2
k1 k2
end
let k3 = 100
let k4 = 1000
let k5 = 1
execute ‘c:\roulette.txt’ k4
let k6 = sum(c4 >= 0)/k4
print k6
hist c4
```

roulette.txt:

```
random k3 c3;
discrete c1 c2.
let c4(k5) = sum(c3)
let k5 = k5 + 1
```