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Abstract

In an attempt to better understand the results of previous bargaining experiments, we report an experiment in which the participants alternate between bargaining against another human subject and bargaining against a computer. The results suggest that the identity of the opponent matters. In the first round, initial demands of the computer are closer to the equilibrium outcome than demands made of the human opponents. This difference is attenuated in subsequent rounds. The incidence of rejections of initial offers made by human subjects matches closely that observed in previous studies, whereas no offers made by the computer are rejected.

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Consider the following standard two-stage bargaining problem. Two players bargain over the division of \$20, according to the following rules. Player 1 (the leader) proposes a division. If player 2 (the follower) accepts the proposal, the game ends with the players receiving their respective shares. If player 2 rejects the proposal, the game proceeds to a second round. In the second round, the sum available is reduced to \$5.00. Player 2 proposes a division. If player 1 accepts the proposal, the game ends with the players receiving their respective shares. Otherwise, the game ends with both players receiving zero.

Game theory makes a very precise prediction about rational behaviour in this game (Rubinstein, 1982). Player 1 should demand \$15.00 in the first stage and player 2 should accede to this demand, receiving the remaining \$5.00. To see this, player 1 should view the game from player 2's perspective. The best that player 2 can hope for if the game proceeds to stage 2 is \$5.00. Therefore, player 2 should accept an offer of \$5.00 in the first round. Similarly, by considering player 1's options in the second stage, it can be seen that player 2 should not accept anything less than \$5.00 in the first stage. Deducing this, player 1 should offer \$5 in the first stage, no more, no less. This is the so-called subgame perfect equilibrium of this game.[1]

This prediction can be tested experimentally. Indeed, this and similar bargaining games have been extensively tested in recent years. The results have been disappointing for the theorist. In a recent survey of the experimental evidence, Ochs and Roth (1989) identify three empirical regularities in the results:

1. initial demands lie between equal division and the subgame perfect equilibrium.

2. a substantial proportion of first-period are rejected.

3. a substantial proportion of rejections are followed by disadvantageous counteroffers, that is player rejects an offer which is greater than his/her subsequent demand.

By and large, real flesh and blood does not behave with the precision suggested by game theory.

We can identify at least three possible reasons for these results.

1. Players are not solely concerned with their own return. "Fairness" is important.

[1](14.99, 5.01) is also a subgame perfect equilibrium.

2. Players do not believe that their opponents will behave rationally.

3. Players themselves do not behave rationally.

Our experiment was designed to distinguish between hypotheses 1/2 and hypothesis 3, by alternating between computer and human opponents. If players depart from equilibrium behaviour because of fairness or doubts about the rationality of their opponents, their behaviour should change when facing a computer rather than another human participant. Conversely, if non-equilibrium behaviour is observed because players are themselves irrational, the identity of the opponent should be irrelevant.

1 Experimental design

In many reported bargaining experiments, the players interact through computer terminals to preserve anonymity. We follow this practice, making the interface between the player and her opponent identical irrespective of the nature of the opponent. Our experimental design follows closely that of Binmore et. al. (1985).

Twenty four subjects were subjects recruited from first year undergraduates enrolled in computer science, economics, mathematics, management science and statistics. In this way, we hoped to obtain subjects who were numerically adept but untrained in quantitative analysis. Each played four bargaining games in pairs.

Subjects were prevented from communicating prior to the experiment. They were shown into separate rooms and given an instruction sheet to read (Appendix). The supervisor then emphasized the following:

- the sum available was reduced from \$20 to \$5 in the second stage.
- The computer would be attempting to maximize its own return, and would assume that the student would do the same (except during the practice rounds).
- The computer could not learn from experience.
- Each player should note at the beginning of each round whether the opponent was another student or the computer.

Each played two games as player 1 and two as player 2. One game in each role was played against the human opponent, the other against the computer. In other words, each player played one game in each box of the following table. The order in which they were assigned to the different roles was chosen randomly, as was the order in which they met the different opponents (computer or human).

	Player 1	Player 2
Human opponent		
Computer		

We were careful to ensure that the students were not told that they would be playing the *same* human opponent twice. As regards the computer, participants were told that "the computer has been programmed to strike the best possible deal for itself. It assumes you are also trying to maximize your monetary payoff. The computer has no capacity for learning".

To familiarize the subjects with the experiment, the experimental rounds were preceded by two practice rounds playing against the computer, where the computer's strategy was chosen randomly. To eliminate any variations in this learning process, the same random strategy was used in all practice rounds.

Participants were paid $5 dollars for attending plus their agreed share in one of the rounds, which was chosen at random. Their expected return from equilibrium behaviour was $15 and the whole procedure took no more than 15 to 20 minutes.

One subject made initial demands of zero from both the computer and the human opponent. When questioned afterwards, he explained that religious conviction prevented him from seeking to exploit his bargaining power for money. Since this behaviour would be dominant in our small sample, we recruited another subject pair and omitted his experiment from further analysis.

2 The results

We first consider first *initial demands*. As expected, initial demands lie between the equal division ($10) and the subgame perfect equilibrium ($15). Overall, the average demand made of the computer is 13.81 compared to 13.08 of the human opponent. The difference is not significant.

Half the subjects faced the human opponent first. For this subgroup, the mean initial demand increased from 12.00 to 13.25. Two out of 12 subjects made lower demands of the computer. For the second group who faced the computer first, their average demand of the human subject fell slightly from 14.38 to 14.17. Three out of 12 made higher demands of their human opponents. Overall these results are consistent with a difference in bargaining behaviour with the identity of the subject, but the effect is slight and statistically insignificant in this small sample.

One of the advantages of having a small sample is that it is possible to examine individual behaviour more closely. This we do in Table 1, which documents the initial offers and responses for each subject in the four rounds. We examine these round by round.

In Round 1, twelve subjects adopted the role of player 1 — 6 facing another student, 6 facing the computer. The mean demand made of the human subjects was 10.83; the mean demand of the computer was 15.00, which is the equilibrium prediction. Round 1 suggests that the identity of the opponent matters.

At first sight, Round 2 suggests the opposite conclusion. In Round 2, each player switches roles (Player 1 becomes 2, 2 becomes 1) but retains the same opponent. We observe little difference in the demands made of the different opponents. The mean demand of human opponents was 13.17, that of the computer 13.75. (bottom panels, column 2). But if we focus attention on the subset of games involving a human opponent, there is a marked change in behaviour in going from Round 1 (mean demand 10.83) to Round 2 (mean demand 13.17).

However, to dismiss a role for the nature of the opponent would be too hasty. Our results from Rounds 1 and 2 take on a different perspective when compared to the results from previous experiments, especially that of Binmore, Shaked and Sutton (1985), whose design is most similar to ours. The latter also detected "a marked change in behaviour" between their Rounds 1 and 2, with the modal initial demand shifting from equal division to the equilibrium outcome. The behaviour of human bargaining pairs on our experiment replicates closely their results. What distinguishes our results from theirs is the Round 1 behaviour, where the subjects bargaining with the computer behaved differently to their peers who were bargaining with another student.

Round 3 defies a simple conclusion.[2] Consider those players whose earlier experience was with a human opponent (top panel). There seems to be types of behaviour. Subjects 3 and 4 distinguish sharply between opponents, offering equal division to their human opponent, demanding the equilibrium outcome from the computer. These subjects act consistently as "fairmen" (Neelin, Sonnenschein and Spiegel, 1985; Binmore,

[2] We cannot compare with Binmore, Shaked and Sutton, as their experiments had only two rounds.

Table 1: Initial demands and responses

	Round							
	1		2		3		4	
Subject	v. Human Subject				v. Computer			
Pair	Demand		Offered		Demand		Offered	
1	14.00	A	5.50	A	11.50	A	5.00	A
2	11.00	A	6.00	A	8.00	A	5.00	A
3	10.00	A	8.00	R	15.00	A	5.00	A
4	10.00	A	6.00	A	15.00	A	5.00	A
5	10.00	A	10.00	A	10.00	A	5.00	A
6	10.00	A	5.50	R	10.00	A	5.00	A
Mean	10.83		6.83		11.58		5.00	
S. D.	1.46		1.65		2.62		0.00	
	v. Computer				v. Human Subject			
7	19.00	R	5.00	A	15.00	R	8.00	A
8	12.00	A	5.00	A	12.00	A	6.00	A
9	14.00	A	5.00	A	14.50	A	5.50	R
10	18.00	R	5.00	A	15.00	A	5.00	A
11	12.00	A	5.00	A	14.50	A	5.50	A
12	15.00	A	5.00	A	15.00	A	6.00	A
MEAN	15.00		5.00		14.33		6.00	
S. D.	2.71		0.00		1.07		0.96	
	v. Human Subject				v. Computer			
1	6.00	A	14.50	A	5.00	A	15.00	A
2	9.00	A	14.00	A	5.00	A	14.99	A
3	10.00	A	12.00	R	5.00	A	14.50	A
4	10.00	A	14.00	A	5.00	A	15.00	A
5	10.00	A	10.00	A	5.00	A	15.00	A
6	10.00	A	14.50	R	5.00	A	14.99	A
MEAN	9.17		13.17		5.00		14.91	
S. D.	1.46		1.65		0.00		0.18	
	v. Computer				v. Human Subject			
7	5.00	A	13.00	A	5.00	R	12.00	A
8	5.00	A	14.50	A	8.00	A	14.00	A
9	5.00	A	10.00	A	5.50	A	14.50	R
10	5.00	A	15.00	A	5.00	A	15.00	A
11	5.00	A	15.00	A	5.50	A	14.50	A
12	5.00	A	15.00	A	5.00	A	14.00	A
MEAN	5.00		13.75		5.67		14.00	
S. D.	0.00		1.82		1.07		0.96	

Table 2: **First offer rejections**

Subject Pair	Round	Initial Demand	Response	Counter Offer	Response
2	3	12.00	R	2.50	A
2	6	14.50	R	2.50	A
3	7	15.00	R	2.00	A
4	9	14.50	R	1.00	A

Shaked and Sutton, 1985).[3] Subjects 5 and 6 do not distinguish between opponents, offering equal division irrespective, whereas subjects 1 and 2 appear confused or to act randomly. These are neither "gamesmen" nor "fairmen". On the other hand, those subjects whose earlier experience was against the computer (bottom panel) appear to have learnt something from that experience. Their mean demand of their human opponent is 14.33. Half of them seek the equilibrium outcome of 15.00. They act more like "gamesmen".

Round 4 has its own surprise. The mean demands do not differ significantly - 14.00 from the humans, 14.91 from the computer. What is significant is the concentration on the equilibrium outcome of demands from the computer. Previous experiments suggest that while large departures from equilibrium behaviour are quickly eliminated with experience, some deviations from equilibrium persist even with very experienced subjects (Bolton, 1991). A concentration as tight as we observed in Round 4 is unknown in the experimental literature.

So far we have dealt only with initial demands. Turning to *first-period responses*, a striking result emerges. None of the initial offers made by the computer are rejected, whereas four out of the 24 human offers are rejected. These are documented in Table 2. Each of these rejections results in a disadvantageous counter-offer. The significance of this observation is revealed when it is compared with the results of previous experiments (Table 3), which shows the incidence of first period rejections in four studies.[4] The consistency of this observed behaviour is remarkable. So to is the complete absence of first-period rejections when the offer is made by the computer. Subjects seem to regard differently proposals made by the computer.

[3]We note that our subjects included both male and female. We have adopted the existing terms in the literature without wishing to imply any gender exclusively.

[4]The data for the previous studies are taken from Ochs and Roth, 1985, Table 6.

Table 3: **Comparison with previous studies**

	Observations	Rejections	Percentage
Carter and Sunderland	24	4	17
Ochs and Roth	760	125	16
Binmore, Shaked and Sutton	81	12	15
Neelin, Sonnenschein and Spiegel	165	23	14

3 Conclusion

Our experiment yields some evidence that the identity of the bargaining opponent matters. The difference in initial demands in Round 1 is suggestive. While the small sample size prevents us attaching too much credence to this observation, we are encouraged by the close correspondence to the results of Binmore, Shaked and Sutton. Their results suggest that we should not expect a significant difference to persist over repeated rounds of bargaining. More compelling than the difference in demands is the difference in responses to the initial demands of their opponents. The proportion of first-period rejections has demonstrated remarkable constancy through a number of experiments. This was evident in our data despite the small sample size. The absence of rejections of the offers made by the computer, despite the fact that they were uniformly smaller than offers rejected in other rounds, strongly suggests that bargainers respond differently to the different opponents.

Hopes of a decisive test between hypotheses 1/2 on the one hand and hypothesis 3 on the other were unfulfilled. On the contrary, it would seem that all three hypotheses apply, albeit to different individuals. Perhaps the experimental results are disappointing because they presuppose a homogeneous population of bargainers.

One way to explain our results is postulate the existence of three types of bargainers in experimental games. Type I, the "fairmen" act consistently in terms of their objectives but are not concerned exclusively with their own payoff. Fairness is important. Type II are the rational "gamesmen" who act strictly to maximize their own return. They may depart from equilibrium behaviour because they cannot rely on the rationality of their opponent. This latter belief is justified by the existence of "fairmen" and also by the existence of a third type, Type III, who not play rationally, but adopt rules of thumb (e.g. subject pairs 5,6) or choose somewhat randomly (e.g. subject 2).

The existence of Type III players makes distinguishing between "fairmen" and "gamesmen" in experimental evidence extremely difficult. Consider subjects 3 and 4, whose initial demand of their human opponent is 10 and that of the computer 15. Is this because they are "fairmen" whose concern for equity does not extend to the computer. Or is it because they are "gamesmen" with a low prior on the rationality of their opponent?

It is possible that some people will change their behavioural type during the course of any given experiment. Furthermore, recent experiments by Binmore and his associates (unpublished) have shown how players notions of fairness can be conditioned by the course of an experiment. But the existence of at least some Type III players in an experimental population would explain the persistence of non-equilibrium behaviour even amongst experienced bargainers. The evolution of initial demands with experience can be explained either as "fairmen" changing their idea of what is fair with experience or as "gamesmen" updating their information regarding the rationality of the subject population.

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INSTRUCTIONS

Please read these instructions carefully. If you have any questions regarding the procedure, please ask the supervisor before starting. Of course, the supervisor cannot comment on strategy.

General

The purpose of this experiment is to study how people behave in bargaining situations. You will participate in FOUR bargaining rounds. Each round involves bargaining with another player over the division of $20.00 At the end of the experiment, one of the bargaining rounds will be chosen at random and you will be paid in cash what you earned during that round plus the $5.00 attendance fee.

In each round there are two 'players', one of which is yourself. The other player could be either a computer, or could be another student. Before the start of each round, you will be informed whether you are playing against a computer or another student. In all rounds, you will bargain through a computer terminal. You will not meet your opponent face to face.

These instructions are not designed to mislead or deceive you in any way. We are only interested in the bargains you strike.

Using the computer

The computer will prompt you for the necessary information at each stage. Please follow its instructions carefully. When you enter an offer or respond to your opponent's offer, you will be invited to confirm that the computer has recorded your wishes accurately. Please check before proceeding.

You will be taken through two practice rounds before beginning the experiment itself. The practice rounds will be played against a computer, where the computer will be choosing its responses randomly. These are merely to familiarise you with the procedure. You should not attempt to infer the computer's subsequent behaviour from the practice rounds.

Payment

At the end of the experiment, we will be print out a sheet summarising the results of each of the four rounds. The computer will select one of the rounds at random, and you will be paid the share which you agreed to in that round, in addition to the $5.00 attendance fee. Once the sheet has been signed by the supervisor, you should take it to Mrs. K. Smith in Room 425, who will pay you in cash.

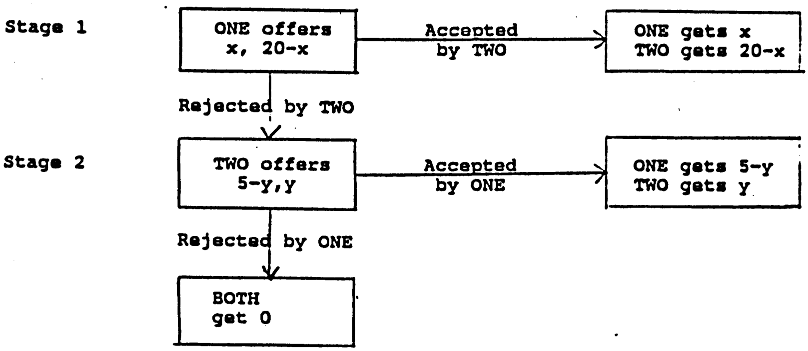
The Conduct of a Round

In EACH round, one of the players will be designated at random as player ONE. Initially player ONE will propose a division of the $20.00 This proposal will be conveyed to player TWO, who can either accept to reject it. Should player TWO agree to the proposed division, it is declared the outcome of that round.

If the player TWO rejects the proposal, the size of the 'pie' is reduced to $5.00. Player TWO then proposes a split of the $5.00 to player ONE. If player ONE accepts, the proposed split of $5.00 is declared the outcome of that round. If player ONE rejects the proposal, the round ends with both players receiving nothing.

Note that there is a substantial penalty for failure to agree in the first stage. If the bargaining proceeds to a second stage (ie. the first proposal is rejected), the total to be shared in that round is reduced from $20.00 to $5.00.

The conduct of a bargaining round is illustrated diagrammatically below:



It it important to note at the start of EVERY round whether the other player is a computer or a person. The computer has been programmed to strike the best possible deal for itself, that is maximise its monetary payoff. It assumes that you are also trying to maximise your monetary payoff. The computer has no capacity for learning.

When you are ready to proceed, please inform the supervisor who will initiate the practice rounds.

THANK YOU FOR YOUR PARTICIPATION

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