Betting Behavior in Two-Person Games with Different Starting Positions

An Experimental Study Based on "Final Jeopardy!"

By Paul Healy

Introduction

In 1990, Barry Nalebuff identified the problem of choosing from the various betting strategies that can be played in a round of Final Jeopardy!, a three person game featured at the end of the Jeopardy! television show in which contestants wager any amount between zero and their current cash balance on a single trivia question. After the wagers are settled, the contestant with the largest cash balance keeps her winning and the other two contestants are give consolation prizes of relatively insignificant value.

Nalebuff identifies that the problem can be divided into situations: one where the leader has more than double the balance of the second-place contestant, and one where the second-place contestant is close enough to the leader that he may win the game in certain situations. However, he does not consider this problem quantitatively and only adds that the optimal strategy will certainly relate to the contestants' probabilities of correctly answering question, which may be estimated by observed proportions of correctly answered questions by the three players throughout the program.

To look at this problem in depth, Andrew Metrick (and assistants) observed 393 rounds of Final Jeopardy between October 1989 and January 1992. Of those games, 104 were classified as "runaway games" in which Player 1 could guarantee a win by betting zero and 76 were classified as strategic games in which Player 1's balance is less than 1.5 times that of Player 2's, which is at least twice that of Player 3's ($x_1 > x_2 > 2x_3$, $x_1 < 1.5x_2$). The latter situation is one in which Player 1 and 2 are involved in a two-player strategic game since they are reasonably safe from the possibility of Player 3 ending with the highest balance.

Metrick finds that the probability of any given player correctly answering the question depends strongly on their cash balance ranking against the other contestants, but not the actual magnitude of that balance. For Player 1 (with the highest balance), he finds that probability to be 0.57. For Player 2, it drops to 0.51. Player 3 answers correctly with probability 0.46.

Metrick uses the observed Final Jeopardy! data to calculate a risk aversion parameter α of 0.000066, which is not significantly different than zero. Under this finding, Jeopardy! players are equally likely to accept $10,000 given with 50% probability or $4,190 given with certainty. This contrasts sharply with the certainty equivalents found for a similar game by Kahneman and Tversky (1979) of $300 to $400. Consequently, the risk neutral hypothesis cannot be rejected.

Under the assumption that players believe their opponents are playing mixed strategies based on the frequencies of different strategies actually observed, Metrick determines whether or not players are using their empirical best-response strategies. He identifies three possible strategies for Player 2 designated Low, High, and All.

"Low" refers to a bet by player 2 (y_2) such that $y_2 < 3x_2 - 2x_1$. In this strategy, Player 2 assumes Player 1 will wager exactly enough to guarantee a win should Player 1 win her wager. Player 2 then wagers an amount small enough such that if Player 1 loses her wager, Player 2 will guarantee a win regardless of the outcome of his wager. For example, if Player 1 has $10,000 and Player 2 has $9,000, Player 2 will assume Player 1 will bet $8,000 to guarantee a win should she get the question right (remember that equal ending balances results in both players 'winning.') Under the Low strategy, Player 2 will then bet $7,000. If Player 1 loses the wager, her balance drops to $2,000, which is equal to the balance of Player 2 should he lose his wager.

"High" refers to a bet larger than the Low strategy but less than Player 2's balance. This strategy does not necessarily guarantee a win for Player 2 conditioned on Player 1's losing the wager. "All" refers to the strategy whereby Player 2 bets his entire balance with the false belief that he needs to win the wager in order to win the game, so he might as well put his entire balance into the wager.

Metrick finds that if Player 2 had wagered zero in the 76 observed games, he would have won every time Player 1 lost her wager, thus giving support for the Low strategy.

Metrick shows that for any set of beliefs fairly similar to the observed strategy frequencies of Player 1, the High strategy is "stochastically dominated" by the All strategy. Metrick then shows that Low is the superior strategy when compared to All. Therefore, High is the least desirable strategy, followed by All, and Low is the best strategy. The mystery is that, of 76 observed games, Player 2 chose the All strategy 32 times, the High strategy 26 times, and the Low strategy only 18 times. Therefore, players perhaps identify the dominance of All to High, but do not recognize Low as dominating both alternatives.

One possible explanation for this effect is that the Low strategy requires one extra step of backward induction. Player 2 needs to first consider how Player 1 will likely respond to Player 2's current balance, and then Player 2 must respond to that response. This is referred to as a "framing" problem. In comparing experienced players (returning champions) to novices, Metrick finds that experienced players are more likely to play the Low strategy. However, this test of the theory is nullified to some extent by the simple observation that no returning champions who previously played an High or All bet switched to a Low bet. Perhaps then, the fact that returning champions tend to be better bettors explains why they are in fact returning champions… not only did they win at least one other Final Jeopardy game, but they have also chosen wisely those wagers to take through the regular Jeopardy rounds.

Experimental Design

In this experiment, I propose to study players' behavior in a two-person game in which Player 1 and Player 2 each bet on independent wagers. The initial cash balances of the players are randomly given such that Player 1 has a balance greater than Player 2 ($x_1 > x_2$), but less than 1.5 times that of Player 2. The wagers have binomial win/loss outcomes. If a wager's outcome is 'win' ('lose'), the associated player's balance is increased (decreased) by the amount of their wager. After the wagers are settled, the two balances of Player 1 and Player 2 are compared. The player with the highest balance keeps her winnings while the other keeps nothing. In the event of a tie, both players keep their earnings.

By the structure of the initial balances, Player 1 has the opportunity to guarantee a highest balance conditioned on her winning the wager by betting enough to "shut out" Player 2 should he also win his wager. However, Player 1 cannot guarantee a win by betting zero since Player 2 can always "catch up" to Player 1's pre-wager balance by wagering a large enough amount. Therefore, both players face a strategic decision in the size of their wagers.

The purpose of this experiment is to observe the behavior of laboratory subjects in a controlled strategic environment similar to the Final Jeopardy! contest when Player 3's balance is small enough to become immaterial. This particular strategic setting is of particular relevance to the field of economics in that most two (or more) person noncooperative games played over several periods feature some point at which one player is behind the other and must take appropriate risks to take the lead. Oftentimes, that individual faces a great deal of uncertainty in the outcomes of the future stages of the game and must determine which strategy is appropriate based on his beliefs about the probabilities of various outcomes. Although such games come from a wide variety of environments and levels of complexity, the simplified Jeopardy! framework nicely isolates the strategic decision required by the players.

The experiment is designed as a 2x2 factorial in which the nature of the probabilities of winning the wager constitutes one factor and the nature of the payout to the winner of the game constitutes the other.

In certain treatments, the probability of both players winning their wager will be commonly known to be 0.50. In other treatments, the probability of winning the wager will be private knowledge and randomly drawn from a uniform distribution supported on [0.25,0.75]. Also, in some treatments, the winner is paid their final cash balance as their take-home winnings, while in other treatments, the subject is paid a flat payment if they win the game.

For the study, three replicates will be run in each of the four cells in the experimental design, resulting in twelve total sessions. In each session, twenty subjects will be recruited and divided into two groups. The need for these two groups is to reduce certain strategic behaviors from "infecting" the entire group. Kandori (1992) has shown that very little information about the past is needed to enforce cooperative play in a community in which players play the prisoner's dilemma game against anonymous changing partners. He observes that a subject attempts to cooperate with opponents until he meets a non-cooperating opponent. If play is infinite, cooperation becomes an equilibrium if the discount factor is high enough as players will lose short-run gains to infinitely defecting opponents.

To prevent this effect of players "infecting" others with their strategic decisions, the design suggested by Cooper, DeJong, Forsythe, and Ross is used in this experiment. The ID numbers of the subjects in a group are listed on one circle and the ID numbers of the other group are listed on another, slightly larger circle. The smaller circle is placed inside the larger and those ID numbers that match up are paired as competitors for the first round. The inner circle is rotated (say, clockwise) one "notch" so that each subject on the inner circle is now matched with the next subject on the outer circle for the next period. Each period, the inner circle is rotated another notch. The process stops after the tenth period as all subjects in the inner group will have been matched with every subject in the outer group, but no subject will be matched with another subject twice or will ever be matched against a previous opponent's opponent. This setup allows for twenty subjects to generate ten observations in each of ten sequential periods.

This rotational matching design also allows for the two groups to be divided into different rooms so that every subject knows that their competitor is a person that they cannot see or interact with outside of the game's framework. The only potential problem with separating the groups is that subjects may not believe that another group of ten subjects exists in the other room.

Within each matching, one subject is randomly chosen to be Player 1 (the player with the higher initial balance) and the other is therefore Player 2. The balance of Player 1 (X_1) is then chosen from a uniform distribution on [5000, 10000] francs (where francs is the laboratory currency.) The balance of Player 2 (X_2) is then chosen from the uniform distribution across $[\{(2/3)X_1 + 1\}, \{X_1 - 1\}]$. This guarantees that Player 2's balance is less than that of Player 1, but is close enough to make the game "interesting," according to Metrick's definition.

Pilot sessions were run manually, while all other sessions will be run on computer. A Perl script will be written so that subjects will receive information via a web page that also allows them to input their wager. The script will record all information into files from which the experimenter can gather all of the data for the session. This script will allow for subjects to "log in" using a given ID and password. Therefore, the computer can control the information disseminated to each subject.

The computerization of the experiment will not change the basic structure of the game and the information given to each subject will be identical in both cases. Furthermore, the computerized sessions do not require the use of two rooms, as subjects can be randomly seated so that subjects cannot determine which other subjects they might compete against. This reduces the chances that subjects believe they are competing against a robot competitor.

The roll of a 100-sided die (with values from 0 to 99, inclusive) represents the wager portion of the game. Each player is given a value (W_i) such that if the 100-sided die returns a number greater than or equal to W_i, then the subject wins the wager. In some treatments, the values of W_i are fixed at 50 and known by all subjects to be common. In other treatments, W_i is randomly drawn for each subject from a uniform distribution on [25, 75] and each subject privately knows their value, although all subjects know that the distribution from which W_i is drawn is common across all subjects.

In hand-run sessions, all of the randomly assigned parameters X_1, X_2, and W_i are created before the session using computer software. In computerized sessions, the parameters are created at the beginning of the current period.

The subjects begin each period by learning the values of X_1, X_2, and W_i for each period, as well as the ID number of the subject with whom they are matched. After this information is received, the player places their wager. The outcomes of the wagers are then determined by the die roll (in hand run sessions) or by computer random number generation (in computerized sessions.) After the wagers are settled and the balances are adjusted, subjects are shown their own final balance, the final balance of the subject they are matched against, and the amount they have earned from the period. In the pilot experiment, subjects were not given their final balance, but were instead asked to calculate this value privately in order to speed up the experiment. Also, the final balance of all subjects was seen by the entire group in the pilot session, which is more information than subjects in the computerized sessions will have available. However, this additional information is not extremely useful as subjects were unable to determine which other subjects were matched against each other and thus observe which balances actually resulted in a "win" for the player.

The instructions for the experiment are carefully worded to prevent any insinuation that the two players are "against" each other in any way. This should help prevent any subject expectations based on the instructions alone. For example, if the instructions strongly emphasized the importance of winning against the other person, then the subject's utility of winning may be inflated by a desire to fulfill the expectations of the experimenter or the experiment's design.

Subjects for this experiment are expected to be mostly undergraduates enrolled in business an economics courses at Purdue University. The expected payout for a $2-per-game session is slightly more than $200. The dollar-to-franc conversion rate for the other treatments will be 1-to-5,000, which gives a less certain expected payout of around $200. Therefore, the entire twelve sessions should cost a total of $2,400. Judging by the pilot experiment, computerized sessions will last approximately one hour, the first twenty minutes of which will be spent in instructions, questions, etc.

The Pilot Session

The pilot session was run in a single room with two groups of four subjects. Information was given to the participants on slips of paper. The subjects wrote the size of their wager for each period on the slip and gave it back to the experimenter. The die rolls for each player (two ten-sided dice were used in place of the hard-to-find 100-sided die) determined the new balances, which were then recorded on the board. Subjects then found their opponent's final balance and determined if they won or lost the round.

All four treatments combinations were attempted, each for three periods. The treatment combinations were randomized beforehand, which caused some confusion on the first period of the second treatment as the experimenter only informed the subjects of one of the two changes between the new treatment and the first. This was corrected on the next period.

The manual running of the experiment was considerably slower than a computerized version. Collecting the wager slips, determining winners all took time and organization on the part of the experimenter. The calculation of new balances after the wagers were determined required quick mental math, which is not always reliable. Menial tasks such as this are ideal for a computer program to perform.

However, the largest problem in the experiment was subject confusion. Participants asked many questions and did not immediately understand that each period is broken into two sequential events: the wagers and the balance comparisons. Furthermore, the distribution of W_i was painfully omitted from the instructions. It is crucial that subjects understand that W_i is drawn from [25, 75] so that they can rely on the expected value of the opponent's W_j to be 50.

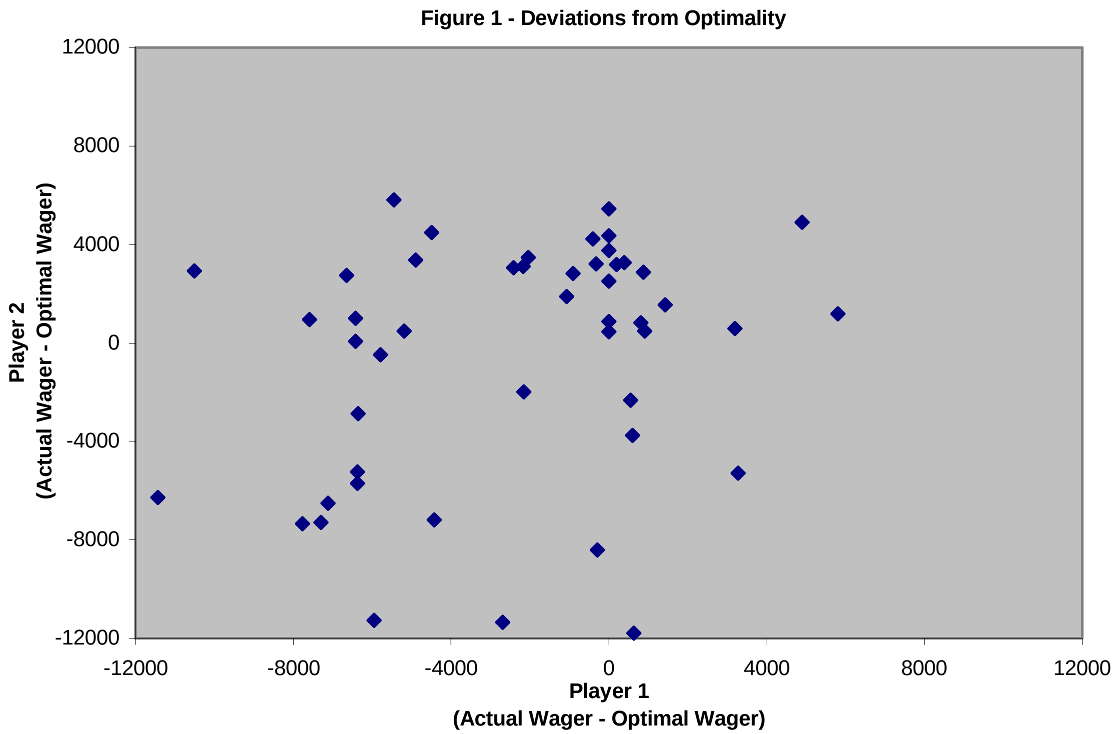
Subjects also asked about the distribution of the initial balances. Since the initial balances of both players in a game are public information within the game, this information should be irrelevant to the decision process. The fact that Player 2's initial balance is dependent on Player 1's balance is also difficult to explain and reveals the (2/3) ratio above which X_2 must be to make the game "interesting" to study. Players may incorporate this 2/3 into their strategies instead of simply looking at the given initial balances. Therefore, the distribution was not given and will not be given in future sessions.

The rapid switching between treatments caused problems in recording as well. Subjects all correctly recorded X_1, X_2, W_i, their actual die roll, and their final balance, but often incorrectly calculated their earnings for the period. In treatments where players were paid a flat $2, some subjects continued to record earnings proportional to their ending balances, and vice-versa. This confusion was undoubtedly complicated by the requirement that subjects divide their "franc" earnings by 5,000 in certain treatments and by the fact that one of the record sheet columns incorrectly asked for "dollars" when it should have required "francs." Again, these problems will disappear as the sessions are run on computer with one treatment per session.

Results

The data set collected from the pilot session is clearly not large enough for statistical tests. However, the general behavior of the subjects can be examined to predict behavior of the subjects that will be used in the full-scale sessions.

The first and most obvious result is that the subjects do not play the optimal strategy suggested by Metrick. The following table shows the deviation of each player's wager from the Metrick strategy.



From Figure 1, we see that players do not consistently choose one strategy over another. Player 2 is more likely to grossly under-wager than over-wager, which is also true of Player 1. There is a clustering of optimal wagers by Player 1 that were matched with excessive wagers by Player 2.

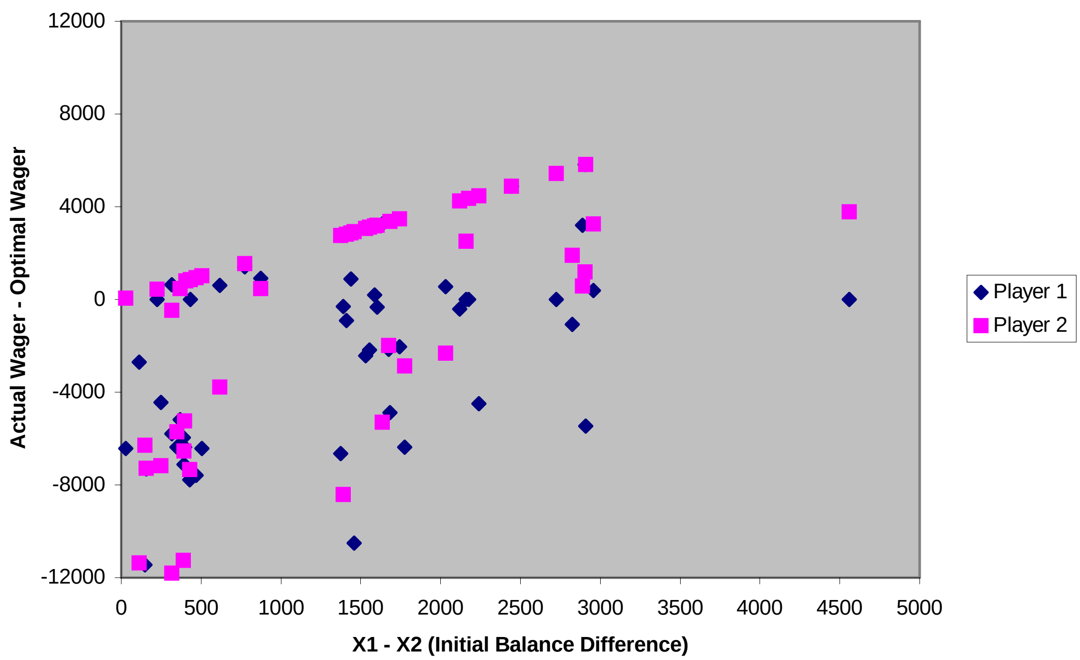
The idea of optimality, as proposed by Metrick, relies on two key assumptions. First, Player 1 believes that Player 2 is willing to bet his entire balance. Second, Player 2 believes that Player 1 will bet enough to "shut out" Player 2 should Player 1 win the wager. The unanswered question is which player under-wagers and which player simply responds to the other player's under-wagering.

The data shows that Player 1 under-wagers over 60% of the time. If Player 1 were exogenously sub-optimal, then Player 2 would have an incentive to increase his bid in order to overtake the sub-optimal Player 1 should they both win the wager. Therefore, it is unlikely that Player 1 is the "cause" of the under-wagering. If Player 2 were exogenously under-wagering, then Player 1 would not need to risk as large of an amount to still "shut-out" Player 2. Therefore, it is likely that Player 2 is the cause of the under-wagering, or that the players are simply ignoring the best strategies to be played by their opponents.

Metrick observed in actual trials of Final Jeopardy! that the All strategy was the most commonly played by Player 2, followed by the High strategy, and then the optimal Low strategy. In this pilot session, High is the most commonly used strategy (64.58%), followed by All (39.58%), and then the optimal Low strategy (35.42%.) Although the subjects in the experiment favored higher wagers, they were less willing to wager their entire balance than were the subjects on the game show. However, the lowest incidence of the Low strategy was maintained in both scenarios.

One factor that may dictate strategy is the "closeness" of the game. Figure 2 attempts to relate the size and direction of wager deviations from optimality to the differences in initial balances between players.

Figure 2 - Wager Deviation vs. Balance Diff



There is a definite trend indicating that lower balance differences (ie, "closer" games) result in bids lower than optimal. This is most likely due to the fact that closer games have higher values of the optimal bid. For example, if Player 1 is only two francs ahead of Player 2, then Player 1's optimal decision is to wager (X_1 – 1) francs. The upward trend in this graph indicates that subjects do not adjust in this manner. In other words, they tend towards certain absolute values (or, perhaps upper bounds) to the magnitude of their bet. As the game gets closer, they are reluctant to increase the size of their bet appropriately.

The graph also shows deviations above zero (over-betting) in games that are not as close. Therefore, subjects are also reluctant to shrink their bets down when necessary. These conclusions strongly indicate that players have a pre-selected range of values from which they draw their wagers.

The easily discernable positively sloped line in the data for Player 2 represents those periods in which Player 2 bet their entire balance. As the balances of the two players diverge (the game gets less "close"), the optimal bid becomes smaller. Therefore, betting the entire balance of Player 2 becomes increasingly further from optimality as the differences increase. This explains the positive slope of the points. This strategy of betting-it-all by Player 2 occurs in nearly 40% of the observations.

The combined evidence of Figures 1 and 2 indicates that, in closer games, Player 2 tends to under-wager (which is then followed by Player 1 appropriately under-wagering,) while in games that are not as close, Player 2 "risks it all" and severely over-wagers. In general, Player 1 recognizes this tendency and is more likely to wager an optimal amount to guarantee a "shut-out." Therefore, it is felt that Player 2 is the least likely to understand the optimal strategies in this game while Player 1 is more likely to both understand the optimal strategy and adjust for sub-optimal behavior on the part of Player 2.

Figure 3 – Treatment Error Means*		**Player 1**	**Player 2**
Factor #1: Probability	**Variable [.25 , .75]**	-34.59%	-3.06%
	Fixed [.50]	-23.90%	7.89%
Factor #2: Payout	**Converted Ending Balance**	-29.76%	2.19%
	$2 Flat Payout	-28.73%	2.64%

*(% of balance actually wagered - % of balance wagered under optimality)

Figure 3 shows the average values of "error" for each of the treatments. Error is measured as the percentage of a player's total balance actually wagered minus the percentage of their total balance that should be wagered under optimality. Negative values indicate under-wagering, positive values indicate over-wagering.

It appears that Player 1 significantly under-wagers across all treatments and that Player 2 plays, on average, fairly near the optimal strategy. However, the averages can be deceiving, as Figures 1 and 2 clearly show a large variance among the data.

From this initial data, it appears that the certainty associated with fixed and known probabilities of winning the wager cause players to bid larger amounts. This indicates an aversion towards uncertainty (recall that uncertainty and risk are not the same.) It also appears that a flat payout of two dollars leads to slightly higher wagering, although this effect is clearly smaller than the previous and is unlikely to be significant even with a larger data set.

Figure 4: Treatment Error Means*

		Player 1		**Player 2**	
		Factor 1: Probability			
		Variable	Fixed	Variable	Fixed
Factor 2: Payout	Converted Ending Balance	-39.9%	-19.6%	-4.3%	8.7%
	$2 Flat Payment	-29.3%	-28.2%	-1.8%	7.1%

*(% of balance actually wagered - % of balance wagered under optimality)

Figure 4 uses the same measure of error as Figure 3. When the data is averaged within treatment combinations, it is apparent that interaction effects exist in this model for both players. Therefore, main effects of factor levels cannot be compared if these interactions are found to be significant, which would invalidate the conclusions drawn from Figure 3.

For both players, it is found that in variable probability sessions, the flat payment increases wager size towards optimal levels, while in the fixed probability treatments, flat payments result in lower wagers. This indicates that the sessions with the most uncertainty (variable probabilities combined with converted ending balances) result in the lowest wagers.

One final note is that players rarely allow the possibility of a tie. There is clearly some utility to beating the other player and earning $2 greater than tying the other player and earning $2. Of the 17 times that Player 1 wagered enough to shut-out Player 2, only two were calculated to tie Player 2 should they both win the wager. Three other wagers were calculated to defeat Player 2 by only one or two francs. Clearly, Player 1 has no reason to end up one franc above Player 2 when they would earn the same payout in a tie.

Therefore, this belief in "beating" your opponent drives behavior towards more clear-cut "winner/loser" outcomes.

Discussion

Although the pilot session provided insight into the final conclusions of this research, there is still enough ambiguity to be settled by a more rigorous and complete experiment.

The computerization of the experiment will remove many of the other-regarding behaviors that could influence the strategies used by the subjects in the pilot session. Several subjects in the pilot quickly determined the subject with whom they were matched for each period, thus completely removing the anonymity needed for a "clean" set of data.

It is expected, however, that the general results of this pilot experiment will extend into the full-scale sessions. Subjects will likely wager suboptimally and show signs of uncertainty aversion. The tendency towards a fixed, limited range of wagers from which the subjects' strategies are chosen is also likely to be continued.

One aspect of Metrick's calculated optimal strategy is the reliance on the aforementioned expectations. Namely, Player 1 must expect that Player 2 is willing to wager his entire balance and Player 2 must accept that Player 1 will wager exactly enough to shut her out. However, if Player 2 consistently plays the Low strategy, Player 1 can relax her assumption and begin to wager smaller amounts. As Player 1's wager becomes smaller, Player 2's Low strategy requires a smaller and smaller wager. Eventually, if this cycle of updated expectations continues, Player 1 will wager ($X_1 - X_2$) and Player 2 will wager zero. However, it is unlikely that Player 2 will allow this continuously updated set of strategies to reach this endpoint, since smaller wagers by Player 1 quickly open the opportunity for Player 2 to wager a very large amount and win the game when both players win their wagers. The motivation for Player 2 to wager a larger amount should be greater in the converted-payout sessions, since opportunities to win higher balances increase the expected return of a betting strategy. In the $2-payout sessions, an equilibrium can be achieved with Player 1 wagering ($X_1 - X_2$) and Player 2 wagering zero, since this gives Player 1 an expected return of $2 and Player 2 an expected return of $1, both of which are not dominated by the expected returns of any other strategy.

Conclusion

Andrew Metrick's paper and this experiment certainly raise important questions about the nature of competition in first place vs. second place scenarios. At the heart of the matter is the players' expectations of the other player's strategy. These strategic decisions result in different levels of investment by both parties in an attempt to be the leader at the end of the time horizon. However, both studies clearly show sub-optimal behavior that may be caused partly by expectations different than those proposed by theory. Further study into the nature of participants' expectations could help identify why players in these scenarios do not behave as current theory predicts.

Instructions for Experiment

(For Sessions with Converted Balance Payoffs and Variable Odds)

This is an experiment in the economics of market decision-making. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money that will be paid to you in cash at the end of the experiment.

You have been randomly assigned an ID number and password for this experiment. Use these to log into your computer at this time.

This experiment will last for 10 periods. In each period, you will be randomly matched with another person in this room. You will never be matched with anyone twice and you may never be matched with some people at all.

You will be given an initial cash balance in "francs" for each period. **Francs will be converted to dollars at 5,000 francs to 1 dollar**. You will wager some or all of your francs on a simple bet. The person with whom you are matched will be placing a similar wager. If you win your bet, your cash balance is increased by the amount of your wager. If you lose your bet, your cash balance is decreased by the amount of your wager.

After the bet is settled and your cash balances are adjusted, your balance will be compared to the person you are matched with. **If your balance is higher, it will be converted to dollars and added to your earnings and the other person will receive zero earnings. If the other person's balance is higher, you will receive no earnings for the period, while the other player's balance will be converted to dollars for them to keep. If you have the same size balance as the other person, both balances will be converted to dollars for both of you to keep.**

At the beginning of each period, you will be shown a computer screen that tells you which period is the current period, which player ID you are matched with, what your initial franc balances are, and what you're betting on. This screen will give you all of the information you need to make your decisions.

The bet will consist of a randomly generated number from 0 to 99. Your computer screen will tell you what number it takes for you to win the wager. **This number, called your "Minimum Die Roll Needed" was randomly chosen by the computer and can be anything from 25 to 75**. If the "0 to 99" randomly generated number is equal to or larger than your Min. Die Roll Needed number, you win the wager. If not, then you lose the wager. Write the size (in francs) of your wager in the appropriate blank on your computer screen at the beginning of the period. Press the "Submit Wager" button when you have entered your wager. At that time, the computer will randomly generate your "0 to 99" number and let you know if you've won the wager or not. It will also display your new cash balance, in francs. Each person gets his or her own "0 to 99" randomly generated number each period

At this point, your computer screen will continually "refresh" itself until the person whom you are matched with has finished their wager. At that time, you will be given the final balance for you and the other person, as well as the earnings for the period paid to both you and the other person.

If your ending balance is equal to or greater than the other person, you will be paid ONE DOLLAR for every 5,000 FRANCS in your final balance. If not, you will be paid nothing.

The computer will keep a running total of your dollar earnings for the experiment, which is continually displayed at the bottom of the screen. Press the "Next Period" button to move on to the next period when you are ready.

At the end of the experiment, each person will be taken into the hallway and paid in cash. You will leave one at a time from the experiment. No other subjects will know how much you earned.

This process will be repeated over 10 periods. The first period, Period 0, does not count towards your actual earnings and will be used for practice.

Do not talk or communicate in any way with other people besides the experimenter.

If you have questions at any time, raise your hand and wait until the experimenter comes to you. If you have computer problems or questions, please raise your hand. Do not run any other applications or use the computer for any other purpose during this experiment.

Instructions for Experiment

(For Sessions with Converted Balance Payoffs and Fixed Odds)

This is an experiment in the economics of market decision-making. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money that will be paid to you in cash at the end of the experiment.

You have been randomly assigned an ID number and password for this experiment. Use these to log into your computer at this time.

This experiment will last for 10 periods. In each period, you will be randomly matched with another person in this room. You will never be matched with anyone twice and you may never be matched with some people at all.

You will be given an initial cash balance in "francs" for each period. **Francs will be converted to dollars at 5,000 francs to 1 dollar**. You will wager some or all of your francs on a simple bet. The person with whom you are matched will be placing a similar wager. If you win your bet, your cash balance is increased by the amount of your wager. If you lose your bet, your cash balance is decreased by the amount of your wager.

After the bet is settled and your cash balances are adjusted, your balance will be compared to the person you are matched with. **If your balance is higher, it will be converted to dollars and added to your earnings and the other person will receive zero earnings. If the other person's balance is higher, you will receive no earnings for the period, while the other player's balance will be converted to dollars for them to keep. If you have the same size balance as the other person, both balances will be converted to dollars for both of you to keep.**

At the beginning of each period, you will be shown a computer screen that tells you which period is the current period, which player ID you are matched with, what your initial franc balances are, and what you're betting on. This screen will give you all of the information you need to make your decisions.

The bet will consist of a randomly generated number from 0 to 99. Your computer screen will tell you what number it takes for you to win the wager. **This number, called your "Minimum Die Roll Needed" is always going to be 50 for you and for everyone else in the experiment**. If the "0 to 99" randomly generated number is equal to or larger than your Min. Die Roll Needed number, you win the wager. If not, then you lose the wager. Write the size (in francs) of your wager in the appropriate blank on your computer screen at the beginning of the period. Press the "Submit Wager" button when you have entered your wager. At that time, the computer will randomly generate your "0 to 99" number and let you know if you've won the wager or not. It will also display your new cash balance, in francs. Each person gets his or her own "0 to 99" randomly generated number each period

At this point, your computer screen will continually "refresh" itself until the person whom you are matched with has finished their wager. At that time, you will be given the final balance for you and the other person, as well as the earnings for the period paid to both you and the other person.

If your ending balance is equal to or greater than the other person, you will be paid ONE DOLLAR for every 5,000 FRANCS in your final balance. If not, you will be paid nothing.

The computer will keep a running total of your dollar earnings for the experiment, which is continually displayed at the bottom of the screen. Press the "Next Period" button to move on to the next period when you are ready.

At the end of the experiment, each person will be taken into the hallway and paid in cash. You will leave one at a time from the experiment. No other subjects will know how much you earned.

This process will be repeated over 10 periods. The first period, Period 0, does not count towards your actual earnings and will be used for practice.

Do not talk or communicate in any way with other people besides the experimenter.

If you have questions at any time, raise your hand and wait until the experimenter comes to you. If you have computer problems or questions, please raise your hand. Do not run any other applications or use the computer for any other purpose during this experiment.

Instructions for Experiment

(For Sessions with Two Dollar Payoffs and Variable Odds)

This is an experiment in the economics of market decision-making. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money that will be paid to you in cash at the end of the experiment.

You have been randomly assigned an ID number and password for this experiment. Use these to log into your computer at this time.

This experiment will last for 10 periods. In each period, you will be randomly matched with another person in this room. You will never be matched with anyone twice and you may never be matched with some people at all.

You will be given an initial cash balance in "francs" for each period. **Francs will NOT be converted to dollars at any time**. You will wager some or all of your francs on a simple bet. The person with whom you are matched will be placing a similar wager. If you win your bet, your cash balance is increased by the amount of your wager. If you lose your bet, your cash balance is decreased by the amount of your wager.

After the bet is settled and your cash balances are adjusted, your balance will be compared to the person you are matched with. **If your balance is higher, you will receive TWO DOLLARS and the other person will receive zero earnings. If the other person's balance is higher, you will receive no earnings for the period, while the other receives TWO DOLLARS. If you have the same size balance as the other person, BOTH players are paid TWO DOLLARS.**

At the beginning of each period, you will be shown a computer screen that tells you which period is the current period, which player ID you are matched with, what your initial franc balances are, and what you're betting on. This screen will give you all of the information you need to make your decisions.

The bet will consist of a randomly generated number from 0 to 99. Your computer screen will tell you what number it takes for you to win the wager. **This number, called your "Minimum Die Roll Needed" was randomly chosen by the computer and can be anything from 25 to 75**. If the "0 to 99" randomly generated number is equal to or larger than your Min. Die Roll Needed number, you win the wager. If not, then you lose the wager. Write the size (in francs) of your wager in the appropriate blank on your computer screen at the beginning of the period. Press the "Submit Wager" button when you have entered your wager. At that time, the computer will randomly generate your "0 to 99" number and let you know if you've won the wager or not. It will also display your new cash balance, in francs. Each person gets his or her own "0 to 99" randomly generated number each period

At this point, your computer screen will continually "refresh" itself until the person whom you are matched with has finished their wager. At that time, you will be given the final balance for you and the other person, as well as the earnings for the period paid to both you and the other person.

If your ending balance is equal to or greater than the other person, you will be paid TWO DOLLARS, which will be yours to keep. If not, you will be paid nothing.

The computer will keep a running total of your dollar earnings for the experiment, which is continually displayed at the bottom of the screen. Press the "Next Period" button to move on to the next period when you are ready.

At the end of the experiment, each person will be taken into the hallway and paid in cash. You will leave one at a time from the experiment. No other subjects will know how much you earned.

This process will be repeated over 10 periods. The first period, Period 0, does not count towards your actual earnings and will be used for practice.

Do not talk or communicate in any way with other people besides the experimenter.

If you have questions at any time, raise your hand and wait until the experimenter comes to you. If you have computer problems or questions, please raise your hand. Do not run any other applications or use the computer for any other purpose during this experiment.

Instructions for Experiment

(For Sessions with Two Dollar Payoffs and Fixed Odds)

This is an experiment in the economics of market decision-making. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money that will be paid to you in cash at the end of the experiment.

You have been randomly assigned an ID number and password for this experiment. Use these to log into your computer at this time.

This experiment will last for 10 periods. In each period, you will be randomly matched with another person in this room. You will never be matched with anyone twice and you may never be matched with some people at all.

You will be given an initial cash balance in "francs" for each period. **Francs will NOT be converted to dollars at any time**. You will wager some or all of your francs on a simple bet. The person with whom you are matched will be placing a similar wager. If you win your bet, your cash balance is increased by the amount of your wager. If you lose your bet, your cash balance is decreased by the amount of your wager.

After the bet is settled and your cash balances are adjusted, your balance will be compared to the person you are matched with. **If your balance is higher, you will receive TWO DOLLARS and the other person will receive zero earnings. If the other person's balance is higher, you will receive no earnings for the period, while the other receives TWO DOLLARS. If you have the same size balance as the other person, BOTH players are paid TWO DOLLARS.**

At the beginning of each period, you will be shown a computer screen that tells you which period is the current period, which player ID you are matched with, what your initial franc balances are, and what you're betting on. This screen will give you all of the information you need to make your decisions.

The bet will consist of a randomly generated number from 0 to 99. Your computer screen will tell you what number it takes for you to win the wager. **This number, called your "Minimum Die Roll Needed" is always going to be 50 for you and for everyone else in the experiment**. If the "0 to 99" randomly generated number is equal to or larger than your Min. Die Roll Needed number, you win the wager. If not, then you lose the wager. Write the size (in francs) of your wager in the appropriate blank on your computer screen at the beginning of the period. Press the "Submit Wager" button when you have entered your wager. At that time, the computer will randomly generate your "0 to 99" number and let you know if you've won the wager or not. It will also display your new cash balance, in francs. Each person gets his or her own "0 to 99" randomly generated number each period

At this point, your computer screen will continually "refresh" itself until the person whom you are matched with has finished their wager. At that time, you will be given the final balance for you and the other person, as well as the earnings for the period paid to both you and the other person.

If your ending balance is equal to or greater than the other person, you will be paid TWO DOLLARS, which will be yours to keep. If not, you will be paid nothing.

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At the end of the experiment, each person will be taken into the hallway and paid in cash. You will leave one at a time from the experiment. No other subjects will know how much you earned.

This process will be repeated over 10 periods. The first period, Period 0, does not count towards your actual earnings and will be used for practice.

Do not talk or communicate in any way with other people besides the experimenter.

If you have questions at any time, raise your hand and wait until the experimenter comes to you.

If you have computer problems or questions, please raise your hand. Do not run any other applications or use the computer for any other purpose during this experiment.

SUBJECT ROTATION GUIDE

Period 1		Period 2		Period 3		Period 4		Period 5	
A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
A1	B1	A1	B2	A1	B3	A1	B4	A1	B5
A2	B2	A2	B3	A2	B4	A2	B5	A2	B6
A3	B3	A3	B4	A3	B5	A3	B6	A3	B7
A4	B4	A4	B5	A4	B6	A4	B7	A4	B8
A5	B5	A5	B6	A5	B7	A5	B8	A5	B9
A6	B6	A6	B7	A6	B8	A6	B9	A6	B10
A7	B7	A7	B8	A7	B9	A7	B10	A7	B1
A8	B8	A8	B9	A8	B10	A8	B1	A8	B2
A9	B9	A9	B10	A9	B1	A9	B2	A9	B3
A10	B10	A10	B1	A10	B2	A10	B3	A10	B4
Period 6		**Period 7**		**Period 8**		**Period 9**		**Period 10**	
A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
A1	B6	A1	B7	A1	B8	A1	B9	A1	B10
A2	B7	A2	B8	A2	B9	A2	B10	A2	B1
A3	B8	A3	B9	A3	B10	A3	B1	A3	B2
A4	B9	A4	B10	A4	B1	A4	B2	A4	B3
A5	B10	A5	B1	A5	B2	A5	B3	A5	B4
A6	B1	A6	B2	A6	B3	A6	B4	A6	B5
A7	B2	A7	B3	A7	B4	A7	B5	A7	B6
A8	B3	A8	B4	A8	B5	A8	B6	A8	B7
A9	B4	A9	B5	A9	B6	A9	B7	A9	B8
A10	B5	A10	B6	A10	B7	A10	B8	A10	B9

Note: In Period Zero, the experimenter will have the subjects play against a non-optimal robot. The subject's computer screen will say: "Matched Against: COMPUTER" during this period.

PILOT SESSION DATA

Period	*Treatment*	*ID*	*Balance*	*Wager*	*Min Roll*	*ActualRoll*	*ID*	*Initial Balance*	*Wager*	*Min Roll*	*Actual Roll*
1	VarConv	A1	5558	80	60	80	B1	4026	4026	34	91
2	VarConv	A1	9465	65	31	29	B2	8089	8089	30	11
3	VarConv	A1	7147	74	69	5	B3	6800	400	63	64
4	FixTwo	A1	13425	6700	50	56	B4	13037	1000	50	32
5	FixTwo	A1	5071	3800	50	74	B1	5943	5100	50	41
6	FixTwo	A1	11927	9000	50	54	B2	11813	228	50	30
7	VarTwo	A1	10209	8400	40	69	B3	12370	8048	57	91
8	VarTwo	A1	5564	5293	63	93	B4	5934	0	72	45
9	VarTwo	A1	7087	7087	27	27	B1	8675	5700	28	77
10	FixConv	A1	4921	4920	50	33	B2	6331	2609	50	15
11	FixConv	A1	5833	5832	50	38	B3	8556	3111	50	85
12	FixConv	A1	13415	13415	50	45	B4	14872	1450	50	94
1	VarConv	A2	11274	0	72	27	B2	8365	8365	27	7
2	VarConv	A2	7423	7423	36	23	B3	7929	500	61	56
3	VarConv	A2	9857	1600	56	12	B4	8175	8174	65	39
4	FixTwo	A2	4056	4056	50	73	B1	5493	3500	50	45
5	FixTwo	A2	6767	2118	50	29	B2	4648	4648	50	32
6	FixTwo	A2	10739	10739	50	73	B3	12915	8563	50	1
7	VarTwo	A2	5010	10	60	80	B4	5626	5000	27	92
8	VarTwo	A2	9476	2750	50	52	B1	6652	2900	66	61
9	VarTwo	A2	3783	3782	26	93	B2	5525	0	62	19
10	FixConv	A2	9952	4600	50	30	B3	14513	5392	50	0
11	FixConv	A2	5328	0	50	38	B4	7003	1500	50	38
12	FixConv	A2	10535	10535	50	82	B1	7629	3000	50	45
1	VarConv	A3	9694	4500	42	80	B3	12584	10000	33	26
2	VarConv	A3	14070	11000	28	29	B4	12680	1500	71	50
3	VarConv	A3	10125	10000	54	4	B1	9353	9353	33	43
4	FixTwo	A3	3735	3735	50	71	B2	5290	0	50	28
5	FixTwo	A3	3527	3527	50	28	B3	5130	1600	50	51
6	FixTwo	A3	7712	400	50	14	B4	8105	200	50	85
7	VarTwo	A3	8574	5915	54	77	B1	11531	6000	31	75
8	VarTwo	A3	11950	11950	33	93	B2	14395	14395	39	0
9	VarTwo	A3	9056	428	68	34	B3	8629	428	66	49
10	FixConv	A3	6814	791	50	73	B4	7210	50	50	75
11	FixConv	A3	11580	11580	50	47	B1	12012	11150	50	94
12	FixConv	A3	6732	6732	50	79	B2	8970	0	50	12
1	VarConv	A4	8935	4000	31	59	B4	8685	1000	25	92
2	VarConv	A4	13430	1000	64	17	B1	13747	13747	54	86
3	VarConv	A4	8057	8057	47	38	B2	8526	0	45	20
4	FixTwo	A4	8450	8450	50	35	B3	8480	2000	50	47
5	FixTwo	A4	6422	0	50	30	B4	6106	5000	50	51
6	FixTwo	A4	8581	2200	50	85	B1	10612	7100	50	60
7	VarTwo	A4	6944	6944	30	8	B2	7350	7350	41	63
8	VarTwo	A4	7605	0	68	97	B3	7763	150	65	24
9	VarTwo	A4	11588	5000	43	46	B4	11737	3	67	55
10	FixConv	A4	11906	11906	50	22	B1	10272	1700	50	85
11	FixConv	A4	8136	1726	50	55	B2	9909	0	50	45
12	FixConv	A4	8022	8022	50	38	B3	8248	7797	50	20

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