ECONOMIC RESEARCH REPORTS

DOES GAME THEORY PREDICT WELL FOR THE WRONG REASONS: AN EXPERIMENTAL INVESTIGATION

BY

Zeinab Partow
and
Andrew Schotter

RR # 93-46 *December, 1993*

C. V. STARR CENTER FOR APPLIED ECONOMICS

NEW YORK UNIVERSITY
FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF ECONOMICS
WASHINGTON SQUARE
NEW YORK, N.Y. 10003

Abstract

In this paper we attempt to answer the question of whether subjects in laboratory experiments behave according to the predictions of game theory and the refinement literature *for the reasons suggested by the theory itself.* One reason to doubt the logic supporting the refinement selection story is that it requires a thought process that appears to be out of the cognitive reach of most human subjects. Following earlier authors, we examine equilibrium selection in laboratory experiments with signalling games that are characterized by multiple equilibria, where subjects gain experience with different partners. In our experiments, however, players are able only to see their own payoffs, but not those of their partners, and are therefore unable to treat the interaction as a game. Nevertheless, we find that these experimental subjects do indeed converge to the equilibria predicted by the refinement literature. Our findings thus support the hypothesis that players do not analyze games in the manner posited by theory, but follow a non-strategic decision process.

DOES GAME THEORY PREDICT WELL FOR THE WRONG REASONS: AN EXPERIMENTAL INVESTIGATION

by

Zeinab Partow*
Andrew Schotter*

* New York University

The authors would like to thank the C.V. Starr Center for Applied Economics for its financial and technical assistance on this paper.

1. Introduction

Increasingly, experimental economists have been turning their attention to examining the predictive ability of game theory. The topics of application range from testing the notion of sequential equilibrium (see, e.g. Camerer and Weigelt (1988)), to investigating other refinements (see, e.g. Banks, Camerer and Porter (1989), Brandts and Holt (1991, 1992), and Pitchik and Schotter (1988)). The ability of laboratory subjects to perform the backward induction tasks suggested by game theory has been investigated by Neelin, Sonnenschein and Spiegel (1988), McKelvey and Palfrey (1990), and Harrison and McCabe (1990), as has subjects' ability to behave consistently with the notion of forward induction (see, e.g. Brandts and Holt (1990), Van Huyck et. all. (1988), Abdalla et.al. (1989)) and Cachon et. al. (1991)). A clear picture of the performance of the theory has yet to be drawn, however, as the results of some of the papers listed above appear to support the theory while others do not.

But even if each of the studies listed were to strongly support the predictions of the theory, the question would still remain as to whether the subjects in these experiments behave according to the predictions of the theory *for the reasons suggested by the theory itself.* Game theory does not merely provide a prediction for the actions of people; inherent to the theory is the specification of the process through which rational people arrive at their chosen equilibrium strategies. Nash equilibria are supported by mutual best responses, extensive form equilibria are supported by out-of-equilibrium beliefs, and trembling hand equilibria are supported by specific types of mistakes which rule out, for example, correlated mistakes by one's opponents. Consequently, even when the predictions of the theory are correct, we must still wonder if they are correct for the right reasons or whether there is some other, possibly non-strategic, heuristic which is truly determining the behavior of subjects.

Our paper investigates exactly this question. We ask whether subjects in laboratory experiments are engaging in the thought processes prescribed by game theory. Our work is set in the context of the equilibrium-refinement literature, replicating the experiments of Brandts and Holt (BH) (1994, forthcoming) where they, in turn, replicate some experiments found in an earlier paper on refinements by Banks, Camerer and Porter (BCP) (1989). In BCP the authors offer support for the view that subjects, when placed in a game with two Nash equilibria, one more refined than the other, are found to choose the more refined equilibrium for all refinement concepts up to the level of divine equilibria. The BH paper, on the other hand, is the first to question whether the thought processes envisioned by the refinement literature are actually employed by real human subjects in laboratory games. BH posit a naive (non-strategic) dynamic statistical decision process which leads subjects playing these signalling games to a particular refined equilibrium. They argue that the payoff structure used by BCP tends to reinforce the belief structure that supports increasing refinements, and they go on to show that a modification of the payoff structure, which does not change the equilibria of the game, in fact generates outcomes which are ruled out by the refinement literature. BH interpret their ability to generate less refined equilibria in the BCP experiments as evidence that a different, non-game theoretic decision process is at work in these experiments. We agree with their conclusions.

We take the BH agenda to its natural extreme by employing a very simple experimental design. Our subjects play exactly the same signalling games as those used by BH and BCP except for the fact that in our games subjects are able to see their own payoffs *but not the payoffs of their opponents*. As a result it becomes impossible, in our setup, for subjects to employ game theoretical logic, since such a logic obviously requires that players know the payoffs of their opponents, or at least the payoffs of the possible types of opponents they might meet. Our contention is that if our results replicate those of our predecessors, in whose experiments full information about payoffs is available, then we would conclude that game theoretic logic could not be at work in explaining either our results or theirs. We find that our results do, in fact, support the hypothesis that an alternative, non-strategic decision-making process is at work, thus strengthening results already found in BH.

The following section will outline the dynamic decision-theoretic argument of Brandts and Holt concerning refinements; this will be done in the context of a specific example. In light of this argument we will outline our experimental design and procedures in Section 3 and our results in Section 4. Section 5 offers some conclusions.

2. The Brandts and Holt Argument

As mentioned above, the BH paper is motivated by the work of BCP who set out to test the various refinement notions that have been created for games with multiple Nash equilibria. In their paper, Banks et al. use a nested set of games each of which has two Nash equilibria, one more refined than the other. They investigate whether subjects, when given such a game, converge to the more refined equilibrium. Their conclusion is that "subjects refine up to divine". BH, on the other hand, ask the same question that we posed above: Do the subjects in these experiments choose the more refined equilibrium for the 'correct' reasons? Do subjects analyze games in the manner predicted by the refinement literature?

One reason to doubt the logic supporting the refinement selection story is that it requires a thought process that is seemingly out of the cognitive reach of most human subjects. Most simply, in order to be convinced of playing according to an equilibrium refinement, a subject must do the following: First he or she must determine the set of strategies that constitute equilibria for the game. Then, the subject must investigate whether an equilibrium is self-enforcing by asking what the beliefs of agents would be if an out-of-equilibrium message were sent. If these beliefs fail some rationality test (such as equilibrium dominance) then the subject must realize that there exists an incentive for some player to deviate and destabilize the equilibrium. Such an equilibrium would then be rejected and a similar analysis performed on the other equilibria of the game. Each player must, of course, believe that the other players are all also performing this analysis of the game.

As we do, BH question whether such a thought process could be going on in the BCP data and propose an alternative process that they consider more reasonable given the limited calculating abilities of experimental subjects. The alternative, however, is non-game theoretical in spirit and suggests that subjects treat the game they are in not as a game at all. They may in fact be acting as naive decision makers facing opponents who behave probabilistically rather than strategically. To understand the problem, consider the following signalling game taken from BH (Game 1) and replicated by us.

Table I : Game 1

message N	C	D^n	E	message S	C^s	D	E
type H	15,30	30,30	0,45	type H	45,15	0,0	30,15
type L	30,30	15,60	45,30	type L	30,30	0,0	30,15

n = non-sequential Nash equilibrium
s = sequential equilibrium

In this signalling game there are two players: a proponent, player P, and a respondent, player R. The proponent can be of two types, type H or type L, with types being chosen with equal probability before the game starts. The type is revealed to player P but not player R, although player R knows the probability distribution determining types. Once player P knows his type he must send a message of either N or S. The message determines which of the two payoff matrices shown above is relevant for the game. At this point it is player R's turn to move and she chooses an action C, D or E. Payoffs are then determined by the message sent by P, the action chosen by R and by player P's type.

There are two Bayesian-Nash equilibria in this game, only one of which is sequential. In the non-sequential equilibrium, player P sends message N no matter which type he is, while the respondent takes action D regardless of which message is sent. In the sequential equilibrium, on the other hand, both types of player P send message S which is responded to by action C, while a message N receives the reply D. This game thus has two equilibria, one of which is more refined than the other.

The modern refinement literature posits a specific method by which players are to rule out the non-sequential Nash equilibrium. Consider subjects at the Nash equilibrium. Note that if player P is of type H he will receive a payoff of 30 at the equilibrium while if he is of type L he gets 15. Player R receives either 30 or 60. If the out-of-equilibrium message S is ever sent, it should be met by player R with a reply of D, leading to a payoff of 0 for each player. This is clearly a non-credible threat on the part of player R, as it requires that she choose her dominated strategy D instead of her weakly dominant strategy C. The choice of C over D would result in strictly higher payoffs for both players. As a result, both P and R have an incentive to deviate from the Nash to the sequential equilibrium and can be expected to do so. It is this process that game theory expects subjects to work their way through.

Clearly, this is a complex thought process, one that might well exceed the reasoning capabilities of mere mortals. It is this complexity that leads us to question the likelihood that game theoretic logic could in fact be responsible for the observed behavior of subjects in laboratory experiments, even in cases when outcomes are consistent with the predictions of theory. In response to the same set of concerns, BH posit the following naive decision model to explain people's behavior in such games. Assume that player P thinks of his opponent not as a strategic player but as a naive decision machine which chooses actions C, D and E with equal probability. A player P of type H would find it beneficial to choose message S since that message would maximize his expected utility. If player P were of type L, message N would be sent. Likewise, if player R believes that messages N and S are equally likely to be sent by either type of proponent, she will choose action C when S is sent and D when N is sent. These choices may be what we expect in the early rounds of the experiments. As time goes on, however, there exists an incentive for players of type L to switch from message N to message S in order to receive the higher payoff associated with a response C. Players thus converge to the sequential equilibrium. Under the BH logic, *players converge to the refined equilibrium not for game theoretic reasons but for decision-theoretic ones.*

In the next section we outline the experiments we performed to investigate our suspicions regarding the extent to which game theoretic logic is actually used by laboratory subjects.

3. Experimental Design and Procedures

3.1 Our experiments replicate those run by BH, with two variations required by our somewhat different objectives. The first is an informational difference in that subjects in our experiments were provided only with information about their own, but not their opponents' payoffs. The second has to do with the fact that in the BH design, subjects were assigned a particular role (proponents or respondents) and kept that role for the first six rounds of the experiment. (We use the BH instructions (a sample of which is available in the Appendix) except, of course, for the modifications needed by our partial infromation setting. During these six rounds they played against a different subject, with the opposite role, in each period. Players then switched roles and played the same game six more times. Given our informational structure, however, we could not follow this design, since allowing subjects to switch roles and play a second six rounds with the same payoff matrices would provide them with complete information about all payoffs. To prevent this, after the first six rounds were over, players did exchange roles, but also used payoff matrices from a new game with the existence of changes changes being made common knowledge (of course, subjects still only knew their own payoffs in the new game). The result of this design change is that while BH have twelve-period histories of each game (albeit that their players also remain in the same role for only six periods), we have two separate six-period histories for each game.

Two types of signalling games are analyzed. The first pair of games (Games 1 and 2) each have two Nash equilibria, one of which is sequential. The second pair of games (Games 3 and 4) are characterized by two sequential equilibria, only one of which is intuitive (satisfies equilibrium dominance).

Game 1 in the BH paper (BCP's Game 3) was presented and analyzed above in Table I. As noted, this game has two equilibria. The non-sequential Nash equilibrium is for both types of player 1 to send message N, and for player 2 to respond by choosing D. This equilibrium is supported by a (non-credible) threat from player 2 of responding to message S with D. In the sequential equilibrium, both types of player 1 send message S and receive response C, while a deviation to N receives response D. This equilibrium is sequential since the response D to a deviation from message S to message N is a best response to the belief that such a deviation is more likely to come from a player 1 of type L.

Under the BH explanation, convergence towards the sequential equilibrium is purely a result of the very particular features of the game's payoff structure and is not a consequence of the logic of the refinement per se. Brandts and Holt go on to alter the game's payoff structure in a way that preserves the same equilibria, but changes players' behavior in out-of-equilibrium play. In the altered game, Game 2 below, they indeed find that there is no convergence to the sequential equilibrium.

The equilibria of this game are exactly those of Game 1. This game, however, is designed in a way such that experience in the adjustment process should lead to the less-refined, non-sequential equilibrium if naive behavior were used. Under the naive approach, both types of player 1 should send message N; similarly, naive behavior on the part of player 2 would dictate answering message N with response D. As Brandts and Holt find, this adjustment process results in convergence to the non-sequential equilibrium. Note that in this game, under the naive adjustment process, and unlike the situation in Game 1, message S is never used. Players therefore do not realize that a response of D to message S is strongly dominated; it is precisely this dominated response that sustains the non-sequential equilibrium.

Table II: Game 2

message N	C	D^n	E	message S	C^s	D	E
type H	75,30	45,30	75,45	type H	60,15	0,0	0,45
type L	75,30	30,75	75,30	type L	45,60	0,0	45,15

n = non-sequential Nash equilibrium
s = sequential equilibrium

The process is repeated in Game 3 of BH (BCP's Game 4) which is characterized by two sequential equilibria, only one of which satisfies the intuitive criterion. In the less-refined sequential equilibrium both types of player 1 send message S, which is answered with C. A deviation to message I (intuitive) receives response D. This equilibrium is not intuitive since it relies on the belief that a deviation to I is very likely to have come from a type L player. Such beliefs are unreasonable since a type L player earns a payoff of 45 in the sequential equilibrium, but can earn at most 30 if she deviates. In the intuitive equilibrium, both types of player 1 send message I and receive a response C. The out-of-equilibrium message S is answered with D; this relies on the reasonable belief that the deviant is most likely to be of type L. In the intuitive equilibrium, a type L player receives a payoff of 30, while deviating could conceivably yield a payoff of 45; no such incentive to deviate exists for a player of type H. BCP find that experimental subjects converge to the more refined intuitive equilibrium.

Table III: Game 3

message I	C^i	D	E	message S	C^s	D	E
type H	45,30	15,0	30,15	type H	30,90	0,15	45,15
type L	30,30	0,45	30,15	type L	45,0	15,30	30,15

s = sequential equilibrium
i = intuitive equilibrium

BH again argue that this convergence to the more refined equilibrium may be an artifact resulting from the specific payoff structure of the game, and may in fact be explained by naive reasoning on the part of players. The argument is very similar to that used in Game 1. Under naive reasoning, a player of type H would send message I and receive a response C, leading to the intuitive equilibrium. A player of type L would send message S which is answered with D *under the assumption by player 2 that a deviant is more likely to be of type L.* This leads the type L player to switch to message I, thus the convergence to the intuitive equilibrium.

Notice that, for this game, there is an inconsistency in BH's explanation of convergence to the more refined equilibrium under naive behavior. If behavior were strictly naive, then player 2, upon noting a message S, should respond with C, since the total expected payoff under C is 45 (1/2 X (90 + 0)) versus 22.5 (1/2 X (15 + 30)) under a response D. Thus even Brandts and Holt's explanation for the observed convergence to the more refined equilibrium in this case relies on non-naive behavior on the part of player 2. It is interesting that this is the only game where our results did not follow those obtained by Brandts and Holt (and Banks, Camerer and Porter). While their results support convergence to the more refined equilibrium, ours do not; this issue will be addressed in a following section.

Game 4 has exactly the same equilibria as those in Game 3, but the payoff structure has been modified. Again, BH reject BCP's finding of convergence towards the more refined, i.e. the intuitive, equilibrium when the game's payoff structure is altered.

Table IV: Game 4

message I	C^i	D	E	message S	C^s	D	E
type H	45,30	0,0	0,15	type H	30,90	30,15	60,60
type L	30,30	30,45	30,0	type L	45,0	0,30	0,15

s = sequential equilibrium
i = intuitive equilibrium

Operating from a naive point of view, players of type H would send message S while players of type L would send message I. The best response for player 2 is to answer both messages with C. This would lead type L players to switch to message S in search of a payoff of 45, and thus result in convergence to the less refined equilibrium. Again, this explanation is somewhat unsatisfactory in that it leaves open the question of why a type H player would not switch to message I in search of a payoff of 45 under the intuitive equilibrium (since player 2 responds to both messages with C).

3.2 Experimental Procedure

We attempted to duplicate Brandts and Holt's experimental procedures as closely as possible, with the two exceptions indicated above. Subjects were recruited from undergraduate economics classes to take part in the experiments.

Twelve subjects were recruited for each of four experimental sessions. In each session, half the subjects were initially assigned the role of proponents, the other half were respondents (see appendix for a copy of the instructions). Subjects played one game (Game 1 or Game 3) for six periods. In each period a proponent and respondent were paired; after each period subjects were rematched in a way such that no person would meet the same partner more than once in the same role; the matching process also ensured that no contagion occurred. At the beginning of each matching a die was thrown separately for each proponent to determine their type, H or L. Each proponent then decided on a message to send which was individually transmitted by the supervisor to the paired respondent. Respondents were not informed of their partner's type, but did know that the types were equally likely. Respondents then chose a response which was again communicated privately to the paired proponent. Finally, respondents were told their partners' type, and all subjects calculated their earnings from tables provided in the instructions to the game. The tables indicated each player's own payoffs, but not those of her partner. At the end of six periods a new game was begun (Game 2 or Game 4) and all players switched roles. Those who were proponents were now respondents, and those who were respondents became proponents. This second game was also played for six periods, under the same conditions, i.e., subjects knew that the game being played had changed but only knew their own payoff matrix entries.

Each session lasted about one and one-half hours. As in BH's experiments, subjects received a base payment of $10; in addition, in each period subjects could earn either $.50 or $2.00 depending on their payoff that period and on an element of chance. Average earnings were close to $22.

4. Results

The results we obtained as well as those reported in BH and BCP are summarized below in Table V. The striking similarity between the results obtained in our partial information design and those obtained by BCP and BH with high information designs, particularly in Games 1, 2, and 4, supports our hypothesis that game theoretical logic is not the determinant of the results obtained by either us, BCP or BH. In fact, our results for Games 1 and 2 are stronger -- more consistent with the predictions of game theory -- than those obtained by Brandts and Holt.

In our version of Game 1, only 5% of the outcomes were non-Nash (versus 10% found by BH and 25% for BCP), while 64% were sequential (vs. 58% for BH and 63% for BCP). In

Game 2, we find that 22% of the outcomes are non-Nash (vs. 28% in BH); we also find a

Table V: Proportion of Outcomes by Refinement

Game	Refinements				
	Non-Nash	Nash	Sequential	Intuitive	Sample Size
1**	.25	.12	.63		60
1*	.10	.32	.58		72
1	.05	.31	.64		72
2*	.28	.50	.22		72
2	.22	.65	.13		72
3**	.34		.13	.53	90
3*	.34		.19	.47	72
3	.31		.40	.29	72
4*	.41		.46	.13	72
4	.39		.44	.17	72

1** and 3** are the results obtained by BCP for the first five rounds of their experiments.
1*, 2*, 3*, and 4* are the results obtained by Brandts and Holt for the first six periods of their experiments.

bigger shift towards the Nash outcome and away from the sequential as the payoff structure is modified. In Game 4 we find the choices split 39%, 44% and 17% across the non-Nash, sequential and intuitive outcomes respectively, while the same choices were made in the BH experiment with 41%, 46% and 13% frequencies. For Game 3 our results are less satisfactory. Here, while the percentage of outcomes which were non-Nash was approximately the same in our experiment as in BH and BCP (31%, 34% and 34% respectively), the percentage of outcomes consistent with the sequential and the intuitive equilibria differed substantially with 40% of our subjects choosing the sequential outcome (as opposed to 19% in BH and 13% in BCP) and 29% choosing the intuitive outcome (with 47% and 53% for BH and BCP respectively). We consider the difference in our results from BH to be a property of the actual parameters used in Game 3 and the problems these parameters present for the naive decision analysis proposed by them.

Despite the differences noted for Game 3, our results confirm the man conjecture of this paper that game theory is capable of predicting the outcomes of games but possibly for reasons other than those defined by game theorists.

4.1 A Closer Look at Naive Decision Rules

Our paper departs slightly from that of BH in that while we agree that game theoretic logic may be too complex for less than perfectly rational agents, we make no claim as to what the precise logic is that people actually employ to choose equilibrium strategies. Nevertheless, BH offer us one such process and it is of interest to investigate how the predictions of their specific process compare with our data.

Tables VI to IX present a breakdown of messages sent by proponents. The tables highlight type dependence in each of the games, verify the accuracy of the prediction of behavior when subjects are assumed to rely on the naive approach, and illustrate the evolution of players' choices as the games progress. Cell entries show the number of observations: for example, in Game 1, period 5, two type H players sent message N (a total of twelve messages are sent each period).

In Game 1 (Table VI) predictions of proponents' choices based on the naive approach are that players of type H should send message S, while type L players send message N. In fact, 35 of 41 (85%) messages sent by type H players are sequential, and relatively more sequential messages are sent as the game progresses. Type L players, on the other hand, begin by sending Nash messages, but switch to sequential messages in the final periods. Such switching indicates the likelihood that learning has taken place during the game's initial stages.

Table VI: Type Dependence and Convergence -- Game 1

	Period					
Type/Message	1	2	3	4	5	6
H/N	1	1	1	-	2	1
H/S	4	5	5	8	7	6
L/N	7	4	3	1	1	2
L/S	-	2	3	3	2	3

One explanation is that type L players sending message N receive the Nash response D, and thus a low payoff of 15. In an attempt to obtain a higher payoff, players try a response S. In this case, the payoff is 30, and thus the convergence towards the sequential message. A message S is *almost never* answered with D (the response D is employed only once in the forty eight times that an S message is sent), the (non-credible) threat that supports the Nash equilibrium because that response is strictly dominated. Thus the payoff structure in this game encourages experimentation on the part of players of type L. As BH predict, convergence to the more refined equilibrium is thus possible in this game because players are encouraged to gain experience in all subgames (which is not the case in Game 2, for example.)

Predictions of player behavior based on the naive approach imply that in Game 2 (Table VII) both types of players should send message N; for both types of players, message N strictly dominates message S. The predictions are generally realized, with message S sent only 13 out of 72 instances (18%); nine of these thirteen messages were sent by the same two players. As has been previously noted, in this game the sequential message S is not (or is not *supposed* to be) attempted, and thus players do not learn that the zero payoffs which support the Nash equilibrium form a non-credible threat.

Table VII: Type Dependence and Convergence -- Game 2

	Period					
Type/Message	1	2	3	4	5	6
H/N	7	7	4	5	5	7
H/S	-	2	1	2	1	-
L/N	5	2	6	4	4	3
L/S	-	1	1	1	2	2

In Game 3 (Table VIII) our results do not match those found by Brandts and Holt. Naive behavior predicts that type H players send message I, while type L players send message S. Upon seeing a message S, respondents, according to Brandts and Holt's argument, should realize that the sender is most likely to be of type L, and would thus respond with an action that encourages the type L player to *switch* from message S to the more refined message I, thus the convergence they find towards the intuitive equilibrium. When players are unable to observe their partners' payoffs, however, there exists no reason for respondents to believe that a message S was sent by a type L proponent. Their naive response in this case results in a payoff of 45 to the type L proponent, while switching to message I would yield the proponent at most 30. This is exactly what we observe in our experiment, where only 11 out of 40 S messages (27%) were answered with action D, indicating that most respondents did not realize that the sender was likely to be of type L. There was thus no incentive for the proponent to switch to a message consistent with the intuitive outcome.

The divergence of our results for Game 3 from those of Brandts and Holt indicates that naive behavioral rules may not be a completely accurate representation of rules actually employed by experimental subjects. It appears that for certain characteristics of the payoff structure naive rules are sufficient for convergence to more refined equilibria, while such rules may be an insufficient in other cases. What differentiates the payoff structure in Game 3 from that in Game 1 where players did converge to the refined equilibrium?

Table VIII: Type Dependence and Convergence -- Game 3

	Period					
Type/Message	1	2	3	4	5	6
H/I	6	2	5	5	7	4
H/S	1	1	2	2	1	1
L/I	-	-	2	-	-	1
L/S	5	9	3	5	4	6

In Game 3, while *out-of-equilibrium* responses do tend to support the more refined equilibrium, the incentive for players of type H to switch to the intuitive equilibrium is not very strong[1]. A deviation from message I to message S does not result in a response D as argued by Brandts and Holt, but in a response C. The incentive to switch to message I is thus weakened, although some incentive to switch still exists for type H players. However, no incentive to switch to message I exists for type L players since sending message S is a weakly dominant strategy. In this game, the more refined equilibrium suffers from not being supported by proper out-of-equilibrium reinforcement.

In Game 4 (Table IX), 34 out of 39 type H players (87%) send message S, while 20 out of 33 type L players (61%) send message I. These are the messages predicted by naive behavior. Of the thirteen messages sent by type L players that did not match the prediction, ten were sent by the same two players. Our results for this game are consistent with those obtained by Brandts and Holt. One issue here is that there is a bias against type H sending an I message as a result of the presence of zero payoffs; this mitigates against convergence to the more refined equilibrium. Another is the large number of non-Nash outcomes in this game. Many of these non-Nash outcome are the result of a response D to message I, an indication that respondents were trying to obtain a payoff of 45 rather than the payoff of 30 associated with the refined equilibrium. The *relative risk* of a zero payoff was apparently not significant enough to push these players towards the intuitive equilibrium.

Table IX: Type Dependence and Convergence -- Game 4

	Period					
Type/Message	1	2	3	4	5	6
H/I	2	-	2	-	1	-
H/S	5	2	4	5	9	9
L/I	2	7	3	7	-	1
L/S	3	3	3	-	2	2

5. Conclusions

This paper has attempted to uncover whether human subjects in laboratory experiments adhere to the predictions of the theory of games for the reasons that are specified by the theory and that underlie the refinement literature. In our experiments, subjects play the same set of signalling games used by Brandts and Holt (1994, forthcoming) and Banks, Camerer and Porter (1989) but unlike the case of BH and BCP they do so in a partial information setting in which players are informed only of their own payoffs in the game and not those of their opponents.

Since the game theoretic logic required of rational players is predicated upon subjects knowing the payoffs of other players in the game, at least probabilistically if the game is one of incomplete information, if our partially informed subjects play according to the predictions of the theory then they must be doing so for other reasons.

We do in fact find that our subjects converge to the equilibria predicted by the refinement literature. In comparing our data to that of Brandts and Holt and Banks, Camerer and Porter, we see that it is consistent with the results of both of these studies. More precisely, when given a choice between a more or a less refined equilibrium, our subjects tend to choose the more refined equilibrium in those circumstances where the BCP subjects do, but also choose the less refined equilibrium in those circumstances predicted by Brandts and Holt's more naive theory. Thus our results strengthen those already found by Brandts and Holt and support our belief that laboratory outcomes consistent with the predictions of game theory are only a necessary condition for the validation of the theory.

References

Abdalla, A., Cooper, R., DeJong, D., Forsythe, R., and Ross, T. "Forward Induction in Coordination and Battle of the Sexes Games: Some Experimental Results," Working Paper 899-22, University of Iowa, 1989.

Banks, J., Camerer, C. and Porter, D. "Experimental Tests of Nash Refinements in Signaling Games," mimeo, 1989.

Brandts, J. and Holt, C. "Adjustment Patterns and Equilibrium Selection in Experimental Signalling Games. International Journal of Game Theory, (forthcoming) July 1994.

Brandts, J. and Holt, C., "An Experimental Test of Equilibrium Dominance in Signalling Games," mimeo, August 1991.

Brandts, J. and Holt, C., "Dominance and Forward Induction: Experimental Evidence," mimeo, August 1990.

Cachon, G., Camerer, C., and Johnson, E., "Forward Induction, Mutual Rationality and Reasoning Process in Simple Games," mimeo, University of Pennsylvania, 1991.

Camerer, C. and Weigelt, K., "An Experimental Test of Sequential Equilibrium Reputation Models," Econometrica, Vol. 56, 1988, pp. 1-36.

McKelvey, R., and Palfrey, T., "An Experimental Study of the Centipede Game," Cal-Tech working paper 732, May 1990.

Pitchik, C., and Schotter, A., "Perfect Equilibria in Budget Constrained Sequential Auctions: An Experimental Story," Rand Journal of Economics, Vol. 19, No. 3, Autumn 1988.

Van Huyck, J., Battalio, R., and Beil, R., "Asset Markets as an Equilibrium Selection Mechanism: Coordination Failure, Same Form Auctions and Forward Induction," Texas A & M, working paper 8-40, 1988.

APPENDIX

INSTRUCTIONS

Introduction

You are going to take part in an experimental study of decision making. The funding for this study has been provided by several foundations. The instructions are simple, and by following them carefully, you may earn a considerable amount of money. At this time, you will be given $10.00 for coming on time. All the money that you earn subsequently will be yours to keep, and your earnings will be paid to you in cash today at the end of this experiment. We will start by reading the instructions, and then you will have the opportunity to ask questions about the procedures described.

Before we proceed, we will choose a "supervisor". The supervisor will observe the way in which we perform the experiment and will help us at several moments. The supervisor will earn the maximum of the earnings that the remainder of you have earned at the end of the experiment. Now, we will assign a number to each of you, and then the supervisor will be chosen by the throw of two dice.

Earnings

The experiment consists of a series of separate periods in which each of you must choose among several alternatives. Each period consists of two parts. In part I you will be matched with another participant, and the decision that you and the other participant make will determine the "points" earned by each of you. In part II, you will have a chance of winning an amount of money in accordance with the points you earned in Part I. We will start by describing Part II so that you will understand how the points that you earn determine your earnings in dollars and cents. We will subsequently describe Part I in detail so that you can understand how the points are earned.

Instructions for Part II

At the end of Part I, you will have earned between 0 and 100 points, according to the rules to be explained later. The amount of money that you earn in Part II will depend partly upon the number of points you won in Part I and partly on chance. Here we have two dice, each with ten sides that are equally likely. In Part II, these two dice will be thrown to determine a number between 0 and 99. The white die will determine the "tens" digit and the red die will determine the "units" digit. If the result of the dice throw is a number smaller than the number of points you won in Part I, you will earn $2.00. If the number resulting from the throw is greater than or equal to the number of points you won in Part I, you will earn $0.50. In this way, if you have earned 100 points in a period, you will be assured of cash earnings of $2.00. If you have earned 0 points in a period, you will be assured of cash earnings of $0.50. Note that the more points you earn, the higher your chances will be to earn $2.00 for the period.

Summary

The period begins.

Part I: Decisions determine the points that you earn.

Part II: The result of throwing the dice determines your earnings in cash:
$2.00 if the result is less than the points you earned.
$0.50 if the result is greater than or equal to the points you earned.

The period ends, and the following period begins.

Instructions for Part I

In each period, you will be matched with another participant; one of you will be referred to as the "proponent", and the other will be referred to as the "respondent". At the beginning of each period the proponent will choose between two possibilities, N or S. Then this decision will be communicated to the respondent. After learning about the decision made by the proponent, the respondent will make a decision by choosing among different possibilities: C, D and E. Next, the decision of the respondent will be communicated to the proponent. The payoff tables you will be using will only indicate your own payoffs. The participant you are matched with will not see your payoff tables, nor will you see his/her tables. Given these decisions, the earnings in points will be determined by one of the following two tables:

TABLE H (selected with probability 1/2)

Proponent's Decision	Respondent's Decision	Your Earnings (in points)
N	C	15
S	C	45
N	D	30
S	D	0
N	E	0
S	E	30

TABLE L (selected with probability 1/2)

Proponent's Decision	Respondent's Decision	Your Earnings (in points)
N	C	30
S	C	30
N	D	15
S	D	0
N	E	45
S	E	30

Note that the earnings will depend on two decisions made and on the table of earnings being used. The table of earnings, H or L, will be chosen by a throw of a 6-sided die; a 1, 2, or 3 yields table L and a 4, 5, or 6 yields H.

The proponent will observe the die throw, and therefore will know the table employed before making his/her decision. On the other hand, the respondent will not know which table is being employed until after his/her decision is made.

Supervisor

At the beginning of each period, the supervisor throws the die that determines the table of earnings in points to be employed in this period, The supervisor may communicate with the organizers of the experiment in order to comment on the procedures, but he/she will not be allowed to communicate with the participants in the experiment, unless there is a question about procedures being followed.

Record of Results

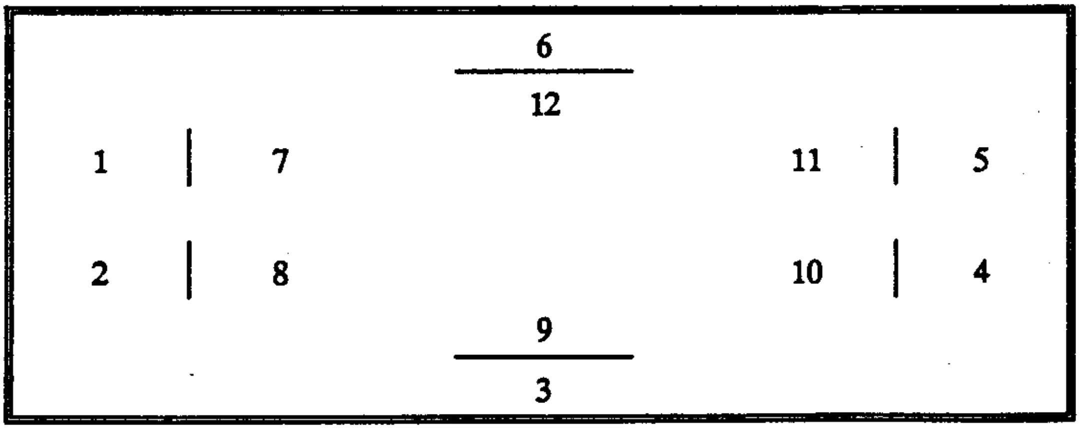
Now, each of you will examine the record sheet for part A. This sheet is the last one attached to these instructions. Your identification number is written in the top part of this sheet. The next line indicates your designation: proponent or respondent. All of the proponents for this experiment will be in the same room, and an equal number of the respondents will be in an adjacent room.

Now examine the column on the left side of your record sheet for Part A. The number in this column shows the period (the first row corresponds to period 1 and so on). Going from left to right, you will see the column titled "other participant" and the number in this column shows the identification number of the participant that you are matched with in each period. Note that in each period you are matched with a different participant. To the right, you can see columns for your decisions, the other participant's decision, and the earnings table. You must record your decision as soon as you make it.

Once you know the decision of the other participant and the relevant earnings table, you will be asked to record this information in the suitable column, and your earnings in points in the "your earnings" column. Then the throw of dice will determine your earnings in dollars and cents. Both the result of the throw of the dice and the amount earned ($2.00 or $0.50) will be recorded in the appropriate columns of your record sheet.

More on the Pairing of Proponents and Respondents

The box below shows the initial matching of subject numbers for the first period. The proponents' numbers are 1, 2, ... 6. so you can think of the proponents as being located on the outside of a circle, with the respondents (7, 8, ... 12) located on the inside. After each period the proponents move to the next respondent in a clockwise direction. For example, proponent 1 is matched with respondent 7 in the first period, with respondent 12 in the second period etc. Respondent 7 is matched with proponent 1 in the 1st period and with proponent 2 in the second period, etc. The 6 periods in this experiment allow each proponent to go around the circle. Notice that no proponent is ever matched with the same respondent twice, and no respondent is matched with the same proponent twice. Moreover, no person is ever matched with anyone who has ever been matched with the same proponent twice. Moreover, no person is ever matched with anyone who has ever been matched with someone who has been matched with them previously. If you were able to tell a story to every person that you meet, and they told it to everyone they met, etc., then you would never meet anyone who had heard the story. The circular movement in the pairing process causes all participants who have had contact with you, either direct or indirect, to be located "behind" you in one direction around the circle.



Summary

Each period begins with the throw of a 6-sided die that determines the table of earnings that will be employed during this period. Once the proponent has observed the die throw, he/she will make his/her decision and record it. Afterwards, the respondent will be informed of the decision made by the proponent, and the respondent in turn will make a decision, without knowing the result of the die throw. Finally, the decision of the respondent will be shown to the proponent, and the result of the die throw that determines the earnings table will be communicated to the respondent. With this information, each participant will be able to use the appropriate earnings table to determine his/her earnings in points for this period, Then one of use will come to each participant's table to throw the 10-sided dice separately for each person, and the resulting number will determine whether that person's earnings $2.00 or $0.50. Finally, each participant will register this amount in the square of the right side corresponding to the period that has just finished.

Later periods will be performed in the same way until the end of period 6, at which time we will read to you the instructions for another experiment on decision making.

Final Remarks

At the end of today's session, we will pay to you in private the amount that you have earned. You have already received the $10.00 participation payment. Therefore, if you earn and amount X during the following experiments, your total earnings for today's session will be $10.00 + X. Your earnings are your own business, and you do not have to discuss them with anyone.

During the experiment, you are not permitted to speak or communicate with the other participants. If you have a question while the experiment is going on, please raise your hand and one of us will come to your desk to answer it.

At this time, do you have any questions about the instructions or procedures?

The experiment is about to begin. You are not permitted to speak with other participants during the experiment. Please don't ask public questions during the experiment. If you need to ask anything during the experiment, please raise your hand and one of us will come to your desk to answer it. Now please change to the seat that will be indicated to you.