Stability in an Evolutionary Game: an Experimental Study

Sean W. O'Donnell
University Undergraduate Research Fellow, 1994-1994
Texas A&M University
Department of Economics

ABSTRACT: This paper studies the dynamic process in an evolutionary game. Using a replicator dynamic, the theoretical prediction is for subjects to use a symmetric mixed strategy equilibrium, while the two asymmetric strict Nash equilibria become unstable. Two experimental treatments are used to observe the actions of subjects in one population with a random, pair-wise matching protocol. Previous work suggests that subjects are unable to learn in aggregate population dynamics. The data confirms that subjects are unable to coordinate on the mixed strategy Nash equilibrium as an Evolutionary Stable Strategy.

APPROVED
Undergraduate Advisor
Exec. Dir., Honors Program

Introduction

Three troublesome aspects of the Nash equilibrium solution concept, achieved by mutual best responses from the players, has been its inability to assign a unique outcome, the existence of asymmetric equilibria and the mixed-strategy equilibrium. Can players who have never met, or do not share a common history, coordinate on asymmetric Nash equilibria? Prominent game theorists regard symmetry as indispensable in players coordinating on a Nash equilibria. In what situations will players overcome the Nash equilibrium's inability to assign a unique solution in multiple equilibria games? And, can players achieve an assigned Nash mixed equilibrium?

A shortcoming of economics has always been its focus on static fixed point equilibria, often at the expense of dynamic processes and stability. Evolutionary biologists have used the Hawk-Dove games to develop the evolutionary stable strategy as a unique, dynamic equilibrium. This paper examines the class of Hawk-Dove games known as Battle of the Sexes. Often found in theoretical biology literature, as well as economic literature, Hawk-Dove examines evolutionary fitness of same-species competition within one population.

Given an initial frequency of players using a replicator A, the basins of attraction will lead the population to a resting point, or equilibrium. For the resting point to be evolutionary stable requires that the population be impervious to mutant invasion. In many cases, asymmetric equilibria are discarded as the mixed-strategy equilibrium becomes the unique evolutionary stable strategy. Yet such a conjecture is highly controversial among game theorists who question the stability of mixed-strategy equilibrium in empirical observations. Crawford (1989) has argued that the Evolutionary Stable Strategy will be unstable because, unlike inherited strategies, subjects are incapable of learning across aggregated individuals.

Through experiments in the Texas A&M University economic science laboratory network, this paper will report the outcome of population means in evolutionary games. The theoretically predicted outcome will be that subjects either mix their pure strategies or purify their pure strategies within a population. Whether subjects mix or purify their strategies will be indeterminable, but the actions subjects take will be observable, and hence, reportable.

The advantage of the Hawk-Dove game selected for study in this paper is that it combines the non-uniqueness problem with two asymmetric and one mixed-strategy Nash equilibria. To observe the dynamic process, a one population, random pair-wise matching protocol was used. The random matching protocol among pairs creates a situation where subjects should base future decisions on historical information. Such a matching protocol will theoretically eliminate the development of conventions as seen in repeated games.

I would like to thank Dr. Van Huyck and Dr. Battalio for providing me with considerable research support. The two NSF proposals, "Strategic Behavior, Dynamical Systems, and Equilibrium Selection," Dr. Van Huyck, P.I, and "Learning Equilibrium Behavior," 1994, Dr. Van Huyck, P.I. contain sections on learning mixed strategies and provided the conceptual foundation for my thesis. In addiion, the assistance of their staff made it possible to modify the programs and conduct high-quality experimental sessions.[1]

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[1] I am glad that I did not need to write a personal check to pay the subjects in sessions I conducted.

Theoretical Design

In this paper, the experiments incorporate game theoretic concepts and designs. Game theory requires strict definitions and rigorous theorems to provide a foundation for understanding. Therefore, it is appropriate to begin with the definition of a game (Fudenberg and Tirole, 1993, Binmore, 1992). A strategic form, or normal form, representation of a game incorporates three elements in its definition:

1) the set of players, $i \in N$, which are taken to be finite within the set

$N = \{1,2,...,I\}$;

In economic terms, a player is defined as an "agent". For experiments, players are defined as participants or subjects.

2) the pure-strategy space, $s_M \in S$, for strategies $S = \{1,2,...,M\}$;

That is, each agent has M pure strategies. A strategy is a rule for choosing an action at every information set. On the other hand, a pure strategy is a rule that assigns an action to every information set controlled by a player. Obviously, the differences are subtle; a pure strategy assigns to, rather than choosing at, every information set. This will become more apparent with the extensive form representation of a game.

3) payoff functions π_i, defining each player i's von Neumann-Morgenstern

utility function $\pi_i(s)$ for each strategy profile $s = (s_1,s_2,...,s_I)$.

So a strategic form game can be summarized as $G = \{N;S_1,...,S_M;\pi_1,...,\pi_I\}$. The class of games I will study in this paper will be restricted to

1) $N = \{1,2\}$, Player I and Player II

2) $S = \{Up, Down\}$ the pure strategies Up and Down

3) von Newmann-Morgenstern utility payoffs,

$$\pi_1(\text{Up,Up}) = a, \qquad \pi_1(\text{Down,Up}) = c,$$
$$\pi_2(\text{Up,Up}) = e, \qquad \pi_2(\text{Down,Up}) = g,$$
$$\pi_1(\text{Up,Down}) = b, \qquad \pi_1(\text{Down,Down}) = d,$$
$$\pi_2(\text{Up,Down}) = f, \qquad \pi_2(\text{Down,Down}) = h.$$

Therefore the game can be represented as $G = \{N = \{1,2\}; S_1, S_2; \pi_1, \pi_2\}$.

A visual depiction of this game will help provide a more intuitive understanding of this game in figure 1:

		Player II	
		Up	Down
Player I	Up	(a,e)	(b,f)
	Down	(c,g)	(d,h)

Figure 1: 2 X 2 Game

In figure 1, Player I's payoffs are designated as (a,b,c,d) and Player II's payoffs are designated as (e,f,g,h). The strategic form properties of this game are that they contain the players, Player I and Player II or $N = \{1,2\}$, the pure strategies, Up and Down, or $S = \{Up, Down\}$ and the von Neumann-Morgenstern utility payoffs, here depicted as $\pi_i(s)$ = (a,b,...,h).

I will further restrict my analysis to the class of symmetric games defined by using the following qualitative restrictions:

$$a = e,$$
$$b = g,$$
$$c = f,$$
$$d = h,$$

Note that symmetry can be defined algebraicly as $A^T = B$,

$$\text{where } A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}, \tag{1}$$

$$\text{and } A^T = B = \begin{bmatrix} a & c \\ b & d \end{bmatrix}.$$

Symmetric matrices have the useful property of displaying the same pay-off matrix to each player, therefore allowing the game theorist to focus on only on Player I. This results in the following symmetric game,

		Player II	
		Up	Down
Player I	Up	(a,a)	(b,c)
	Down	(c,b)	(d,d)

Figure 2: 2 X 2 Symmetric Game

In addition the following restrictions will be imposed on the von Neumann-Morgenstern utility functions:

where $a < c < d < b$.

This game is often used by evolutionary biology, to analyse evolutionary competition and fitness. In evolutionary biology this game is referred to as the Hawk-Dove game. In this game our players are two birds of the same species who must compete for land in which to forage. The value of the game is v, which, in a biological sense, is the number of offspring one can support or evolutionary fitness. A player has two strategies, to choose a hawkish, or belligerent (Hawk), approach or a dovelike, peaceful, approach (Dove). This game can be seen visual in figure 2. If Player I and

		Player II	
		Hawk	Dove
Player I	Hawk	(w,w)	(v,0)
	Dove	(0,v)	(½v,½v)

Figure 3: Hawk - Dove Game

Player II choose to act like doves, they will have to split the land, therefore reducing the reward of the game in half ($\frac{1}{2}v$). However, if one player should choose to act like a hawk while the other chooses a dovelike strategy, the hawk will gain while the dove loses. Finally, if both players choose to be hawks, both violent tendencies will be aroused, resulting in damage c. Their payoffs will be one-half the value of the game minus the cost of fighting ($w = \frac{1}{2}(v - c)$).

Our particular interest in this game is based on a stability argument in a paper by V. Crawford (1989) to study Evolutionary Stable Strategies in modified Hawk-Dove games. To achieve his game, the following inequalities are imposed,

$$c>a$$
$$b>d.$$

These inequalities guarantee that the mixed-strategy equilibrium discussed below, will be evolutionary stable or an ESS.

We have used the following payoff matrix, figure 4, from the NSF proposal, 1994 to examine these issues. We will continue to refer to the game as `HD' although some of the properties of the original game have been changed.

		Player II	
		Up	Down
Player I	Up	(1,1)	(6,3)
	Down	(3,6)	(0,0)

Figure 4: HD Game

Recall that a pure strategy is a rule that assigns an action to every information set. In the case of a 2x2 strategic form game, the information node contains two pure strategies. The extensive form representation of this game shows us the relationship between information sets and pure strategies.

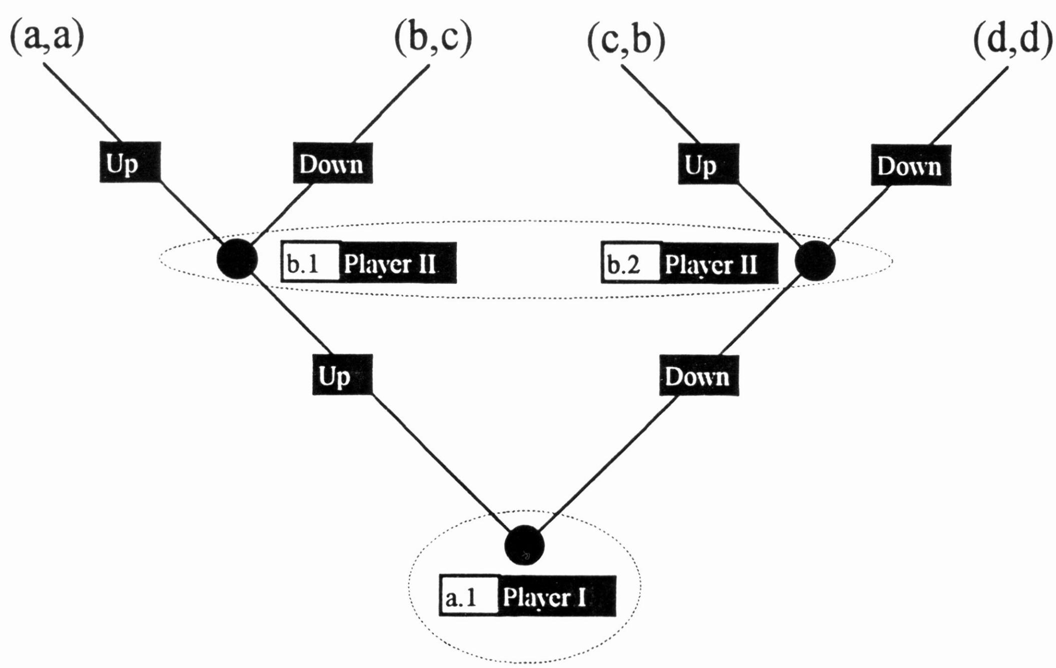

Figure 5: Symmetric 2x2
(Extensive Form Game)

Figure 5 represents the extensive form representation of the 2x2 symmetric game Figure 2. There exist three nodes, a.1, at which Player I makes a choice, and b.1, b.2, where Player II choses. In a game of perfect information, every information set, represented by the dotted-line circle, contains one and only one node. However, this symmetric game is one of imperfect information since players move simultaneously. Player II's information set contains two nodes, representing the fact that she effectively does not know at which node she is at. Therefore, though Player II has two nodes, she has only two pure strategies, Up and Down.

With a definition of strategies in hand, we can move to the concept of a best response. Player *i*'s best response, or reply, to the strategy s_j chosen by player *j* in a two player game is the strategy $s_i^{\cdot}$ that yields the greatest payoff. This can be written as

$$\pi_i(s_i^{\cdot}, s_j) \geq \pi_i(s_i^{'}, s_j) \text{ for all strategies } s_i^{\cdot} \text{ given } s_j . \qquad (2)$$

A best response is strict when there is no other strategy that will produce a payoff that is as good, satisfying the following condition

$$\pi_i(s_i^{\cdot}, s_j) > \pi_i(s_i^{'}, s_j) \text{ for all strategies } s_i^{\cdot} \text{ given } s_j . \qquad (3).$$

A solution is defined as the theoretical assignment of strategies to players over an array of choices, or, in other words, the assigning of strategies in such a way as to satisfy a theoretical solution concept. There are several solution concepts available in game theory. The most basic these is dominance solvable. A strategy is dominant if it is a player's best response to any strategy a player may chose (4).

$$\pi_i(s_i^{\cdot}, s_j) \geq \pi_i(s_i^{'}, s_j) \text{ , for all } s_i^{-} \text{ in } S_i \text{, not equal to } s_i^{\cdot} \text{ and for all } s_j \text{ in } S_j \qquad (4)$$

In this special case, a player can guarantee a (weakly) higher payoff regardless of the other's actions by selecting the dominant strategy. If Player I chooses Up when Player II plays Down, his pay-off is *b*. If Player II were to choose Up, while Player I continued with Up, her pay-off would be *a*, but by playing Down, Player I would get the higher pay-off *c*. In Figure 4, we can see that neither Up nor Down dominate the other strategy.

Of the various solution concepts available, the seminal game theory equilibrium concept is the Nash equilibrium. A Nash equilibrium is defined as an assignment to each player of a strategy such that it is optimal for him when others use their own assigned strategies. In other words, a Nash equilibrium exists where each player is using their best response to the other players' strategies. Therefore, we can use the mathematical representation of a best response, (3), as a representation of a strict Nash equilibrium.

Examination of Figure 4 shows that there exists two strict Nash equilibrium. This can be reasoned out. A requirement of a Nash equilibrium is that the strategies of both players are mutual best responses. We can identify the Nash equilibria by searching for fixed points where each player's action is a best response: if Player I choses Up, Player II can secure a strictly higher pay-off by selecting Down and if Player II plays Down, Player I's strict best response is Up. This identifies Up, Down as a Strict Nash Equilibrium, SNE. Similar arguments identify Down, Up as a SNE. Therefore, the SNE equilibria exist at $\{Up, Down; Down, Up\}$.

Since both pure strategy NE are asymmetric, an immediate question raised to game theorists is how players could coordinate on one of the strict Nash equilibria in a one-shot, single-stage game? In repeated games, players may be able to develop conventions that help assign strategies. Still, game theorists are wary of these equilibria because of the asymmetry of the pure strategy selections and non-uniqueness of the Nash equilibria. In evolutionary biology much of the focus is on games where each period different players meet. They have used this theory to try and explain evolution by deriving an Evolutionary Stable Strategy equilibrium. Stability of the strategies imply dynamic analysis, whereas most economics has focused on static fixed-points. Further, because of the matching protocol assumed players will not be able to use repeated game strategies based on concepts like reputation, threats, or punishment.

For the analysis of the dynamic process, we can think of the two pure strategies (Up, Down) as replicators defined as strategic behavior determinants that can replicate through education or imitation. To follow the replication through the dynamic process, we can use the following differential equation as a replicator dynamic,

$$\frac{dp}{dt} = p(1-p)\left(1-\frac{4}{3}p\right) \tag{7}$$

where p (abbreviated from $p(t)$) is the fraction of population using action Up over time. Note that q, or $1-p$, will be the fraction of the population hosting the Down replicator.

Thus far the Hawk - Dove game has two Nash equilibrium, $\{p=1,q=0;p=0,q=1\}$ which in the dynamic process can be thought of as rest-points. Using the replicator dynamic, we can map the trajectory of p over time given an initial point. Since a replicator dynamic can only be solved for a given an initial point, we must know the basin of attraction in which the initial point lives. A basin of attraction is defined as the set of initial points which converge on a resting point through the dynamic process.

If the resting points are chosen as the initial p, the replicator dynamic is equal to zero, and therefore, there is no rate of change. For the initial p's to be local attractors, the trajectory of the replicator dynamic must stay close to the resting points. However, when $p > 3/4$, then $p'(t) < 0$, or $p(t)$ is strictly decreasing and when $p < 3/4$ the function is strictly increasing. The two asymmetric Nash equilibrium are not local attractors.

To establish evolutionary stability, we must eliminate any replicator that is susceptible to invasion by a mutant replicator. In other words, for a replicator to be evolutionary stable, $\tilde{p}$ must be a better response to p than p is to itself. In terms of the HD game, if $p=1$, or the entire population is playing Up, will the expected fitness level of one mutant replicator Down (expected fitness is equivalent to the von Neumann - Morgenstern expected utility pay-offs) be better off, or vice versa, will a mutant Up replicator be better off in a population of all Down replicators? The answer reveals that the two asymetric Nash equilibria are not stable.

A further available solution concept is to mix the pure strategies over some non-negative probability distribution. This equilibrium can be expressed mathematically in (8). The implications of this is that there may be pay-offs that are as large as the weak Nash equilibrium. The payoffs of the profile of mixed strategies are the expected values of the pure strategies. In this case, Player I will chose Up with p probability and Down with $(1 - p)$ probability. An important property of mixed strategies is that there exists a p such that

$$\mathrm{c}p + \mathrm{a}(1 - p) = \mathrm{d}p + \mathrm{e}(1 - p), \qquad (8)$$

see Fudenberg and Tirole, 1993 or Binmore, 1992. If Player II selects $p=p^*$, the mixed strategy equilibrium, then Player I will be indifferent between choosing either Up or Down. Recall the symmetric HD game shown in figure 6 below.

		Player II	
		Up	*Down*
Player I	*Up*	1	6
	Down	3	0

Figure 6: *HD Game*

In this game, the pure strategies are defined Up or Down. If Player I chooses Up, II's best response is to choose Down, because 3 is preferred over 1. Further, if Player I chooses Down, Player II will respond by choosing Up as his strategy. It is at {(6,3),(3,6)}that strict pure (asymmetric) Nash equilibria exist. The third equilibrium, the mixed strategy equilibrium, can be solved by solving for p in

$$1p + 6(1 - p) = 3p + 0(1 - p) \qquad (9).$$

This solves to $p = 0.75$, such that Player I will choose pure strategy Up three quarters of the time.

		Player II: Up	Player II: Down	
Player I	Up	1	6	p=.75
	Down	3	0	(1 - p)=.25

Figure 7: *HD Game with Probability* Distribution

Considering the strategies available to Player I and Player II in the HD game, we can construct a graphical representation of their best responses.

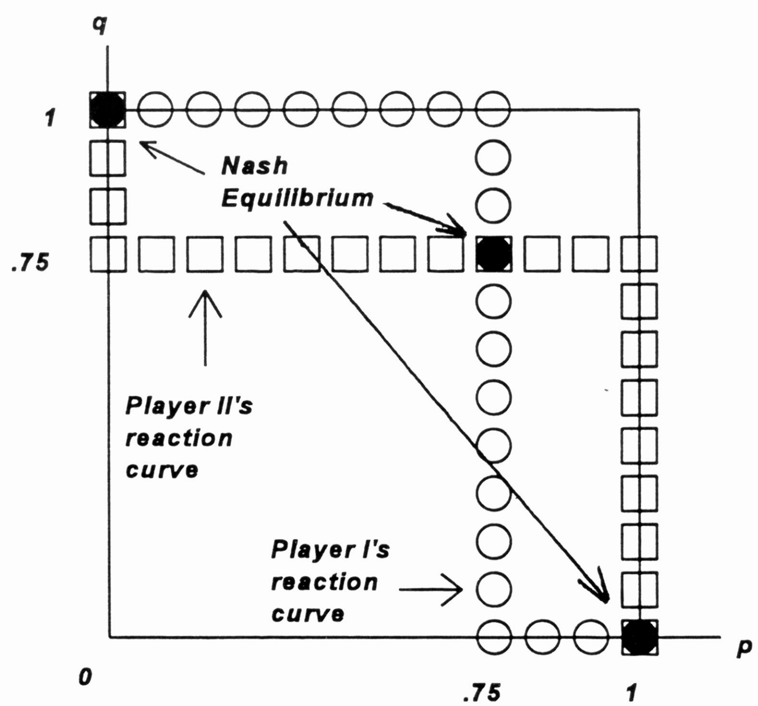

Figure 8: Best Response Correspondence for Hawk-Dove Game

To understand these curves, one should reason through the players' best responses. If Player I chooses Up with frequency p=1, Player II will choose Up with frequency q=0. Further, if Player I chooses Up with p=0, Player II's best response is to choose Up with frequency q=1. If Player I mixes with probability p=⅔, Player II will choose a probability q such that she exploits Player I's actions. Only at $p = 0.75$ would the best response curves converge, representing a point where Player I will mix at $p = 0.75$. It is important to stress that the mixed strategy is a weak best response, meaning that any response to Player I's mix strategy $p = 0.75$ is a weak best response.

This is further clarified by stating the correspondence relationship, $R(q)$,for Player I's best response curve.

$$R(q) = \begin{cases} \{1\} & \text{for } 0 \geq q > \frac{3}{4} \\ [1,0] & \text{for } q = \frac{3}{4} \\ \{0\} & \text{for } \frac{3}{4} < q \leq 1 \end{cases} \tag{10}$$

The points where the best response curves intersect have been labeled in Figure 8 as Nash equilibrium. The best response graph shows us three points where a Nash equilibrium exist, $\{p=1,q=0;p=0,q=1;p=0.75,q=0.75\}$.

Whether the mixed strategy is an evolutionary stable strategy can be determined in much the same was as the two asymmetric Nash equilibria. If the initial point corresponds to the resting point p=0.75, using the same replicator dynamic

$$\frac{dp}{dt} = p(1-p)\left(1-\frac{4}{3}p\right) \tag{11}$$

it is established that the trajectory, or rate of change, will be equal to zero, as with the two asymmetric Nash equilibria. Recall that when $p > \frac{3}{4}$, then $p'(t) < 0$, or $p(t)$ is strictly decreasing and when $p < \frac{3}{4}$ the function is strictly increasing, as illustrated in Figure 9.

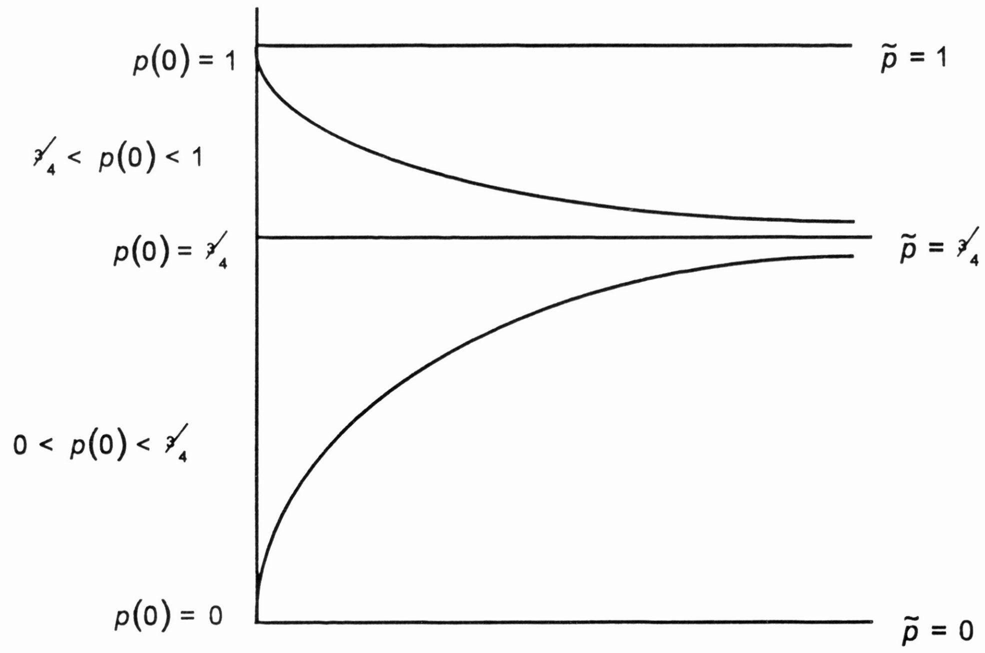

Figure 9: Fraction of H
in HD Game

As with the two asymmetric Nash equilibria, for $p = 3/4$ to be an evolutionary stable strategy, it must be able to repeal a mutant invasion such that any deviation will essentially become extinct. Figure 9 gives us some insight into this process. If p is to deviate from $p = 3/4$, the replicator dynamic tells us that it will return to the resting point $p = 3/4$. The resting point $p = 3/4$ is both a local attractor and the Evolutionary Stable Strategy since the replicator dynamic converges on that point. To appreciate this better, we can use another interpretation of a mixed strategy, where the population mixes its pure strategies, or in the case of evolutionary games, its replicator dynamic over some positive probability distribution.

Thus, in terms of the three Nash equilibria, $\{p=1,q=0;p=0,q=1;p=0.75\}$, it is only the symmetric mixed equilibrium that becomes the unique solution for the random, pair-wise matching protocol that is assumed by the biologists.

Experiment

The purpose of this paper is to test the abstract concept of an evolutionary stable strategy through laboratory experiments. Using established standard procedure (Davis and Holt, 1993) a total of 46 subjects participated in two separate treatments in a classroom laboratory using a computer interface. (This research is covered under Dr. J. Van Huyck's NSF proposal, "Learning Equilibrium Behavior," and has been approved by the appropriate human subject review panel.)

Before the experiment began, each human subject, recruited from undergraduate economic courses at Texas A&M, was required to follow on individual interfaces the instructions read by an experimenter. At any time during the experiment, subjects could refer back to these instructions. Following the instructional period, a questionnaire was distributed to determine whether every subject understood the payoff table. These procedures are an attempt establishing common information in the subjects.

The computer interface that subjects used during the experiment includes the following historical information in the record sheet on the right hand side of the main screen: past periods, subject's past choices, opponents past choices, and subjects earnings each period. A record sheet opposite of the decision matrix provides for the theoretical requirement of unique historical information by which to make a decision next period. (See Appendix A for the instructions and screen displays.)

The main screen of the interface is composed of a tool bar along the top of the screen, the matrix design on the left hand side, and a record sheet on the right hand side, see figure 10. The tool bar provides subjects with the period and balance to that period.

To finalize an action each period, the subject clicks on the proceed button, confirming the proceed command once. At any time during the experiment, subjects may refer to an enlarged record sheet or the instructions by going to the record or instr function on the tool bar.

In order to test the stability of mixed strategy equilibrium in the HD class of games, a random, pair-wised matching protocol in one population was used. A population of size eight participated in a session of 75 periods, where subjects were randomly paired with members of the population, therefore having a $\frac{1}{n-1}$ probability of being paired with any subject in the next period.

Payoffs earned by subjects are achieved by converting one unit to one dime, or each unit is equal to one penny. Using money assumes inducing preferences that result in an affine von Neumann-Morgernstern utility function.

A.1 Treatment 1: Matrix Design

Treatment 1 consisted of the Hawk-Dove game used in Figure 7 requires subjects to choose between pure strategies Up, $\{p=1\}$ or Down, $\{p=0\}$. Subjects select their action by selecting either Up or Down with a mouse and highlighting the chosen strategy. Subjects then enter their choice.

The payoff matrix A was chosen so that subjects would be faced with a game where there existed two asymmetric strict Nash equilibria and one weak symmetric Nash equilibrium resulting from mixing strategies with frequency $p=\frac{3}{4}$. A payoff matrix

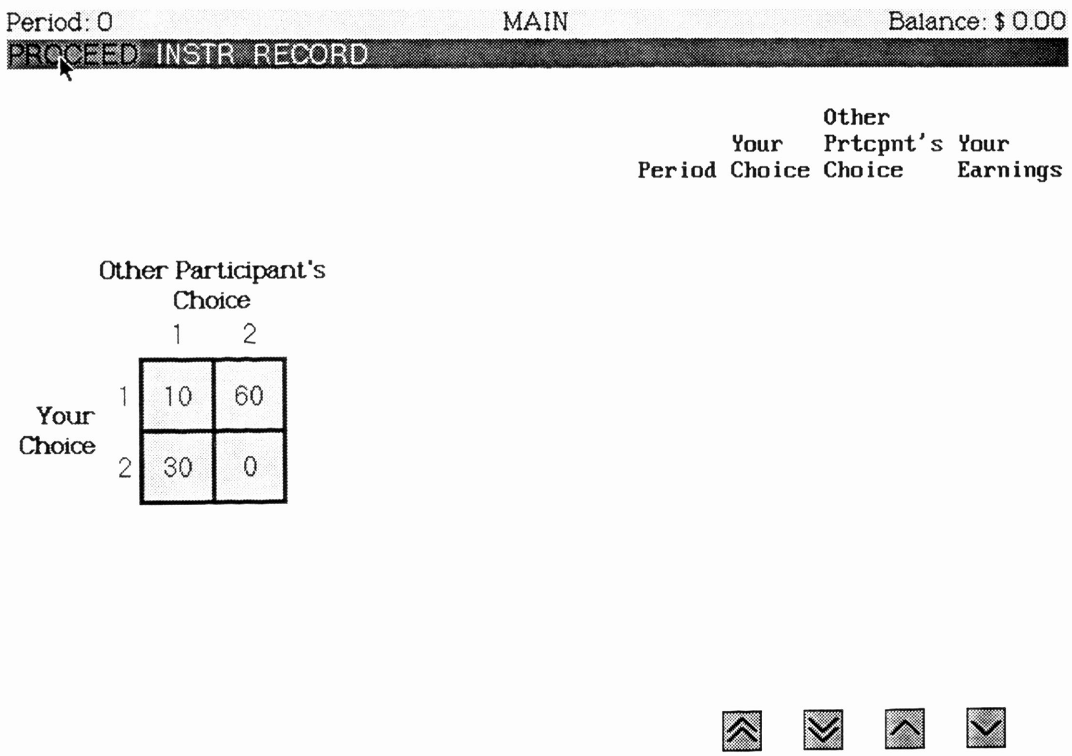

Figure 10: Main screen of treatment one's computer interface

with the mixed strategy $p=\frac{1}{2}$ is problematic because it could be argued that subjects just flip-a-coin and assign equal probability to Up and Down. We wanted to move the predicted equilibrium away from the value $p=\frac{1}{2}$ to separate our prediction from the random $p=.5$ hypothesis. The requirement of an even sized population and, for treatment 2, an even integer value between 0,1,2,...,98,99,100 for the equilibrium further entered our decision on the design. Of course, a larger population size could have been used, but doing so would increase the amount of resources required for paying subjects. Therefore, the matrix A for Treatment 1 had to be such that the symmetric Nash equilibrium was achievable through.

Recall that there exist two strict, asymmetric Nash equilibria, $\{p=1,q=0;p=0,q=1\}$ and the weak symmetric mixed Nash equilibrium, $p=\frac{3}{4}$. Further recall the two interpretations of mixed strategies; mixing of a player's pure strategies over a positive probability distribution or a population where pure strategies are played by a fraction of its members. The mixed strategy interpretation of this treatment for individual subjects is to select replicator Up, $\{p=1\}$, 75% of the periods. The pure strategy solution has six subjects playing one and two subjects playing two.

A.2 Matrix Design Results

Each sessions' individual subject's choice per period is reported in Appendix A, together with the mean data plotted below. Since this paper examines the aggregate action of the population, figures 11 through 14 graph the five-period means for each

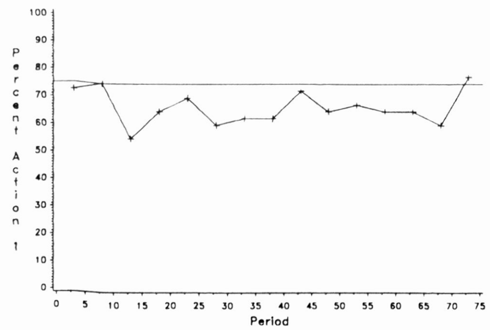

Figure 11: Matrix Session 1 Group 0

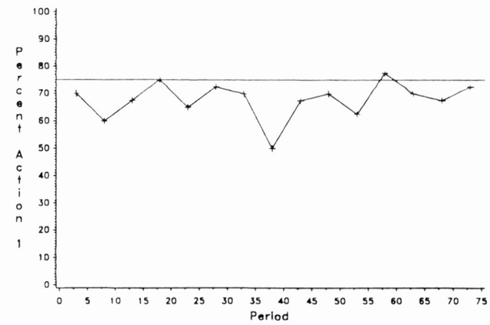

Figure 12: Matrix Session 1 Group 1

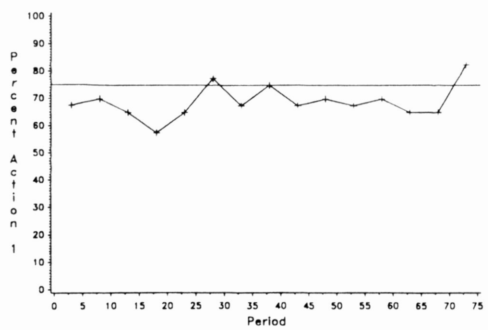

Figure 13: Matrix Session 2 Group 0

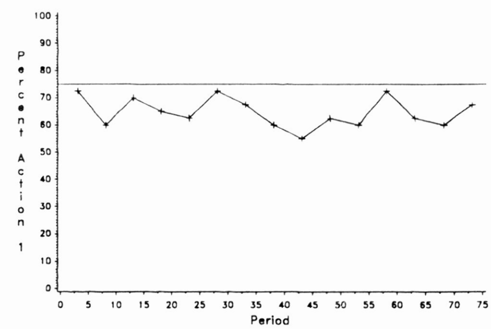

Figure 14: Matrix Session 2 Group 1

session. For the population to achieve the evolutionary stable strategy of p=¾, given an initial starting point p_0, subjects frequency p, or the fraction of the population playing up, p should follow the trajectory of the replicator dynamic in Figure 9.

An immediate observation is that four graphs are remarkably similar, suggesting that no session was contaminated by environmental or other factors. The graphs also reveal that subjects never began the game with an initial five-period mean point of p_0=¾. The four groups achieved a point p>¾ only four times and none of these were consecutive. Indeed, the five-period means were consistently below the 75% mark and above the 50% mark. Though subjects would have to achieve p=¾ to satisfy the theoretical requirement for the evolutionary stable strategy, the subjects ability to stay within the 50 to 75% percent does suggest some stability.

Of particular interest is the last five data points on the five-period mean table and graph. By the last 25 periods, could subjects achieve the symmetric mixed-strategy Nash equilibrium? Because the distribution of the data for each session was skewed towards one tail, a Chi-squared null hypothesis test was used. The Chi-squared tested the hypothesis that the observed frequency of Ups and Downs in the 40 observations of each five-period was equal to the theoretically expected frequency. The last five five-period means were tested individually against the expected {*Up*=30,*Down*=10} using Microsoft Excel 5.0. The result was that none of the sessions contained a five-period group that came within 25% of the hypothesis, therefore rejecting the hypothesis that the observed frequency of Ups and Downs equaled the expected frequency, $Pr < .01$.

A second Chi-squared null hypothesis test was used to test the hypothesis that subjects completely randomized pure strategies. Using {*Up*=20,*Down*=20} as the expected frequency, the Chi-squared test also rejected the hypothesis that the subjects were mixing their pure strategies $p=½$, $Pr < .01$.

Though subjects were fairly stable within the 50% to 75% region, the population of each session failed to achieve the theoretically prescribed solution of an evolutionary stable strategy. However, we can rule out the possibility that in a population where subjects were not "forward-looking" the outcome was to simply randomize, suggesting other dynamics are at work.

B.1 Treatment 2: Blue Box Design

Figure 15 shows Treatment 2's main screen for the computer interface used by subjects in Session 3 and Session 4. (Appendix B contains the instructions, screens and data.) Observe that the main screen for Treatment 2 is identical to Treatment 1 except for the decision matrix, where the payoff is displayed to the immediate right of the blue box rather than contained in matrix cells. By including this information, we stay within the theoretical parameters of the evolutionary stable strategy, i.e. common information and readily available unique history, while presenting subjects with a third interpretation of the mixed strategy, one in which subjects may select 75, or $p=.75$, directly.

The use of the Blue Box design is very simple. Subjects use a cross-hair within the box to place chose a value X (subject's choice) and Y (other participant's choice), which is an integer between 0 and 100, to weight an action on pure strategy Up and on the expected action of the other participant. By placing the cross-hair in the extreme lower right corner, $\{X=100, Y=100\}$, the subject is making an equivalent action of $\{p=1, q^e=1\}$, where q^e is the expected, or hypothetical, choice of the other participant.

The choice $\{X=100, Y=100\}$ therefore corresponds to the action $\{Up, Up\}$. When the subject chooses $\{X=0, Y=0\}$, the action $\{Up, Up\}$ is played with probability $\{p=0, q^e=0\}$, or the subject chooses $\{Down, Down\}$ with 100% probability.

Payoffs are calculated by multiplying the product of the weights placed on p and q by the payoff matrix A, as in (p). Using the expected value equation to determine actual payoff, the effects of expected value are essentially erased. Indeed, the advantage of the blue box design over probability bars is that the blue box eliminates complications from such concepts as expected value and allow us to address this issue of the theory more directly.

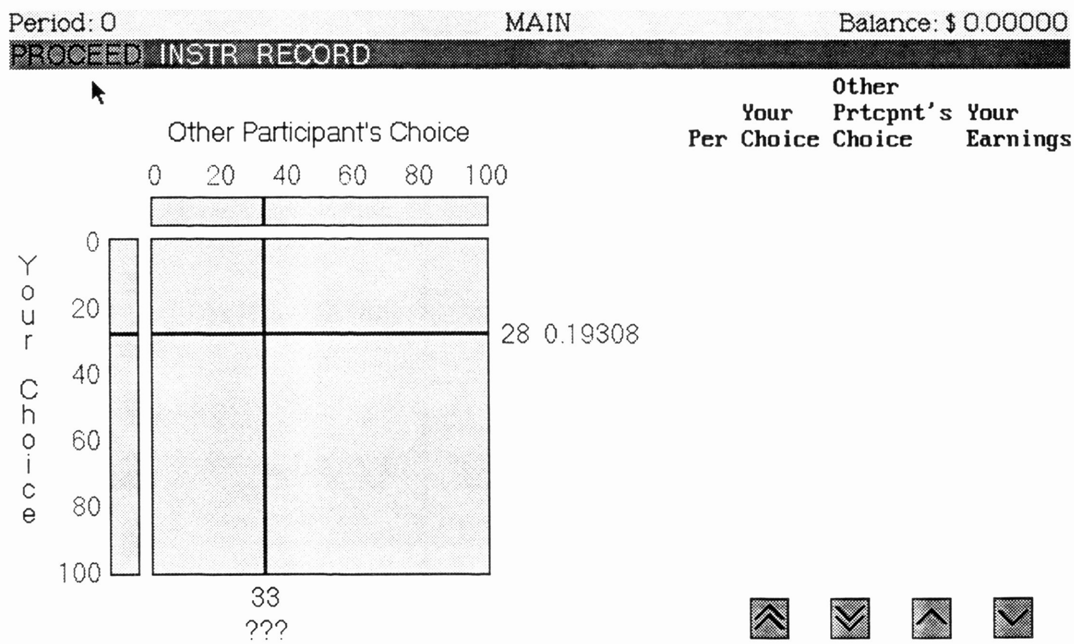

Figure 15: Main screen for treatment two's computer interface.

OTHER PARTICIPANT'S CHOICE

YOUR CHOICE	0	25	50	75	100
0	0.00000	0.07500	0.15000	0.22500	0.30000
25	0.15000	0.17500	0.20000	0.22500	0.25000
50	0.30000	0.27500	0.25000	0.22500	0.20000
75	0.45000	0.37500	0.30000	0.22500	0.15000
100	0.60000	0.47500	0.35000	0.22500	0.10000

Figure 16

Figure 16 represents the payoffs available to players at each p and q. Note that by maximizing a pay-off for each probability q assigned by an opponent gives a subject's best response curve. At $q=0$ through $q=0.5$, the subject's best response is to play Up with probability $p=1$. If opponent chooses $q=0.75$, the subject is indifferent between $p=[0,1]$. Finally, the subject's best response to $q=1$ is to choose Up with probability $p=0$. Therefore, figure 16 contains the same mapping of the correspondence relationship of the best response curves found in figure 8.

B.2 Blue Box Design Results

Figures 17 and 18 are the graphic representation of the data. Unlike Treatment 1, individual choices are not integers, but percentages of pure strategy Up. The evolutionary stable strategy for the population is still achieved at $p=¾$. The theoretical mapping of the trajectory of subjects frequency p, given an initial starting point p_0, can be found in Figure 9.

The most striking feature of figures 17 and 18 is the similarity to figures 11 through 14. It is remarkable that subjects in two very different interfaces should achieve very similar outcomes. Though Session 3 began with an initial five-period mean $p_0>¾$, the aggregate populations of Session 3 and 4 never again achieved a point $p>¾$. Given what we know about Treatment 1, the subjects did not settle on the "knife-edge" of $p=¾$, the evolutionary stable strategy. However, the populations' five-period means were tighter, staying within the 60% to 75% level.

Using the observations in the last five five-period mean groupings, a Chi-squared null hypothesis test was used. The Chi-squared tested the hypothesis that the observed percentage of Ups and Downs in the 40 observations of each five-period was equal to the theoretically expected frequency. The last five five-period means were tested individually against the expected $\{p=.75,(1-p)=.25\}$ using Microsoft Excel 5.0. As expected from the results of Treatment 1, the hypothesis was rejected, $Pr < .01$.

I also tested against the hypothesis that the subjects randomized by choosing $\{p=.5,(1-p)=.5\}$. The second Chi-squared null hypothesis test brought back the expected results of rejecting the hypothesis that the subjects were mixing their pure strategies $p=\frac{1}{2}$, $Pr < .01$.

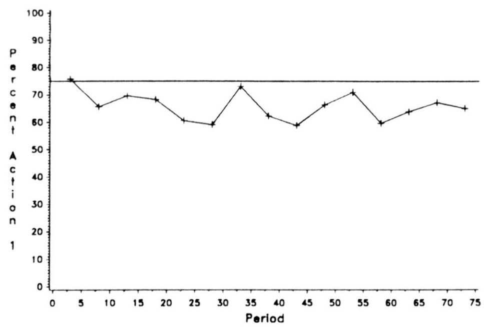

Figure 17: Blue Box Session 3

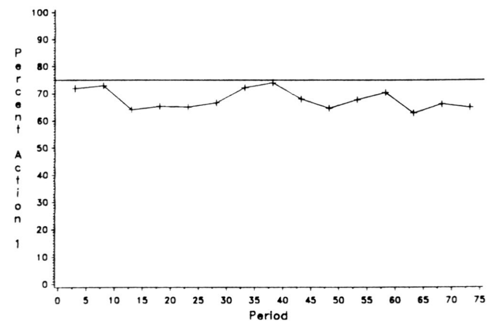

Figure 18: Blue Box Session 4

Conclusion

Nash equilibrium has been an essential solution concept in game theory apparatus. This paper examined circumstances where the Nash equilibrium assignment was insufficient to determine a dynamic outcome solvable by myopic players. In experiments where subjects were placed in a one population, random pair-wise matching protocol, I attempted to observe the Evolutionary Stable Strategy in a dynamic process. Borrowing from the theoretical biologist's interpretation of a same-species population, where members depended on unique past experience to determine present action, subjects were provided with common information about the game and a complete historical record of both their actions and the actions of the player they were randomly matched with each period. Through the replicator dynamic, the Evolutionary Stable Strategy outcome prediction was for subjects to use the mixed-strategy $p=\frac{3}{4}$.

This paper used two treatments to observe the different possible methods of mixing strategies. Treatment 1, consisting of a 2×2 symmetric payoff matrix allowed subjects to either mix strategies over periods or to purify strategies such that 6 members of the population were playing the pure strategy (replicator) Up and 2 were playing the pure strategy Down. Treatment 2, the blue box design, allowed a third option to players, to mix their pure strategies in each period by assigning a probability to the pure strategy Up. Though we cannot know subjects' strategies, these two treatments allow us to observe the actions of subjects, and thereby, provide at least one interpretation of the results.

Our results confirmed Crawford's argument that a mixed-strategy equilibrium cannot be an Evolutionary Stable Strategy. In both treatments subjects were unable to coordinate on the mixed-strategy Nash equilibrium. Recall that the definition of a local attractor is one in which, given an initial point p_0, it is the resting point of a basin of attraction. This requires that the trajectory of the replicator dynamic simply converge to the resting point. While it appears that the aggregate population mean was consistently between $p=½$ and the resting point $p=¾$, subjects failed to achieve the Evolutionary Stable Strategy. The results from Treatment 2 confirmed that subjects did not use the interface provided to select an action 75, or $p=¾$. The data in Appendix B shows that the modal choice was the action 100, which is the pure action Up. The second most frequent action was 0, which is the pure action Down.

It is interesting, in examining the individual data, that subjects tended to achieve a higher ending balance than predicted by the Evolutionary Stable Strategy assignment. Under the predicted outcome, subjects would achieve $0.225 per period, resulting in an ending balance of $16.875. However, only 9 subjects in all the 4 sessions earned less than the expected earnings (the lowest being -$2.375), while, for the most part, the remaining subjects realized earnings were significantly higher than $16.875 (the highest being +$8.125). Subjects' ability to find an outcome more socially efficient than the predicted implies that subjects attempted to develop conventions or repeated game effects.

Although beyond the scope of this thesis, it would be interesting to know if the individual subjects' co-evolution could be organized by any of the current learning theories. Also, how would the observed outcomes change if a larger value was used for the size of the population? Would a larger size population reduce the correlation in the subject's choices that is making the outcome more efficient than the mixed-strategy equilibrium?

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Appendix A

Matrix Design

Sessions sess01, (groups 0 and 1), and sess04, (groups 0 and 1)

This appendix contains a description of the laboratory implementation for sessions 1 and 2. The matching protocal and the graphical user interface were first developed in the paper *More on the Origin of Conventions: Evidence from Cordination Games*, John B. Van Huyck, Raymond C. Battalio, and Fredrick W. Rankin, laser-script, September 1994. The computer interface and the instructions used correspond to the one population, no label treatment in that paper.

In the instructions that are contained below we have printed the instruction file that is read by the software that conducts the experiment. We have left most of the control commands in the printed text. For example, the first line given below is, ^HP^CPAINSTRUCTIONS, where the command, *^HP^*, signals the start of a new screen on the computer terminal.

^HP^CPAINSTRUCTIONS

This is an experiment in the economics of strategic decision making. Various agencies have provided funds for this research. If you follow the instructions and make appropriate decisions, you can earn an appreciable amount of money. At the end of today's session, you will be paid in private and in cash.

It is important that you remain silent and do not look at other people's work. If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you. If you talk, laugh, exclaim out loud, etc., you will be asked to leave and you will not be paid. We expect and appreciate your cooperation.

You will be making choices on a Logitech mouse, which is located on the mouse pad in the middle of your table. You may move the pad to the right or left if this would be more comfortable. Hold the mouse in a relaxed manner with your thumb and little finger on either side of the mouse. Rest your wrist naturally on the table surface. When you move the mouse, let your hand pivot from the wrist. Use a light touch. Your cursor (a white arrow on your screen) should move when you slide the mouse on the mouse pad. If it does not, raise your hand.

To participate, you must be able to move the cursor onto an object and click any one of the mouse buttons. We will call pointing at an object and then clicking your mouse "clicking on" an object displayed on the screen. Click on the page down icon located below to display the next page.

PAGE 1

^HP^CPAGENERAL

In this experiment you will participate in a group of eight people. At the beginning of period one, each of the participants in this room will be randomly assigned to a group of size eight and will remain in the same group for the duration of the experiment. The experiment consists of seventy-five separate decision making periods.

^E1At the beginning^E0 of each decision making period you will be randomly re-paired with another participant. Hence, at the beginning of each decision making period, you will have a one in seven chance of being matched with any one of the other seven participants in your group.

At the beginning of each period, you and all other participants will choose an action. An earnings table is provided which tells you the earnings you receive given the action you and your currently paired participant chose. The actions you may choose are row 1 or row 2. Everyone has the same earnings table which will be continuously displayed on the monitor in the front of the room during the experiment. Click on the page down icon located below to display the next page.

PAGE 2

^HP^CPA   Your earnings each period will be found in the box determined by your action and the action of the participant that you are paired with for the current decision making period. Your action determines the row and the other participant's action determines the column of the earnings table. The value in the cell determined by the intersection of the row and column chosen is the amount of money that you earn in the current period. The earnings, displayed in ^CKAgreen^CPA, in each earnings cell is the amount of money, in cents, that you earn.

The earnings each period for the participant that you are currently paired with can be determined by reversing your positions.

Click on the page down icon now to view the earnings table while I describe how the earnings for each decision making period are calculated. You can review this page at any time during the experiment by returning to the instructions.

EARNINGS TABLE

Your Choice	**Other Participant's Choice**	**Your Earnings**	**Other Participant's Earnings**
1	1	10	10
1	2	60	30
2	1	30	60
2	2	0	0

PAGE 3

^HP^HM^CPA

[NOTE: The computer screen has a graphical depiction of the payoff matrix in this space. The matrix shown is identical to the actual matrix used on the main screen]

EARNINGS TABLE

Your Choice	**Other Participant's Choice**	**Your Earnings**	**Other Participant's Earnings**
1	1	10	10
1	2	60	30
2	1	30	60
2	2	0	0

PAGE 4

^HP^CPAMAIN SCREEN

We will now view the main screen. You will use the main screen to make your choices each period. While you view the main screen I will read the description of the screens contained in the next two pages. You can review the text that I am reading at any time during the experiment by returning to the instructions. Click on the word "MAIN" located on the second line down from the top of the screen now. (The second line is the light blue line on your screen).

The top line of the main screen displays the title of the screen and the current period number. The second line has the word "PROCEED" the abbreviation "INSTR" and the word "RECORD" on it. During the session you will be able to return to these instructions by clicking on "INSTR." You will also be able to view the history of play by clicking on "RECORD", which we will explain in a moment.

The remainder of the screen contains the blue earnings table, a historical record of your past choices, the other participants past choices, and your earnings for each period of this session.

Please look at the monitor at the front of the room while I demonstrate how you make and enter a choice. Do not use your main screen until you are instructed to do so.

PAGE 5

^HP^CPA^HR7 Making a choice consists of clicking any mouse button while the cursor is in the row of your choice. When you have clicked on the earnings table, your cursor is replaced by a green highlight around the row that contained the cursor when you clicked the mouse. You can change the highlighted row by sliding your mouse up or down. Click the mouse a second time and your cursor returns, but a row remains highlighted. To enter your choice for the current period you need to confirm your choice. You confirm your choice by first clicking on the word "PROCEED" and then clicking on "YES" to confirm and enter your choice for the current period. This confirmation step lets you catch any mistakes you make.

Please make a choice now, click on proceed and then click on "NO". Notice that the row is no longer highlighted and you may now make a different choice.

Before making another choice click on "PROCEED" without making a choice and notice that you do not receive the message:

^Rû^COA^E1DO YOU WANT TO PROCEED?^E0^CPA

Please make a choice now, click on "PROCEED" and then confirm your choice by clicking on "YES".

PAGE 6

^HP^CPAWAITING SCREEN

During a session a waiting screen will appear after you have made a choice. While you are waiting, you can view the instructions and the record of play by clicking on "INSTR" or "RECORD." When all participants have made a choice for the current period you will be automatically switched to the outcome screen. The choice displayed is the choice that you made during the demonstration of the main screen. You will automatically return to the instructions. Click on "WAITING" now.

OUTCOME SCREEN

During a session, after everyone has made their choices, the outcome screen will appear. The outcome screen summarizes what happened each period for ten seconds. Your choice will be highlighted in ^CKAgreen^CPA. The column determined by the other participant's choice will be highlighted in ^CEA^E1red^E0^CPA. The screen is not active. The choice displayed for your choice reflects the choice you made during the demonstration of the main screen. We have choosen column one as the other participant's choice during the instructions. Click on "OUTCOME" now.

PAGE 7

^HP^CPA^HRRECORD SCREEN^HR9

The record screen records the period outcomes and updates your earnings balance. A copy of the record screen is given at the top of this screen. The first three entries on the record screen are: "^E1Period^E0", "^E1Your Choice^E0" and "^E1Other Participant's Choice ^E0". The record screen will indicate your choice in ^CKAgreen^CPA each period. The fourth entry is your earnings for a period which are recorded under the entry "^E1Your Earnings^E0". Finally, your current balance, which includes all of your earnings up to and including the current period, will be recorded under the entry "^E1Balance^E0". In the first period your balance is zero.

During the session the record screen will be displayed for twenty seconds. You may proceed to the next period by clicking on "RETURN" before the twenty seconds have expired. Remember you can always return to the record screen from either the main screen or the waiting screen.

Click on the word "RECORD" located on the second line down from the top of your screen now. As the experiment proceeds the records for the earlier periods will scroll off the top of the record screen. You may review the earlier records by clicking on the page up, page down, line up and line down icons located at the bottom of the record screen. Click on "RETURN" now to return to the instructions before twenty seconds have expired.

PAGE 8

^HP^CPAQUESTIONNAIRE^HR10

We will now pass out a questionnaire to make sure that all participants understand how to read the earnings table. Please fill it out now. Raise your hand when you are finished and we will collect it. If there are any mistakes on any questionnaire, I will go over the relevant part of the instructions again. Do not put your name on the questionnaire.

Click on the page down icon located below to display the next page.

PAGE 9

^HP^CPASUMMARY

^E1***^E0 The experiment consists of seventy-five separate decision making periods.

^E1***^E0 At the beginning of period one, each of the participants in this room will be randomly assigned to a group of size eight and will remain in the same group for the duration of the experiment. Hence, you will remain grouped with the same seven other participants for the next seventy-five periods.

^E1***^E0 ^E1Each period^E0 you will be randomly re-paired with one of the seven other participants in your group. Hence, at the beginning of each decision making period, you will have a one in seven chance of being matched with any one of the seven other participants in your group.

^E1***^E0 You make a choice by clicking on a row, which highlights the row in green; clicking the mouse a second time, which restores your cursor, and then clicking on proceed and yes to confirm your choice of the highlighted row.

^E1***^E0 Remember that you can view the instructions or the record screen by clicking on the appropriate word on the light blue bar.

^E1***^E0 Remember that you may proceed to the next period by clicking on "RETURN" before the twenty seconds have expired. You can always return to the record screen from either the main screen or the waiting screen.

Click on the page down icon located below to display the next page.

PAGE 10

^HP^CPA^E1***^E0 Your balance at the end of the session will be paid to you in private and in cash.

We have completed the instructions. Again, it is important that you remain silent and do not look at other people's work.

If you have a question, please raise your hand, and an experimenter will come to assist you. If there are no questions, period one of the experiment will begin.

PAGE 11

Period: 0 MAIN Balance: $ 0.00

PROCEED INSTR RECORD

Period	Your Choice	Other Prtcpnt's Choice	Your Earnings

Other Participant's Choice

		1	2
Your Choice	1	10	60
	2	30	0

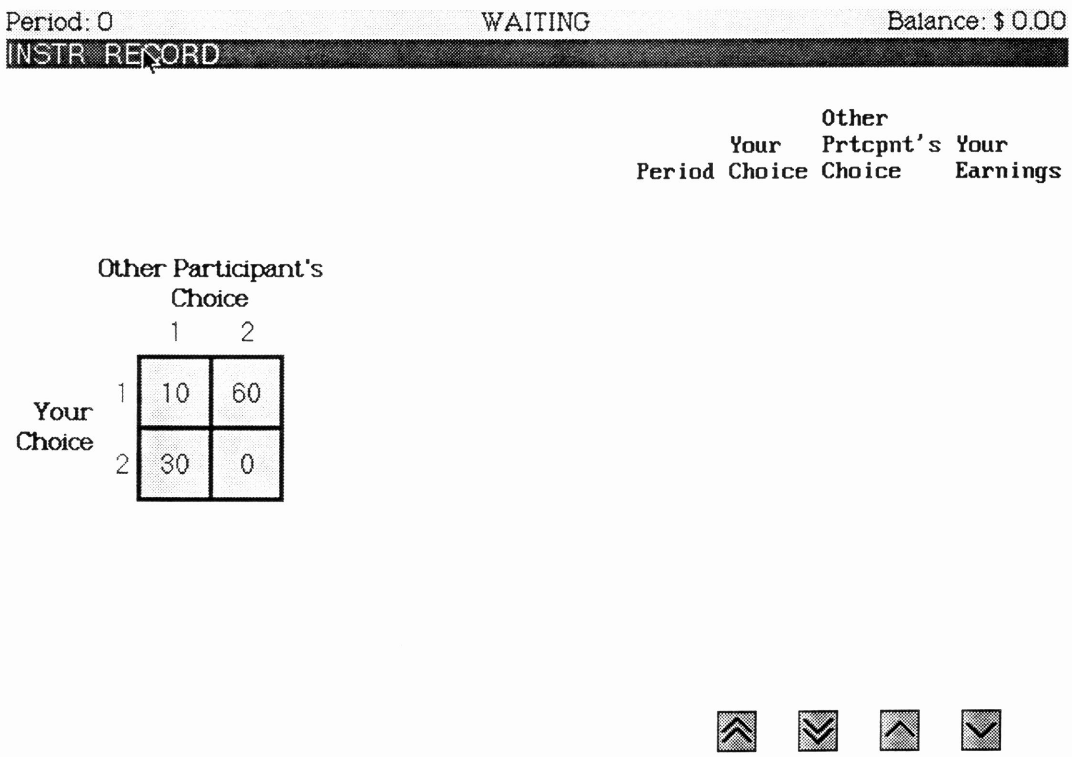
Period: 0 MAIN Balance: $ 0.00

PROCEED INSTR RECORD

Period	Your Choice	Other Prtcpnt's Choice	Your Earnings

Other Participant's Choice

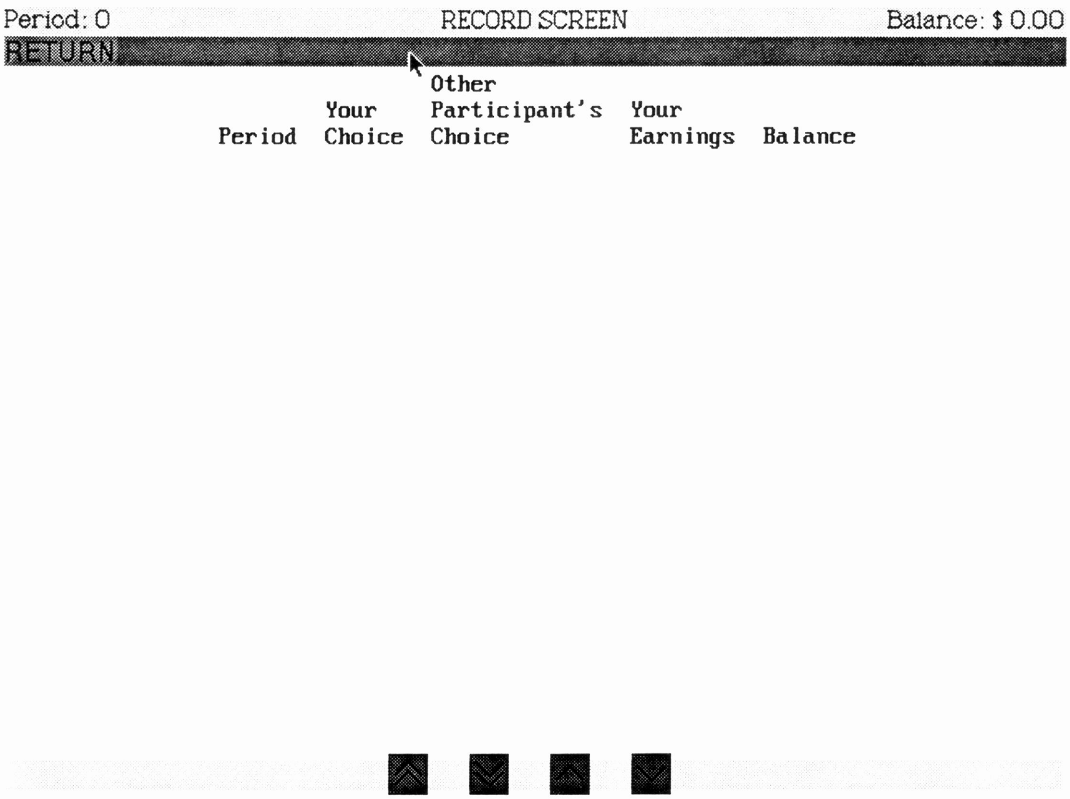
Your Choice	1	2
1	10	60
2	30	0


Period: 0
WAITING
Balance: $ 0.00
INSTR RECORD
Other
Your
Prtcpnt's
Your
Period
Choice
Choice
Earnings
Other Participant's
Choice
1
2
Your
Choice
1
10
60
2
30
0

Period: 0 OUTCOME Balance: $ 0.00

Other Participant's Choice

		1	2
Your Choice	1	10	60
	2	30	0


Period: 0
RECORD SCREEN
Balance: $ 0.00
RETURN
Period
Your Choice
Other Participant's Choice
Your Earnings
Balance

QUESTIONNAIRE

Using the earnings table, please fill in the following blanks. Raise your hand when you are done or if you have a question.

YOUR CHOICE	OTHER PARTICIPANT'S CHOICE	YOUR EARNINGS	OTHER PARTICIPANT'S EARNINGS
1	1	________	________
1	2	________	________
2	1	________	________
2	2	________	________

I. The data on pages A-14 and A-15 is the mean data for sessions sess01, groups 0 and 1 and sess02, groups 0 and 1. The variables are defined as follows:

SESSION	The session number.
GRP	The group number.
SUMCH1	A count of action 1 for each 5 period interval.
SUMCH2	A count of action 2 for each 5 period interval.
NUMCH1	The total number of subject choices, 5 periods and 8 subjects.
NUMCH2	The total number of subject choices, 5 periods and 8 subjects.
PER1	The mid-point of the 5 period interval.
PERCH1	The percent of actions that are 1,(SUMCH1/(SUMCH1+SUMCH2)).

The figures for sessions sess01 and sess02 (groups 0 and 1) use PER1 and PERCH1 for the X and Y axis.

II. Appendix pages A-16 through A-19 contain the individual subject data for each subject's choice for each period for sessions sess01 and sess02 (groups 0 and 1). The variables are defined as follows:

SESSION	The session number.
GRP	The group number.
Period	The period number.
C1-C8	The choices for the eight subjects.

MEAN DATA

---------------------------- **SESSION=sess01 GRP=0** ----------------------------

SESSION	GRP	SUMCH1	SUMCH2	NUMCH1	NUMCH2	PER1	PERCH1
sess01	0	29	11	40	40	3	0.725
sess01	0	30	10	40	40	8	0.750
sess01	0	22	18	40	40	13	0.550
sess01	0	26	14	40	40	18	0.650
sess01	0	28	12	40	40	23	0.700
sess01	0	24	16	40	40	28	0.600
sess01	0	25	15	40	40	33	0.625
sess01	0	25	15	40	40	38	0.625
sess01	0	29	11	40	40	43	0.725
sess01	0	26	14	40	40	48	0.650
sess01	0	27	13	40	40	53	0.675
sess01	0	26	14	40	40	58	0.650
sess01	0	26	14	40	40	63	0.650
sess01	0	24	16	40	40	68	0.600
sess01	0	31	9	40	40	73	0.775

------------------------------ SESSION=sess01 GRP=1 ------------------------------

SESSION	GRP	SUMCH1	SUMCH2	NUMCH1	NUMCH2	PER1	PERCH1
sess01	1	28	12	40	40	3	0.700
sess01	1	24	16	40	40	8	0.600
sess01	1	27	13	40	40	13	0.675
sess01	1	30	10	40	40	18	0.750
sess01	1	26	14	40	40	23	0.650
sess01	1	29	11	40	40	28	0.725
sess01	1	28	12	40	40	33	0.700
sess01	1	20	20	40	40	38	0.500
sess01	1	27	13	40	40	43	0.675
sess01	1	28	12	40	40	48	0.700
sess01	1	25	15	40	40	53	0.625
sess01	1	31	9	40	40	58	0.775
sess01	1	28	12	40	40	63	0.700
sess01	1	27	13	40	40	68	0.675
sess01	1	29	11	40	40	73	0.725

------------------------------ SESSION=sess02 GRP=0 ------------------------------

SESSION	GRP	SUMCH1	SUMCH2	NUMCH1	NUMCH2	PER1	PERCH1
sess02	0	27	13	40	40	3	0.675
sess02	0	28	12	40	40	8	0.700
sess02	0	26	14	40	40	13	0.650
sess02	0	23	17	40	40	18	0.575
sess02	0	26	14	40	40	23	0.650
sess02	0	31	9	40	40	28	0.775
sess02	0	27	13	40	40	33	0.675
sess02	0	30	10	40	40	38	0.750
sess02	0	27	13	40	40	43	0.675
sess02	0	28	12	40	40	48	0.700
sess02	0	27	13	40	40	53	0.675
sess02	0	28	12	40	40	58	0.700
sess02	0	26	14	40	40	63	0.650
sess02	0	26	14	40	40	68	0.650
sess02	0	33	7	40	40	73	0.825

------------------------------ SESSION=sess02 GRP=1 ------------------------------

SESSION	GRP	SUMCH1	SUMCH2	NUMCH1	NUMCH2	PER1	PERCH1
sess02	1	29	11	40	40	3	0.725
sess02	1	24	16	40	40	8	0.600
sess02	1	28	12	40	40	13	0.700
sess02	1	26	14	40	40	18	0.650
sess02	1	25	15	40	40	23	0.625
sess02	1	29	11	40	40	28	0.725
sess02	1	27	13	40	40	33	0.675
sess02	1	24	16	40	40	38	0.600
sess02	1	22	18	40	40	43	0.550
sess02	1	25	15	40	40	48	0.625
sess02	1	24	16	40	40	53	0.600
sess02	1	29	11	40	40	58	0.725
sess02	1	25	15	40	40	63	0.625
sess02	1	24	16	40	40	68	0.600
sess02	1	27	13	40	40	73	0.675

INDIVIDUAL SUBJECT DATA

---------------------------------- SESSION=sess01 GRP=0 ----------------------------------

SESSION	GRP	PERIOD	C1	C2	C3	C4	C5	C6	C7	C8
sess01	0	1	2	1	1	1	1	2	1	1
sess01	0	2	1	2	2	2	1	1	1	1
sess01	0	3	1	1	1	1	2	1	2	1
sess01	0	4	2	1	1	1	1	1	1	1
sess01	0	5	1	1	1	1	2	2	2	1
sess01	0	6	1	1	1	2	2	1	1	1
sess01	0	7	1	2	1	1	2	1	1	1
sess01	0	8	1	2	1	1	1	1	2	1
sess01	0	9	2	2	1	2	1	1	1	1
sess01	0	10	2	1	1	1	1	1	1	1
sess01	0	11	1	2	1	2	1	1	2	2
sess01	0	12	2	2	1	1	1	1	2	2
sess01	0	13	1	1	1	1	1	1	1	2
sess01	0	14	1	2	1	2	2	2	2	2
sess01	0	15	2	1	1	2	1	1	2	1
sess01	0	16	1	2	1	1	1	1	1	2
sess01	0	17	1	2	1	1	2	1	1	2
sess01	0	18	1	1	2	1	1	1	2	2
sess01	0	19	1	1	1	1	1	2	2	2
sess01	0	20	1	1	1	2	2	1	1	2
sess01	0	21	2	1	1	1	1	1	2	2
sess01	0	22	2	1	2	1	1	2	2	2
sess01	0	23	1	1	1	2	1	1	1	1
sess01	0	24	1	2	1	1	1	1	1	1
sess01	0	25	2	2	1	1	1	1	1	1
sess01	0	26	1	1	1	2	2	1	2	1
sess01	0	27	2	1	1	2	1	1	2	2
sess01	0	28	2	1	1	1	1	1	2	2
sess01	0	29	1	1	1	2	1	1	2	2
sess01	0	30	1	1	1	2	1	2	1	2
sess01	0	31	2	2	1	1	1	1	1	2
sess01	0	32	1	2	1	1	1	2	1	2
sess01	0	33	1	1	1	2	1	1	1	2
sess01	0	34	1	1	1	1	2	1	2	1
sess01	0	35	2	2	1	2	2	1	2	1
sess01	0	36	1	1	1	2	1	1	2	2
sess01	0	37	1	1	2	1	1	1	1	1
sess01	0	38	2	2	1	1	1	2	1	2
sess01	0	39	2	1	2	2	1	2	1	2
sess01	0	40	1	1	1	1	1	2	2	1
sess01	0	41	1	1	1	2	2	1	2	1
sess01	0	42	1	1	1	1	1	1	2	1
sess01	0	43	1	1	1	1	1	1	1	2
sess01	0	44	2	2	1	2	1	1	2	2
sess01	0	45	2	1	1	1	1	1	1	1
sess01	0	46	1	1	1	1	1	1	1	1
sess01	0	47	1	1	1	2	1	1	2	2
sess01	0	48	1	1	1	2	1	1	2	2
sess01	0	49	1	1	1	1	2	2	1	2
sess01	0	50	2	2	1	1	1	2	2	2
sess01	0	51	2	1	1	1	1	2	2	1
sess01	0	52	1	1	1	2	1	1	1	1
sess01	0	53	1	1	1	2	1	2	1	2
sess01	0	54	1	2	1	2	1	1	2	2
sess01	0	55	1	1	1	1	1	2	2	1
sess01	0	56	2	1	1	1	1	2	2	2
sess01	0	57	1	1	1	1	2	1	1	1
sess01	0	58	2	1	1	2	1	1	1	1
sess01	0	59	2	1	1	2	1	1	2	1
sess01	0	60	1	2	1	1	2	2	2	1
sess01	0	61	1	1	2	1	1	2	2	2
sess01	0	62	1	1	2	1	1	1	2	2
sess01	0	63	1	2	2	2	1	1	2	1
sess01	0	64	2	1	1	2	1	1	1	1
sess01	0	65	1	1	1	1	1	2	1	1
sess01	0	66	1	1	1	1	1	2	2	1
sess01	0	67	2	2	1	1	1	1	2	2
sess01	0	68	2	1	1	2	1	1	1	2
sess01	0	69	1	1	1	2	1	2	2	2
sess01	0	70	1	1	1	1	1	2	2	2
sess01	0	71	1	1	1	2	1	1	2	1
sess01	0	72	2	1	1	2	1	1	1	1
sess01	0	73	1	1	1	1	1	1	1	2
sess01	0	74	1	1	1	1	1	1	2	2
sess01	0	75	1	1	1	1	1	1	2	2

---------------------------------- SESSION=sess01 GRP=1 ----------------------------------

SESSION	GRP	PERIOD	C1	C2	C3	C4	C5	C6	C7	C8
sess01	1	1	2	1	1	1	1	1	1	1
sess01	1	2	1	1	1	1	1	1	1	1
sess01	1	3	2	2	2	2	1	2	2	1
sess01	1	4	1	2	1	2	1	2	2	1
sess01	1	5	1	1	2	1	1	1	1	1
sess01	1	6	1	2	1	1	1	2	1	1
sess01	1	7	2	1	1	2	2	2	2	1
sess01	1	8	1	2	2	2	1	1	1	1
sess01	1	9	2	1	1	1	2	2	2	1
sess01	1	10	1	1	1	2	1	1	2	1
sess01	1	11	2	1	1	2	1	1	1	1
sess01	1	12	1	2	2	1	1	1	1	1
sess01	1	13	2	2	1	2	2	1	1	1
sess01	1	14	1	2	1	2	2	1	1	1
sess01	1	15	2	1	2	1	1	1	1	1
sess01	1	16	1	1	1	2	1	1	1	1
sess01	1	17	2	2	2	2	2	1	1	1
sess01	1	18	1	1	1	1	1	1	1	1
sess01	1	19	1	2	2	1	1	1	1	1
sess01	1	20	1	1	1	2	1	2	1	1
sess01	1	21	2	2	2	1	2	2	1	1
sess01	1	22	1	1	2	1	1	2	1	1
sess01	1	23	2	1	2	1	1	2	1	1
sess01	1	24	1	1	2	1	1	1	1	1
sess01	1	25	2	2	2	1	1	1	1	1
sess01	1	26	1	2	2	1	2	1	1	1
sess01	1	27	2	1	1	1	2	1	1	1
sess01	1	28	1	1	1	1	2	1	1	1
sess01	1	29	2	1	1	1	1	2	1	1
sess01	1	30	2	2	2	1	1	1	1	1
sess01	1	31	1	2	2	2	2	1	2	1
sess01	1	32	1	2	2	1	1	2	1	1
sess01	1	33	2	1	1	1	1	2	1	1
sess01	1	34	1	1	1	2	1	1	1	1
sess01	1	35	1	1	2	1	1	1	1	1
sess01	1	36	1	2	2	1	2	1	2	1
sess01	1	37	2	2	2	1	2	2	2	1
sess01	1	38	1	2	2	1	1	1	2	1
sess01	1	39	1	2	1	1	1	2	2	1
sess01	1	40	2	2	1	1	2	1	2	1
sess01	1	41	1	1	2	1	1	2	1	1
sess01	1	42	2	2	1	1	2	1	1	1
sess01	1	43	1	1	2	1	2	2	1	1
sess01	1	44	2	1	1	1	1	1	1	2
sess01	1	45	1	2	2	1	1	2	1	1
sess01	1	46	2	1	1	1	1	1	1	2
sess01	1	47	1	2	2	1	1	2	1	1
sess01	1	48	2	1	1	1	1	2	1	1
sess01	1	49	1	2	2	2	1	1	1	1
sess01	1	50	2	2	1	1	1	1	1	1
sess01	1	51	2	1	2	2	1	1	1	1
sess01	1	52	1	2	2	1	1	1	1	2
sess01	1	53	2	1	1	1	1	1	1	1
sess01	1	54	2	2	2	1	2	1	1	2
sess01	1	55	1	1	2	2	1	2	1	1
sess01	1	56	2	1	1	1	1	1	1	1
sess01	1	57	1	1	1	1	2	1	1	1
sess01	1	58	2	2	2	1	1	1	1	1
sess01	1	59	1	1	1	1	2	1	1	1
sess01	1	60	2	2	2	1	1	1	1	1
sess01	1	61	2	1	1	1	1	1	1	1
sess01	1	62	2	2	2	1	2	1	1	1
sess01	1	63	2	2	2	1	1	2	1	1
sess01	1	64	1	2	1	1	2	1	1	1
sess01	1	65	2	1	1	1	1	1	1	1
sess01	1	66	1	1	1	2	2	1	1	1
sess01	1	67	2	2	2	2	2	1	1	1
sess01	1	68	1	1	1	1	2	1	1	1
sess01	1	69	1	2	2	2	1	1	1	1
sess01	1	70	2	1	1	1	2	1	1	1
sess01	1	71	1	1	1	1	1	1	1	1
sess01	1	72	2	2	1	1	1	2	1	1
sess01	1	73	2	2	1	1	2	1	1	1
sess01	1	74	2	1	1	1	2	1	2	1
sess01	1	75	2	2	1	1	1	1	1	1

---------------------------------- SESSION=sess02 GRP=0 ----------------------------------

SESSION	GRP	PERIOD	C1	C2	C3	C4	C5	C6	C7	C8
sess02	0	1	2	1	2	1	1	1	1	1
sess02	0	2	1	1	1	1	1	1	1	1
sess02	0	3	1	1	1	2	2	2	2	2
sess02	0	4	1	1	1	1	2	1	2	2
sess02	0	5	1	1	1	1	2	2	2	1
sess02	0	6	1	1	1	1	1	2	2	2
sess02	0	7	1	1	2	1	1	1	2	2
sess02	0	8	1	1	2	1	1	1	2	1
sess02	0	9	1	2	1	1	2	2	1	1
sess02	0	10	1	1	1	1	1	2	1	1
sess02	0	11	1	1	1	2	1	2	1	1
sess02	0	12	1	1	2	1	1	2	1	2
sess02	0	13	1	1	2	1	1	2	1	2
sess02	0	14	1	1	2	1	1	2	2	1
sess02	0	15	1	1	2	1	1	2	2	1
sess02	0	16	1	1	2	1	1	2	2	1
sess02	0	17	1	1	2	1	1	2	2	1
sess02	0	18	1	1	2	2	1	2	2	1
sess02	0	19	1	1	2	1	1	2	2	1
sess02	0	20	1	1	2	2	1	1	2	2
sess02	0	21	1	1	2	1	1	2	2	2
sess02	0	22	1	1	2	1	1	2	1	1
sess02	0	23	1	2	2	1	1	1	2	1
sess02	0	24	1	1	2	1	1	2	2	1
sess02	0	25	1	1	1	2	1	2	1	1
sess02	0	26	1	1	1	1	1	2	1	2
sess02	0	27	1	1	1	2	1	2	1	1
sess02	0	28	1	1	1	2	1	2	1	1
sess02	0	29	1	1	1	2	1	2	1	1
sess02	0	30	1	1	1	2	1	1	1	1
sess02	0	31	1	1	1	1	1	2	2	1
sess02	0	32	1	1	1	2	1	2	2	2
sess02	0	33	1	1	1	2	1	2	1	1
sess02	0	34	1	1	1	2	1	2	1	1
sess02	0	35	1	1	1	2	1	2	1	2
sess02	0	36	1	1	1	2	1	2	1	1
sess02	0	37	1	1	1	2	1	2	2	2
sess02	0	38	1	1	1	1	1	2	1	1
sess02	0	39	1	1	1	1	1	2	1	2
sess02	0	40	1	1	1	1	1	2	1	1
sess02	0	41	1	1	1	1	2	2	1	2
sess02	0	42	1	1	1	1	1	2	2	1
sess02	0	43	1	1	1	1	1	2	2	2
sess02	0	44	1	1	1	1	1	2	2	1
sess02	0	45	1	1	1	1	1	2	2	2
sess02	0	46	1	1	1	1	1	2	2	1
sess02	0	47	1	1	1	1	1	2	2	2
sess02	0	48	1	1	1	1	1	2	2	1
sess02	0	49	1	1	1	1	1	2	2	2
sess02	0	50	1	1	1	1	1	2	2	1
sess02	0	51	1	1	1	1	1	2	2	2
sess02	0	52	1	2	1	1	1	2	2	1
sess02	0	53	1	1	1	2	1	2	2	2
sess02	0	54	1	1	1	1	1	2	1	1
sess02	0	55	1	1	1	1	1	2	1	2
sess02	0	56	2	2	1	1	1	2	2	1
sess02	0	57	1	1	1	1	1	1	2	2
sess02	0	58	1	1	1	1	1	1	2	1
sess02	0	59	1	1	2	1	1	1	2	2
sess02	0	60	1	1	1	2	1	1	2	1
sess02	0	61	1	1	1	1	1	1	2	2
sess02	0	62	1	1	2	2	1	1	2	1
sess02	0	63	2	1	1	1	1	1	2	2
sess02	0	64	1	1	1	2	1	1	2	1
sess02	0	65	1	1	1	2	1	2	2	2
sess02	0	66	1	1	1	2	1	2	2	1
sess02	0	67	1	1	2	2	1	2	2	2
sess02	0	68	1	1	2	1	1	1	2	1
sess02	0	69	1	1	2	1	1	1	2	1
sess02	0	70	1	1	2	1	1	1	2	1
sess02	0	71	1	2	1	1	1	1	2	1
sess02	0	72	1	2	1	1	1	1	2	1
sess02	0	73	1	1	1	1	1	1	1	1
sess02	0	74	1	1	1	1	1	2	2	1
sess02	0	75	1	1	1	1	1	2	1	1

---------------------------------- SESSION=sess02 GRP=1 ----------------------------------

SESSION	GRP	PERIOD	C1	C2	C3	C4	C5	C6	C7	C8
sess02	1	1	1	2	1	1	1	1	1	1
sess02	1	2	1	1	1	2	2	2	1	1
sess02	1	3	1	2	1	2	1	2	1	2
sess02	1	4	1	1	1	1	2	1	1	1
sess02	1	5	1	1	1	1	1	2	1	2
sess02	1	6	1	1	1	2	2	1	1	2
sess02	1	7	2	1	1	1	1	1	1	2
sess02	1	8	2	1	2	1	2	2	1	2
sess02	1	9	2	1	1	2	1	1	1	2
sess02	1	10	2	2	2	1	1	1	1	1
sess02	1	11	1	1	1	1	1	2	1	1
sess02	1	12	1	1	1	2	2	1	1	1
sess02	1	13	2	1	1	1	1	2	1	2
sess02	1	14	1	1	1	1	2	2	1	2
sess02	1	15	2	1	1	2	2	1	1	1
sess02	1	16	2	1	1	1	1	2	1	1
sess02	1	17	1	1	2	1	1	1	1	1
sess02	1	18	2	1	1	2	2	1	1	1
sess02	1	19	2	1	1	1	2	2	1	2
sess02	1	20	1	1	2	2	1	2	1	2
sess02	1	21	2	1	1	1	1	2	1	2
sess02	1	22	2	2	1	1	2	1	1	2
sess02	1	23	2	1	1	2	1	1	1	2
sess02	1	24	2	1	1	1	1	1	1	2
sess02	1	25	1	1	1	1	2	2	1	2
sess02	1	26	2	1	1	2	2	2	1	1
sess02	1	27	2	1	1	1	1	2	1	1
sess02	1	28	1	1	1	1	1	1	1	1
sess02	1	29	2	1	2	2	1	2	1	1
sess02	1	30	1	1	1	1	1	2	1	1
sess02	1	31	2	1	1	1	1	2	1	1
sess02	1	32	1	1	2	2	1	2	1	1
sess02	1	33	1	1	2	1	1	2	1	1
sess02	1	34	2	1	1	1	2	1	1	2
sess02	1	35	1	2	2	1	1	1	1	2
sess02	1	36	2	2	2	2	1	2	1	1
sess02	1	37	1	2	1	1	1	2	1	1
sess02	1	38	1	2	1	2	1	2	1	1
sess02	1	39	1	2	2	1	2	1	1	1
sess02	1	40	2	2	1	1	1	2	1	1
sess02	1	41	2	2	1	1	1	2	1	1
sess02	1	42	2	2	1	2	2	1	1	2
sess02	1	43	1	2	2	1	1	1	1	2
sess02	1	44	1	2	1	1	1	2	1	1
sess02	1	45	2	2	2	2	1	2	1	1
sess02	1	46	1	2	2	2	1	2	1	1
sess02	1	47	2	2	2	1	1	1	1	2
sess02	1	48	2	2	1	1	1	1	1	1
sess02	1	49	1	2	1	1	1	2	1	2
sess02	1	50	1	1	2	1	1	2	1	1
sess02	1	51	2	1	1	1	1	2	1	1
sess02	1	52	2	1	1	1	1	1	1	1
sess02	1	53	2	1	2	1	1	2	1	1
sess02	1	54	2	1	2	2	1	2	1	2
sess02	1	55	2	2	2	1	1	2	1	2
sess02	1	56	1	2	1	1	1	2	1	2
sess02	1	57	1	2	1	1	1	1	1	1
sess02	1	58	1	2	2	1	1	1	1	1
sess02	1	59	2	1	1	2	1	2	1	2
sess02	1	60	1	1	1	1	1	2	1	1
sess02	1	61	2	1	2	1	1	2	1	2
sess02	1	62	2	1	1	2	1	1	1	2
sess02	1	63	2	1	1	2	1	2	1	2
sess02	1	64	1	1	2	2	1	2	1	2
sess02	1	65	1	1	1	1	1	1	1	1
sess02	1	66	2	1	2	2	2	2	1	1
sess02	1	67	2	1	1	2	1	2	1	1
sess02	1	68	2	2	1	1	1	2	1	2
sess02	1	69	1	1	2	1	1	2	1	2
sess02	1	70	1	1	1	1	1	2	1	1
sess02	1	71	1	1	1	1	1	1	1	1
sess02	1	72	1	1	1	1	2	1	1	2
sess02	1	73	2	1	2	1	1	2	1	2
sess02	1	74	1	2	1	2	2	2	1	2
sess02	1	75	1	1	1	1	1	2	1	2

Appendix B

Blue Box Design

Sessions sess03 and sess04

This appendix contains a description of the laboratory implementation for sessions 3 and 4. The graphical user interface for the 'blue box' used on the main screen is adapted from the interface first developed for use in *Selection Dynamics, Asymptotic Staability, and Adaptive Behavior*, John B. Van Huyck, Joseph P. Cook and Raymond C. Battalio, Journal of Political Economy, October, 1994. Our interface is a direct implementation of the main screen developed for the action space {0, 1, 2, ... 98, 99, 100} used in the order statistic games described in the NSF proposal 'Learning Equilibrium Behavior', John Van Huyck, Principal Investigator, 1994. We used a new equation to generate the payoffs and modified the instructions as needed.

In the instructions that are contained below we have printed the instruction file that is read by the software that conducts the experiment. We have left most of the control commands in the printed text. For example, the first line given below is, ^HP^CPAINSTRUCTIONS, where the command, *^HP^*, signals the start of a new screen on the computer terminal.

^HP^CPAINSTRUCTIONS

This is an experiment in the economics of strategic decision making. Various agencies have provided funds for this research. If you follow the instructions and make appropriate decisions, you can earn an appreciable amount of money. At the end of today's session, you will be paid in private and in cash.

It is important that you remain silent and do not look at other people's work. If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you. If you talk, laugh, exclaim out loud, etc., you will be asked to leave and you will not be paid. We expect and appreciate your cooperation.

You will be making choices on a Logitech mouse, which is located on the mouse pad in the middle of your table. You may move the pad to the right or left if this would be more comfortable. Hold the mouse in a relaxed manner with your thumb and little finger on either side of the mouse. Rest your wrist naturally on the table surface. When you move the mouse, let your hand pivot from the wrist. Use a light touch. Your cursor (a white arrow on your screen) should move when you slide the mouse on the mouse pad. If it does not, raise your hand.

To participate, you must be able to move the cursor onto an object and click any one of the mouse buttons. We will call pointing at an object and then clicking your mouse "clicking on" an object displayed on the screen. Click on the page down icon located below to display the next page.

PAGE 1

^HP^CPAGENERAL

The experiment consists of seventy-five separate decision making periods. In each period you will be randomly re-paired with another participant. There will be eight participants, including yourself, in this experiment.

^E1At the beginning^E0 of each decision making period you will be randomly re-paired with another participant. Hence, at the beginning of each decision making period, you will have a one in seven chance of being matched with any one of the other seven participants in this experiment.

In each period, every participant will pick a value of X. The values of X you may choose are any one of the 101 integers 0, 1, 2, . . . , 98, 99 or 100. The value you pick for X and the value chosen by your currently paired participant will determine the payoff you receive for that period.

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^HR7^HP^CPAMAIN SCREEN

We will now view the main screen. You will use the main screen to make your choices each period. While you view the main screen I will read the description of the main screen contained in the next four pages. You can review the text that I am reading at any time during the experiment by returning to the instructions. Click on the word "MAIN" located on the second line down from the top of the screen now. (The second line is the light blue line on your screen).

The top line of the main screen displays the current period number, the title of the screen and your current balance. The second line has the word "PROCEED", the abbreviation "INSTR" and the word "RECORD" on it. During the session you will be able to return to these instructions by clicking on "INSTR". You will also be able to view the history of play by clicking on "RECORD", which I will explain in a moment.

The remainder of the screen contains: (1) Two blue bars and a blue box that will help you understand how your choice and the other participant's choice influences your earnings each period, and (2) A historical record of your past choices, the past other participant's choice and your earnings for each period of this session.

Please look at the monitor at the front of the room while I demonstrate how to use the two blue bars and the blue box to calculate hypothetical earnings and how to enter your choice each period. Please do not click your mouse at this time.

PAGE 3

^HP^CPA Please click now on the blue bar labelled OTHER PARTICIPANT'S CHOICE. Notice that the mouse cursor is replaced by a yellow vertical line and that a yellow vertical line also appears in the blue box. Immediately below the blue box the current value that you have chosen for the hypothetical other participant's choice appears as a yellow number. Directly below the value for the hypothetical other participant's choice are three yellow question marks, ???. The question marks are there to remind you that you DO NOT select the other participant's choice. During the experiment the other participant's choice will be determined each period by your paired participant for that period.

By moving your mouse left and right you can select any value between 0 and 100 for your choice of the hypothetical other participant's choice. Click the mouse a second time to select a value for the hypothetical other participant's choice and to restore the cursor.

Now click on the blue bar labelled YOUR CHOICE. Your mouse cursor is replaced by a green horizontal line and a green horizontal line also appears in the blue box. Immediately to the right of the blue box your current choice and your earnings associated with your current choice of X and the current hypothetical other participant's choice appears in green. By moving your mouse up and down you can read off the earnings associated with all of your feasible choices and the currently selected hypothetical other participant's choice. Click the mouse a second time to select a value for your choice and to restore the cursor.

PAGE 4

^HP^CPA Now click again on the blue bar labelled other participant's choice. By moving the mouse left and right you can read off the earnings associated with all of the possible values for the other participant's choice and your currently selected choice of X. However, remember that during the experiment the OTHER PARTICIPANT'S CHOICE is determined by the participant that you are paired with that period. Your actual payoff will only correspond to a hypothetical payoff if the actual other participant's choice corresponds to the hypothetical other participant's choice. Now click the mouse to select a value and to restore the cursor.

Now click on the blue square. Notice that moving the mouse here lets you change both YOUR CHOICE of X and the hypothetical value of the OTHER PARTICIPANT'S CHOICE. Click the mouse a second time to select a value and to restore the cursor.

In summary, the difference in the three active boxes is in what they control. Clicking on the horizontal bar allows you to change the hypothetical value of the other participant's choice while leaving the value of your choice unchanged. Clicking on the vertical bar allows you to change the value of your choice by moving its green line up or down with the mouse while leaving the hypothetical value of the other participant's choice unchanged. Clicking on the blue box allows you to change both values simultaneously.

PAGE 5

^HP^CPA The four columns on the right side of the screen contain the period number, under the label 'Per', a history of your past choices, under the label 'Your Choice', the history of the past other participant's choice, under the label "Other Prtcpnt's Choice', and your earnings for each past period, under the label 'Your Earnings'. When the history fills all of the available lines, only the most recent lines will be displayed. You may use the page up, page down, line up and line down icons at the bottom to review the earlier records.

When you are ready to enter a choice for a period you do so by clicking on "PROCEED", located on the second line of the main screen. Click on "PROCEED" now and notice that the message 'DO YOU WANT TO PROCEED' appears in yellow. To proceed you click on the word "YES" in green at the right side of the line. If you want to change your choice at this point you would click on the word "NO", in red. Click on "NO" now and notice that the choice you had entered is canceled and you must now make another choice to proceed.

Now click on the blue square. Click the mouse a second time to select a value and to restore the cursor. Click on "PROCEED" now. If you click on "YES" your choice for the period will be entered. Please click on "YES" now to return to the instructions.

PAGE 6

^HR8^HP^CPAWAITING SCREEN

During a session a waiting screen will appear after you have made a choice. While you are waiting, you can use the two blue bars and the blue box to perform hypothetical calculations that will help you understand how your choice and the other participant's choice influences your earnings each period, similar to the calculations that you can make on the main screen. NOTICE: the vertical line, your choice and earnings and the horizontal line and the hypothetical value for the other participant's choice are ALL IN YELLOW. This color coding is to remind you that you have already made your choice and are currently waiting for other participants to make their choices. NOTICE: the second line DOES NOT contain PROCEED.

In addition to making hypothetical calculations, you may also view the instructions and the record screen by clicking on "INSTR" or "RECORD." When all participants have made a choice for the current period you will be automatically switched to the outcome screen. The choice displayed on the WAITING SCREEN is the choice that you made during the demonstration of the main screen. You will automatically return to the instructions in twenty seconds. Click on "WAITING" now.

PAGE 7

^HR9^HP^CPAOUTCOME SCREEN

During a period, after everyone has made their choices, the outcome screen will appear for ten seconds. The outcome screen summarizes what happened each period. Your choice and period earnings will be highlighted in ^CKAgreen^CPA. The other participant's choice, determined by the paired participant that period, will be highlighted in ^CEAred^CPA.

During the experiment, after each period's outcome screen has been displayed for ten seconds, you will automatically advance to the next period. Your main screen for the next period will appear and you may then make a choice for that period whenever you are ready. This procedure will continue for seventy-five periods.

The outcome screen is not active and your mouse cursor will not be present. Click on "OUTCOME" now. The value displayed on the outcome screen for YOUR CHOICE is the selection that you made earlier during these instructions. Two different values of the other participant's choice will each be displayed for ten seconds during this demonstration. I have arbitrarily chosen the values of 33 and 66 for the other participant's choice during these instructions. You will automatically return to the instructions.

PAGE 8

^HR10^HP^CPARECORD SCREEN

The record screen records the period outcomes and updates your earnings balance. The record screen contains all of the information contained in the past history on the MAIN SCREEN and the WAITING SCREEN plus an additional column labelled Balance that has your balance at the end of each period. At the beginning of the first period your balance is zero. At the end of each period your current period earnings will be added to your balance. At the end of this experiment you will be paid your ending balance, (the sum of all of your period earnings), in cash.

Click on the word "RECORD" located on the second line down from the top of your screen now. As the experiment proceeds the records for the earlier periods will scroll off the top of the record screen. You may review the earlier records by clicking on the page up, page down, line up and line down icons located at the bottom of the record screen. Click on RETURN to leave the RECORD SCREEN.

PAGE 9

^HP^CPAQUESTIONNAIRE

We will now pass out a questionnaire to make sure that all participants understand how to use the two blue bars and blue box and to make sure that all participants know how to calculate their earnings for the hypothetical other participant's choice and their selection of X. Please fill out the questionnaire now. Do not put your name on the questionnaire. Raise your hand when you are finished and we will collect it. If there are any mistakes on any questionnaire, I will go over the relevant part of the instructions again.

PAGE 10

^HP^CPASUMMARY

^E1***^E0 The experiment consists of seventy-five separate decision making periods.

^E1***^E0 ^E1Each period^E0 you will be randomly re-paired with one of the seven other participants in this experiment. Hence, at the beginning of each decision making period, you will have a one in seven chance of being matched with any one of the seven other participants in this experiment.

^E1***^E0 In each period, every participant will pick a value of X. The value you pick for X and the value chosen by your paired participant for that period will determine the payoff you receive for that period.

^E1***^E0 You make a choice by (i) selecting a value between 0 and 100 for X using the blue bars and\or the blue box, (ii) clicking the mouse a second time to select your choice and to restore your cursor, and then (iii) clicking on "PROCEED" and "YES" to enter and confirm your choice for the current period.

^E1***^E0 Remember that you can view the instructions or the record screen by clicking on the appropriate word on the light blue bar.

PAGE 11

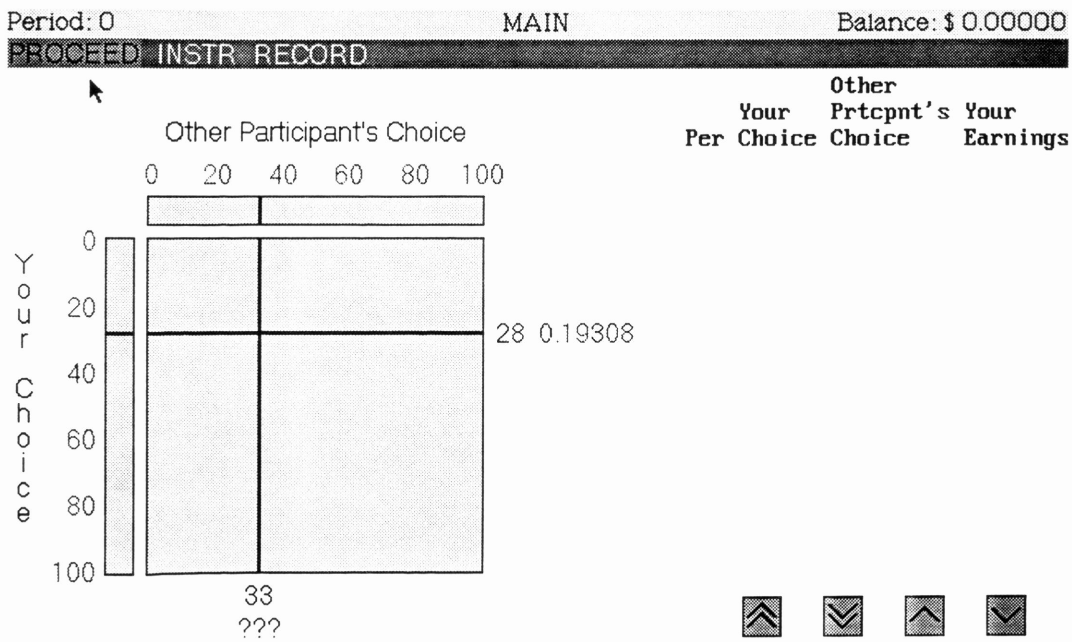
^HP^CPA
^E1***^E0 Your balance at the end of the session will be paid to you in private and in cash.

We have completed the instructions. Again, it is important that you remain silent and do not look at other people's work.

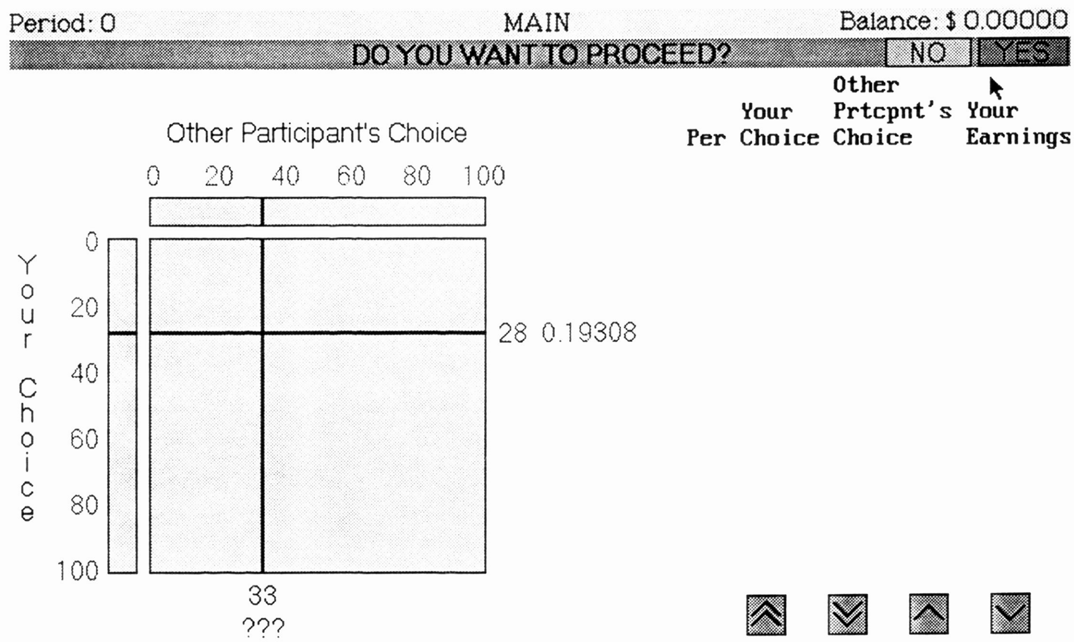
If you have any questions, please raise your hand and an experimenter will come to assist you. If there are no questions, period one of the experiment will begin.

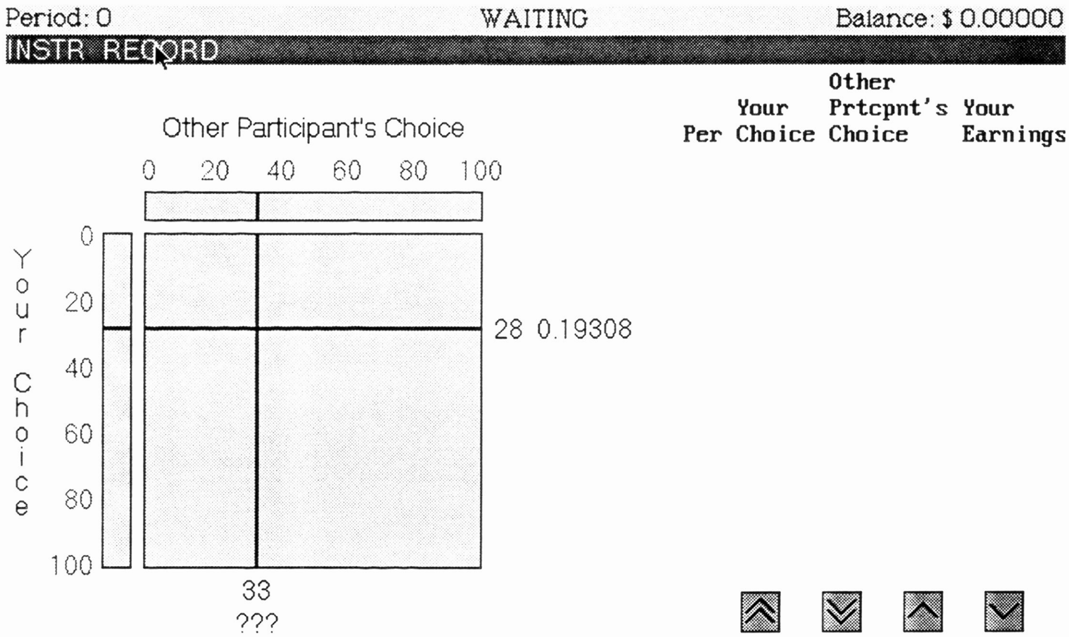
^CPA

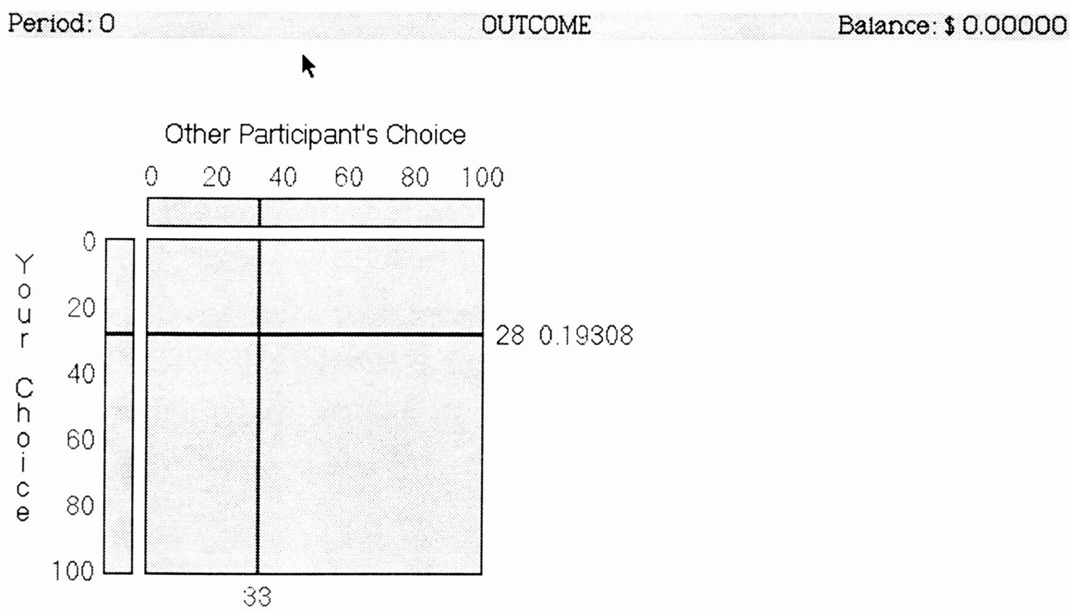
PAGE 12

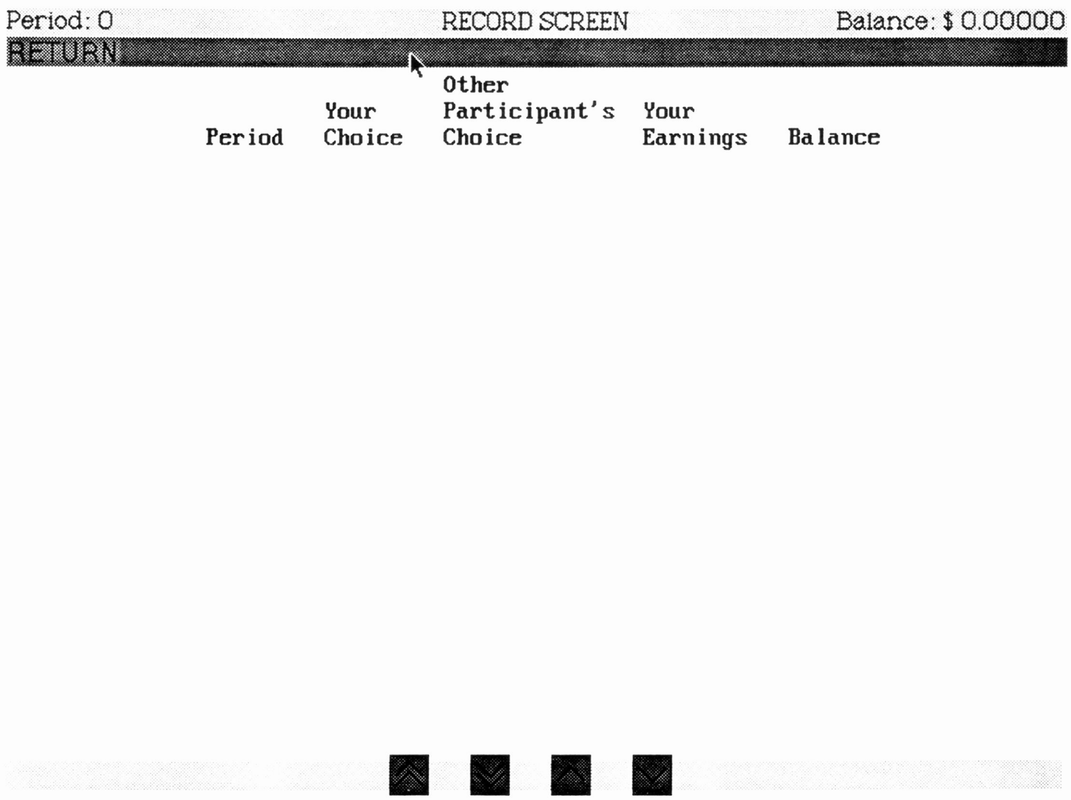


Period: 0
MAIN
Balance: $ 0.00000
PROCEED INSTR RECORD
Other Participant's Choice
0 20 40 60 80 100
Your Choice
0
20
40
60
80
100
28 0.19308
33
???
Per
Your Choice
Other Prtcpnt's Choice
Your Earnings


Period: 0
MAIN
Balance: $ 0.00000
DO YOU WANT TO PROCEED?
NO
YES
Per
Your Choice
Other Prtcpnt's Choice
Your Earnings
Other Participant's Choice
0 20 40 60 80 100
Your Choice
0 20 40 60 80 100
28 0.19308
33
???


Period: 0
WAITING
Balance: $ 0.00000
INSTR RECORD
Other Participant's Choice
0 20 40 60 80 100
Your Choice
0 20 40 60 80 100
28 0.19308
33
???
Per
Your Choice
Other Prtcpnt's Choice
Your Earnings


Period: 0
OUTCOME
Balance: $ 0.00000
Other Participant's Choice
0 20 40 60 80 100
Your Choice
0
20
40
60
80
100
28 0.19308
33


Period: 0
RECORD SCREEN
Balance: $ 0.00000
RETURN
Period
Your Choice
Other Participant's Choice
Your Earnings
Balance

OTHER PARTICIPANT'S CHOICE

YOUR CHOICE

	0	**25**	**50**	**75**	**100**
0	(1)______	________	0.15000	0.22500	(5)_____
25	0.15000	________	________	(3)______	0.25000
50	(6)______	0.27500	0.25000	________	_______
75	________	0.37500	(2)______	0.22500	(7)_____
100	0.60000	________	0.35000	(4)______	0.10000

OTHER PARTICIPANT'S CHOICE

YOUR CHOICE	**0**	**25**	**50**	**75**	**100**
0	0.00000	0.07500	0.15000	0.22500	0.30000
25	0.15000	0.17500	0.20000	0.22500	0.25000
50	0.30000	0.27500	0.25000	0.22500	0.20000
75	0.45000	0.37500	0.30000	0.22500	0.15000
100	0.60000	0.47500	0.35000	0.22500	0.10000

I. The data on page B-14 is the mean data for sessions sess03 and sess04, The variables are defined as follows:

SESSION	The session number.
PER1	The mid-point of the 5 period interval.
PERCH1	The mean value of the actions for the 5 period interval.

The figures for sessions sess03 and sess04 use PER1 and PERCH1 for the X and Y axis.

II. Appendix pages B-15 and B-16 contain the individual subject data for each subject's choice for each period for sessions sess03 and sess04. The variables are defined as follows:

SESSION	The session number.
Period	The period number.
C1-C8	The choices for the eight subjects.

III. Appendix page B-17 contains counts for individual choices and for intervals of choices for subject's actions. The variables are defined as follows:

SESSION	The session number.
GRP1	The 5 period interval.
SCHxxxxx	The interval of actions counted. The SCH__XXX designations are for a single interval for the actions 0, 50, 75 and 100. The SCHZZ_YY designations are for an interval of actions between ZZ and YY, inclusively.

MEAN DATA

SESSION	SESSION	PER1	PERCH1
sess03	sess03	3	75.800
	sess03	8	65.625
	sess03	13	69.650
	sess03	18	68.275
	sess03	23	60.550
	sess03	28	59.075
	sess03	33	73.100
	sess03	38	62.250
	sess03	43	58.825
	sess03	48	66.325
	sess03	53	70.975
	sess03	58	59.700
	sess03	63	63.875
	sess03	68	67.225
	sess03	73	65.075

SESSION	SESSION	PER1	PERCH1
sess04	sess04	3	71.925
	sess04	8	72.950
	sess04	13	64.025
	sess04	18	65.300
	sess04	23	65.075
	sess04	28	66.575
	sess04	33	72.250
	sess04	38	74.050
	sess04	43	68.025
	sess04	48	64.600
	sess04	53	67.800
	sess04	58	70.425
	sess04	63	62.825
	sess04	68	66.200
	sess04	73	64.925

INDIVIDUAL SUBJECT DATA

------------------------------------ SESSION=sess03 ------------------------------------

OBS	SESSION	PERIOD	C1	C2	C3	C4	C5	C6	C7	C8
1	sess03	1	97	50	77	75	65	95	90	29
2	sess03	2	100	75	0	100	75	75	100	50
3	sess03	3	16	70	100	100	85	97	100	19
4	sess03	4	54	60	50	90	80	70	100	78
5	sess03	5	97	86	98	99	80	100	50	100
6	sess03	6	83	80	7	0	77	50	15	90
7	sess03	7	0	80	100	100	5	55	100	20
8	sess03	8	86	100	84	100	82	75	0	97
9	sess03	9	90	100	100	100	100	0	0	94
10	sess03	10	0	100	100	100	99	0	100	56
11	sess03	11	0	100	88	100	96	0	88	13
12	sess03	12	50	70	17	100	96	75	88	2
13	sess03	13	75	67	50	100	100	50	100	52
14	sess03	14	76	60	77	100	100	60	100	99
15	sess03	15	100	9	0	100	100	40	100	88
16	sess03	16	2	15	92	100	100	25	15	98
17	sess03	17	81	0	63	100	100	100	100	93
18	sess03	18	97	1	20	100	96	75	90	66
19	sess03	19	71	1	80	100	100	84	97	48
20	sess03	20	57	1	97	100	100	52	97	17
21	sess03	21	50	1	97	100	100	25	97	63
22	sess03	22	77	1	77	0	100	25	97	62
23	sess03	23	0	1	100	100	100	25	97	65
24	sess03	24	18	1	26	0	100	75	50	68
25	sess03	25	100	10	42	100	100	100	97	75
26	sess03	26	81	25	100	100	100	0	97	67
27	sess03	27	96	20	80	0	100	0	97	69
28	sess03	28	50	25	60	75	100	0	97	74
29	sess03	29	0	25	40	75	100	0	97	97
30	sess03	30	67	5	20	0	100	50	97	77
31	sess03	31	23	100	44	100	100	0	97	87
32	sess03	32	45	100	100	100	100	0	97	91
33	sess03	33	100	100	97	100	100	0	97	99
34	sess03	34	100	100	87	100	100	0	97	100
35	sess03	35	50	2	100	0	100	0	97	14
36	sess03	36	25	20	97	0	100	100	97	73
37	sess03	37	74	20	87	0	100	0	97	69
38	sess03	38	70	20	77	100	100	0	97	70
39	sess03	39	76	20	67	0	100	100	97	72
40	sess03	40	80	15	0	0	100	100	97	73
41	sess03	41	81	15	7	0	100	75	20	81
42	sess03	42	89	15	100	0	100	0	97	97
43	sess03	43	33	15	89	0	100	0	97	91
44	sess03	44	65	15	15	0	100	100	97	94
45	sess03	45	80	15	94	0	100	100	97	79
46	sess03	46	13	15	100	100	100	100	97	33
47	sess03	47	85	5	75	100	100	0	97	36
48	sess03	48	80	5	75	100	100	100	97	88
49	sess03	49	25	10	75	0	100	100	97	64
50	sess03	50	15	22	75	0	100	100	97	72
51	sess03	51	55	97	61	0	100	100	97	74
52	sess03	52	0	97	100	0	100	100	97	77
53	sess03	53	17	20	90	50	100	100	97	89
54	sess03	54	98	25	0	100	100	100	97	79
55	sess03	55	84	15	95	53	100	0	97	78
56	sess03	56	0	10	79	100	100	0	97	86
57	sess03	57	90	100	100	0	100	0	97	84
58	sess03	58	65	100	82	0	100	0	97	13
59	sess03	59	5	15	86	51	100	0	97	81
60	sess03	60	100	25	1	50	100	0	97	80
61	sess03	61	69	15	99	50	100	0	97	82
62	sess03	62	81	10	69	50	100	0	97	98
63	sess03	63	97	100	79	0	100	0	97	100
64	sess03	64	45	100	100	0	100	0	97	99
65	sess03	65	80	15	33	0	100	0	97	99
66	sess03	66	96	10	62	0	100	0	97	95
67	sess03	67	80	25	1	0	100	0	97	94
68	sess03	68	79	15	100	100	100	100	97	99
69	sess03	69	84	20	100	100	100	0	97	79
70	sess03	70	70	100	97	100	100	0	0	95
71	sess03	71	23	100	70	100	100	100	97	80
72	sess03	72	75	100	97	99	100	0	97	83
73	sess03	73	69	100	17	0	100	0	97	86
74	sess03	74	75	0	100	0	100	0	97	67
75	sess03	75	90	1	98	0	100	0	0	85

------------------------------------ SESSION=sess04 ------------------------------------

OBS	SESSION	PERIOD	C1	C2	C3	C4	C5	C6	C7	C8
76	sess04	1	50	55	100	75	66	100	75	35
77	sess04	2	55	55	76	50	71	100	40	100
78	sess04	3	100	55	100	100	73	98	55	100
79	sess04	4	75	55	100	100	66	100	60	50
80	sess04	5	60	59	100	0	58	100	30	80
81	sess04	6	68	53	100	75	64	100	50	40
82	sess04	7	100	100	100	81	72	100	100	20
83	sess04	8	61	54	75	65	87	68	76	99
84	sess04	9	50	100	75	90	70	70	70	40
85	sess04	10	100	99	85	0	66	72	73	50
86	sess04	11	65	100	100	0	100	55	75	10
87	sess04	12	69	100	100	12	60	70	66	100
88	sess04	13	100	100	77	81	95	19	100	40
89	sess04	14	50	100	50	96	76	8	0	70
90	sess04	15	74	100	55	0	71	17	50	50
91	sess04	16	100	100	95	90	71	38	100	100
92	sess04	17	65	100	50	67	70	50	100	0
93	sess04	18	59	100	0	0	70	0	0	0
94	sess04	19	100	100	100	64	68	50	100	100
95	sess04	20	100	100	80	9	71	20	75	50
96	sess04	21	100	100	80	50	60	20	50	20
97	sess04	22	69	100	100	50	65	12	84	50
98	sess04	23	45	100	100	73	60	50	90	0
99	sess04	24	60	100	75	75	65	79	15	100
100	sess04	25	65	100	52	55	65	70	50	49
101	sess04	26	60	100	90	50	60	53	50	65
102	sess04	27	63	100	90	50	70	40	50	50
103	sess04	28	100	100	90	50	59	22	55	100
104	sess04	29	97	100	55	49	50	19	45	100
105	sess04	30	68	100	60	50	55	58	40	100
106	sess04	31	60	100	59	75	58	50	49	100
107	sess04	32	66	100	65	65	58	60	50	100
108	sess04	33	50	100	85	50	55	60	48	100
109	sess04	34	61	100	53	100	70	80	42	100
110	sess04	35	65	100	54	86	90	35	91	100
111	sess04	36	60	100	55	100	90	50	1	100
112	sess04	37	100	100	66	50	50	60	0	0
113	sess04	38	100	100	72	75	57	70	50	100
114	sess04	39	100	100	62	65	100	100	100	65
115	sess04	40	69	100	95	50	100	80	70	100
116	sess04	41	0	100	94	50	100	50	70	37
117	sess04	42	50	100	59	50	100	80	90	100
118	sess04	43	60	100	61	50	100	54	80	0
119	sess04	44	55	100	50	50	100	40	80	40
120	sess04	45	100	100	55	50	100	31	75	60
121	sess04	46	60	100	65	50	100	24	60	80
122	sess04	47	61	100	75	50	100	20	59	0
123	sess04	48	61	100	75	50	100	23	20	100
124	sess04	49	61	100	60	100	100	50	50	100
125	sess04	50	40	100	61	88	100	20	21	0
126	sess04	51	100	100	62	50	100	15	40	0
127	sess04	52	40	100	71	50	100	15	80	60
128	sess04	53	61	100	72	50	100	39	49	100
129	sess04	54	61	100	73	100	100	40	0	100
130	sess04	55	100	100	65	99	100	20	0	100
131	sess04	56	100	100	77	100	100	15	0	100
132	sess04	57	60	100	100	50	100	50	45	100
133	sess04	58	65	100	100	50	100	20	50	0
134	sess04	59	100	100	50	100	100	20	100	40
135	sess04	60	60	100	55	50	100	15	45	100
136	sess04	61	100	100	20	50	100	0	100	100
137	sess04	62	50	100	0	50	100	0	45	100
138	sess04	63	60	100	57	50	100	0	0	100
139	sess04	64	60	100	67	50	100	20	70	36
140	sess04	65	60	100	0	50	100	18	100	100
141	sess04	66	100	100	41	50	100	57	0	50
142	sess04	67	60	100	75	50	100	67	0	100
143	sess04	68	65	100	0	50	100	70	40	50
144	sess04	69	100	100	0	75	100	50	70	100
145	sess04	70	100	100	100	50	100	20	58	0
146	sess04	71	100	100	100	50	100	73	46	0
147	sess04	72	100	100	90	50	100	75	45	0
148	sess04	73	60	100	95	0	100	80	50	0
149	sess04	74	45	100	97	100	100	70	0	0
150	sess04	75	0	100	100	50	98	70	50	3

------------------------------------ SESSION=sess03 -------------------------------------

OBS	GRP1	SCH__000	SCH__050	SCH__075	SCH__100	SCH00_10	SCH11_20	SCH21_30	SCH31_40	SCH41_50	SCH51_60	SCH61_70	SCH71_80	SCH81_90	SCH91100
1	per0105	1	4	4	9	1	2	1	0	4	2	3	8	4	15
2	per0610	7	1	1	13	9	2	0	0	1	2	0	4	6	16
3	per1115	3	3	2	13	5	2	0	1	3	3	2	4	4	16
4	per1620	1	0	1	11	5	4	1	0	1	2	2	3	3	19
5	per2125	3	2	2	11	8	1	4	0	3	0	4	4	0	16
6	per2630	7	2	2	7	8	2	3	1	2	1	3	5	1	14
7	per3135	6	1	0	18	7	1	1	0	3	0	0	0	2	26
8	per3640	7	0	0	9	7	5	1	0	0	0	4	7	1	15
9	per4145	7	0	1	8	8	7	0	1	0	0	1	3	4	16
10	per4650	3	0	4	13	6	3	2	2	0	0	1	6	2	18
11	per5155	5	1	0	11	5	3	1	0	1	2	1	4	3	20
12	per5660	8	1	0	10	11	2	1	0	1	1	1	2	6	15
13	per6165	8	2	0	9	9	2	0	1	3	0	2	2	2	19
14	per6670	7	0	0	12	9	2	1	0	0	0	2	3	1	22
15	per7175	9	0	2	11	10	1	1	0	0	0	3	3	4	18

------------------------------------ SESSION=sess04 -------------------------------------

OBS	GRP1	SCH__000	SCH__050	SCH__075	SCH__100	SCH00_10	SCH11_20	SCH21_30	SCH31_40	SCH41_50	SCH51_60	SCH61_70	SCH71_80	SCH81_90	SCH91100
1	per0105	1	3	3	13	1	0	1	2	3	10	2	7	0	14
2	per0610	1	3	3	9	1	1	0	2	3	2	9	7	4	11
3	per1115	3	4	1	11	5	3	0	1	4	3	5	5	1	13
4	per1620	6	4	1	14	7	1	0	1	4	1	6	4	1	15
5	per2125	1	6	2	9	1	4	0	0	8	5	6	5	2	9
6	per2630	0	8	0	9	0	1	1	2	10	9	4	0	3	10
7	per3135	0	4	1	11	0	0	0	1	7	9	6	2	3	12
8	per3640	2	5	1	16	3	0	0	0	5	4	7	3	1	17
9	per4145	2	8	1	12	2	0	0	4	8	6	2	4	1	13
10	per4650	2	5	2	13	2	3	3	1	5	4	5	3	1	13
11	per5155	3	3	0	16	3	3	0	4	4	1	4	4	0	17
12	per5660	2	6	0	20	2	4	0	1	8	3	1	1	0	20
13	per6165	6	6	0	17	6	3	0	1	7	4	2	0	0	17
14	per6670	5	7	2	16	5	1	0	1	8	3	4	2	0	16
15	per7175	7	5	1	14	8	0	0	0	8	1	2	3	1	17