The Game of Chicken

Anatol Rapoport and Albert M. Chammah

American Behavioral Scientist 1966 10: 10
DOI: 10.1177/000276426601000303

The Game of Chicken

ANATOL RAPOPORT
ALBERT M. CHAMMAH

Behavior in a game simulating brinksmanship and appeasement is analyzed as a function of varying parameters in the game and as over-time trends. Anatol Rapoport is Professor of Mathematical Biology and Senior Research Mathematician at the Mental Health Research Institute, University of Michigan. He is the author of *Fights, Games and Debates; Strategy and Conscience*, and co-author of *Prisoner's Dilemma*. Albert M. Chammah is also at MHRI, as Assistant Research Mathematical Psychologist, he is co-author of *Prisoner's Dilemma*.

■ The game of Chicken simulates the basic features of brinkmanship and appeasement. In its simplest form it can be represented as a 2 x 2 game (two players, each having a choice between two strategies, C and D). The payoff matrix is shown in Figure 1.

	C_2	D_2
C_1	R, R	S, T
D_1	T, S	P, P

Figure 1

The payoffs satisfy the inequalities

$$T > R > S > P, \qquad 2R > S + T. \qquad (1)$$

The designation of the strategies and of the payoffs is adapted from the corresponding designations in Prisoner's Dilemma (cf. Rapoport and Chammah, 1965), to which Chicken is closely related. In Prisoner's Dilemma, C designates the cooperative strategy, so called because the choice of C by both players amounts to a tacit cooperation which results in the maximal joint payoff; D designates the defecting strategy. The payoff R is reward for cooperation; T stands for the temptation associated with the largest individual payoff; S stands for the payoff to the unilateral cooperator (the "sucker" or the "saint"); P stands for the punishment for double defection. These designations are applicable with some modification also in the game of Chicken.

The essential difference between the two games is that whereas in Chicken $S > P$, in Prisoner's Dilemma $P > S$. Consequently, while in Prisoner's Dilemma, strategy D dominates strategy C for both players and so leads to the dilemma (because the outcome DD is worse for both players than CC), in Chicken neither player has a dominating strategy. Indeed, the best response to the choice of C by the other player is to choose D (pre-emption), while the best response to D is C (appeasement).

Nevertheless, Chicken presents a dilemma of its own. If player 1 assumes that player 2 is "chicken," i.e., will play C as the obviously *prudent* choice (note that C is a minimax strategy), player 1 may feel safe in playing the "daring" strategy D. But if he assumes that the other has come to the same conclusion, he cannot play D.

The usual argument for brinkmanship is that if one can *convince* the other player that one is unalterably *committed* to D, for example, by letting him know that one has deliberately destroyed one's own freedom of choice (burned one's bridges), then one can safely play D (against a rational opponent). Thus, Herman Kahn (1965) suggests that in playing Chicken on the road, one might deliberately and conspicuously remove the steering wheel and throw it away. This gives the opposing driver no choice but to swerve from the collision course (i.e., choose the appeasing "chicken" strategy C). Aside from the fact that the formal non-cooperative game does not provide for opportunities of communication, the unalterable commitment to the "daring" strategy D has certain practical drawbacks, as, for example, in the case where the player to be intimidated reasons exactly as the intimidator. Imagine the chagrin of a pre-emptor as he sees that the driver of the car oncoming has removed *his* steering wheel at precisely the same moment.

Returning to the formal difference in the strategic structures of Prisoner's Dilemma and of Chicken, we observe that the payoff matrix of Prisoner's Dilemma has a single equilibrium, namely the outcome DD. An equilibrium is an outcome such that if a player departs from it by choosing another strategy he does not improve his payoff and, in general, impairs it. In Prisoner's Dilemma, DD is such an outcome. Chicken, on the other hand, has two such equilibria, namely C_1D_2 and D_1C_2, as can be seen from Figure 1.

If, as some maintain, the "solution" of a non-cooperative game must be an equilibrium, then the "solution" of Prisoner's Dilemma must be DD, the only equilibrium. Chicken, according to this view, has at least two "solutions," C_1D_2 and D_1C_2. If, however, we demand further that a solution of a symmetric game must not favor either player (since in formal game theory the players are assumed to be psychologically identical) neither of the above solutions of Chicken is satisfactory because each of them favors the one or the other player.

Besides the two equilibria mentioned, Chicken has still another equilibrium. This third equilibrium favors neither player. Let each player choose strategy C with probability

$$p(C) = \frac{S - P}{(T - R) + (S - P)} \qquad (2)$$

Because of inequalities (1), it can be easily seen that $0 < p(C) < 1$, as, of course, should be the case with a probability. Then it can be shown that as long as one of the players plays the mixed strategy given by equation (2), the payoff of the other does not depend on the strategy chosen. Hence a way of *preventing* the other from trying to get more via pre-empting D (or, indeed, via any mixture of C and D) is to play this mixed strategy. Thereby the other's motivation to defect is removed. If both players use it, neither has any motivation to depart from it.

If the two players play the mixed strategy given by (2), each obtains an expected gain of

$$G = \frac{ST - RP}{(T-R) + (S-P)} \qquad (3)$$

If we multiply the right side of (3) by $[(T-R)+(S-P)]$ and take into account the inequalities (1), we observe that $G < R$, i.e., both players get less by choosing the equilibrium mixed strategy than they would have gotten by choosing the (minimax) strategy C.

Therefore, Chicken is a dilemma game like Prisoner's Dilemma. One plays the equilibrium strategy "in self defense," as it were. Each is acting reasonably in removing the other's temptation to pre-empt, since pre-emption by both spells disaster for both. Yet the payoff to both players choosing the equilibrium strategy is less than it would be if each resisted the temptation to pre-empt and trusted the other to do the same. This would lead to the choice of the minimax strategy C by both players, which in this case (unlike Prisoner's Dilemma) is not only a choice which results in the maximum joint payoff, but is also a prudent choice (being a minimax strategy).

In contrast with the equilibrium strategy in Prisoner's Dilemma, which is always the pure strategy D regardless of the payoff matrix, the symmetric mixed equilibrium strategy of Chicken does depend on the payoffs. Therefore, if one should take seriously a normative theory based on the prescription of a symmetric equilibrium, one would hypothesize that the relative frequency of C choices in a large number of plays would correspond to the probabilities in the strategy mixture given by (2).

In actuality, the normative prescriptions of game theory are seldom realized in laboratory experiments. It is not even possible to make accurate estimates as to what degree the experimental results depart from those expected on game-theoretical grounds, since one cannot assume that the actual payoffs, say in money, correspond to the players' utilities. Game-theoretical analysis is of value only to the extent that it reveals the strategic structure of the game. Once the strategic structure is revealed it can be used as a source of ideas in constructing a psychological theory of the game as, we hope, will become clear in the analysis of our experimental results.

METHOD

For the most part we shall be describing the statistics of a volume of data obtained from lengthy runs of iterated plays. The method is identical to that used in our studies on Prisoner's Dilemma (Rapoport and Chammah, 1965). The emphasis will not be on attempts to determine the psychological parameters of individual subjects (as is often the case in learning experiments), but rather on the gross statistical features of the accumulated protocols in relation to the situational variables, e.g., the payoffs of the several games and the time (i.e., the number of plays) elapsed. We shall, however, as in the case of Prisoner's Dilemma, compare the performances of two populations, male and female. We shall also compare the gross features of the performance in Chicken with that of Prisoner's Dilemma.

In assessing differences and trends we shall not, except occasionally, evaluate the statistical significance of the observed differences. This is because our purpose for the present is not the confirmation or the refutation of specific hypotheses but rather the generation of hypotheses. Such hypotheses will be suggested by the observed differences or trends. If some of the hypotheses so suggested seem sufficiently interesting (if, for example, they bring out an intriguing psychological conjecture), it is our hope that subsequent work will be aimed at putting these hypotheses to severe tests, for example, by the use of a large enough volume of data to put the significance of the results beyond question. We feel that all the results which reveal the psychological features of the game situation can be valid only in the gross statistical sense, not with respect to any individual, much less with respect to a particular play or a short sequence of plays. Statistical results approach certainty only when they are obtained from very large masses of data.

In the experiments to be described we used games of the Chicken type with five different payoff matrices, shown in Figure 2.

	C_2	D_2
C_1	1, 1	–2, 2
D_1	2, –2	–3, –3

Game XIII
P = –3

	C_2	D_2
C_1	1, 1	–2, 2
D_1	2, –2	–5, –5

Game XIV
P = –5

	C_2	D_2
C_1	1, 1	–2, 2
D_1	2, –2	–10, –10

Game XV
P = –10

	C_2	D_2
C_1	1, 1	–2, 2
D_1	2, –2	–20, –20

Game XVI
P = –20

	C_2	D_2
C_1	1, 1	–2, 2
D_1	2, –2	–40, –40

Game XVII
P = –40

Figure 2

Note that R, T and S are held constant throughout, while P decreases monotonically (is negative and increases in magnitude) from Game XIII to Game XVII. The designations of the games follow the chronological notation of a larger experimental series. We shall also refer to each game by the magnitude of its P payoff. For example, C(10) will mean the frequency of C choices observed in Game XV, etc.

Our subjects were fifty pairs of University of Michigan male students and fifty pairs of University of Michigan female students, ten pairs being assigned to each game shown in Figure 2. The two players of each pair were seated side by side facing the experimenter and separated from each other by a partition. After the rules of the game (the results of each pair of choices) were explained and the subjects' questions answered, the subjects played one of the five games 300 times in succession. The successive choices were indicated silently to the experimenter by pointing to one of two cards, representing C and D choices respectively. No communication between the players was allowed. Following each play the experimenter announced the outcome, which was entered on score sheets both by the subjects and the experimenter. After every 25 plays each subject computed his net gain or loss for that block. At the end of the session the gains or losses were converted into money at 1 mill per point and added to or subtracted from the subjects' pay ($1.35 per hour) for participating in the experiment.

STATIC RESULTS

The Frequencies of C choices and of the Four Outcomes

Table 1 shows the frequencies of the C choices in percent of total number of plays in each of the give games in each population, and the frequencies prescribed by the equilibrium solution, given by equation (2).

It is interesting to compare these results with analogous ones obtained in Prisoner's Dilemma games. Recall that the "equilibrium solution" of Prisoner's Dilemma prescribes D unconditionally. Indeed, even if the game is played many times in succession (the outcome being announced each time), it can be shown that the unconditional choice of D is the only equilibrium strategy in the super-game induced by the finitely iterated game, if the number of plays is known to each player. In practice, unconditional choice of D is practically never observed in long runs of Prisoner's Dilemma, at least in the laboratory studies. Hence in this case the average player cooperates with greater frequency than is prescribed by the equilibrium solution.

In Chicken, on the other hand, the tendency seems to be in the opposite direction. The average subject cooperates with a frequency smaller than is prescribed by the equilibrium solution. The only exception is Game XIII which, be it noted, of all the five games is closest to Prisoner's Dilemma. (If R, T and S are held constant and P increases, Chicken turns into Prisoner's Dilemma when P becomes larger than S.)

We conclude, therefore, that the difference in the strategic structure between Prisoner's Dilemma and Chicken is attenuated in the experimental setting. Judging by the frequencies of C choices, this difference is not as great as one would expect it to be on game-theoretical grounds.

TABLE 1

Game	Percent C		
	Theoretical (Equilibrium)	Observed Male	Observed Female
XIII $P = -3$	50	64	64
XIV $P = -5$	75	73	69
XV $P = -10$	89	63	54
XVI $P = -20$	95	77	56
XVII $P = -40$	97	81	76

Next we examine the observed C frequencies in relation to P. According to the equilibrium solution these frequencies should increase as P decreases. Common sense suggests the same trend since, other things being equal, the tendency to choose C should increase as the outcome DD is punished more severely. This tendency is observed in Prisoner's Dilemma (cf. Rapoport and Chammah, 1965, p. 39). However, the observed trend in Chicken is not perfect. There is a reversal from C(5) to C(10) which may be due simply to a statistical fluctuation but conceivably to other reasons. The possibility that the reversal is "real" rather than a reflection of a sampling error is corroborated by the same reversal observed in both populations. Let us therefore see what the possible reasons for this reversal may be.

As the punishment for DD becomes more severe (with decreasing P), there may be two pressures operating on the subjects. One is an increasing pressure to play C, since D entails a risk of a larger loss if DD should obtain. However, there may also be an increased pressure to play D, perhaps based on the belief that as the punishment for double defection becomes more severe, each player expects that the other will be reluctant to take the punishment associated with retaliation.

On the other hand, when the punishment becomes excessive the temptation to pre-empt may be attenuated by the prospect of the great risk. It is thus conceivable that some moderate value of P, neither too small to make retaliation seem certain nor too large to make pre-emption too risky, induces the maximum temptation to pre-empt. The statistical significance of the observed inequality $C(10) < C(5)$ is almost at the .01 level (median chi-square two-tail test). The statistical significance of the observed inequality $C(10) < C(20)$ is at about the same level.

Let us now refine our data, separating the four outcomes resulting from paired choices, namely the double cooperative (CC), the double defecting (DD) and the unilateral (CD + DC). Note that in the case of a homogeneous population there is no point in comparing the frequencies of CD and DC since the labeling of the players is arbitrary.

The frequencies of the four outcomes in percent are shown in Table 2.

TABLE 2

Game		Men CC	Men CD + DC	Men DD	Women CC	Women CD + DC	Women DD
XIII	$P = -3$	48	32	20	46	34	19
XIV	$P = -5$	60	26	14	54	29	17
XV	$P = -10$	48	29	23	36	37	27
XVI	$P = -20$	61	31	07	37	39	25
XVII	$P = -40$	68	25	07	57	38	05

From Table 2 we note that the reversal of the trend reflected in the equalities $C(5) < C(10) < C(20)$ is accounted for both by smaller frequencies of the CC outcomes and by larger frequencies of DD outcomes in Game XV. In the remaining games, CC increases and DD decreases monotonically with increasing numerical magnitude of P. The unilaterals (CD + DC) show no discernible trend.

The Conditional Frequencies

There is yet another way of looking at the data with a "greater resolving power," as it were. Consider the probability that player i ($i = 1, 2$) will choose C following the outcome (CC), i.e., the conditional probability

$$x_i = p(C_i \mid C_iC_j) \tag{4}$$

and similarly,

$$y_i = p(C_i \mid C_iD_j) \tag{5}$$

$$z_i = p(C_i \mid D_iC_j) \tag{6}$$

$$w_i = p(C_i \mid D_iD_j) \quad (i = 1, 2) \tag{7}$$

Psychologically, x_i can be interpreted as the propensity to continue "cooperating" after a "collusion" has been established; y_i is the propensity to "give in" to the other's pre-emption of D; z_i is the propensity to respond to the other's bid to cooperate; w_i is either the propensity to give in under pressure of punishment or a bid to cooperate. These conditional probabilities have a similar but not identical interpretation in the context of Prisoner's Dilemma.

Table 3 shows the mean values of x, y, z and w (obtained from corresponding frequencies) averaged over all the subjects playing each game and also the grand means, averaged over the games.

TABLE 3

Game	x	y	z	w	x	y	z	w
XIII $P=-3$	.77	.45	.48	.40	.82	.51	.49	.39
XIV $P=-5$	.90	.53	.42	.36	.88	.44	.40	.36
XV $P=-10$	.78	.50	.62	.42	.79	.48	.36	.39
XVI $P=-20$	.85	.60	.69	.53	.72	.55	.48	.49
XVII $P=-40$	.90	.57	.64	.50	.82	.66	.52	.52
Mean	.84	.53	.57	.44	.81	.53	.45	.43

Table 3 gives us some indication of how the differences in the C frequencies in the different games may come about. We note, for example, that the "dip" in Game XIV is due almost entirely to the corresponding smaller values of x in both men and women. This corroborates to some extent our conjecture that moderate value of P is more conducive to *attempts* to pre-empt (i.e., to defect from CC) than either large or small values.

Next we note that the chief difference in the mean propensities of men and women is in the magnitude of z. (By the median chi-square test, this difference is significant at about the .08 level.) We could therefore make the following conjecture:

The smaller frequency of C choices in women playing the game of Chicken stems principally from their smaller propensity to respond cooperatively to the cooperative choices of the partner. A similar result was obtained from our studies on Prisoner's Dilemma.

Skewness

Another interesting variable is "skewness." Consider a block of 50 plays. Suppose one or the other player pre-empts successfully, i.e., repeatedly plays D, forcing the other player to play C in order to avoid the worst payoff at DD. Then, assuming player 2 to be the pre-emptor in this block, there will be a predominance of CD outcomes in the block. If player 1 is the pre-emptor, there will be a predominance of DC outcomes. It follows, since the CC's and DD's contribute equally to C_1 and C_2, the predominance of one over the other will be reflected in the excess of CD's over DC's, or vice versa.

In order to normalize this index, we introduce

$$Q = \frac{10 \left| C_1 - C_2 \right|}{\sqrt{(C) \cdot (D)}} \tag{8}$$

where C_1, C_2, $C = C_1 + C_2$, and $D = 100 - C_1 - C_2$ are the numbers of the corresponding choices in the block. Actually Q is the number of standard deviations by which the observed value of $C_1 - C_2$ departs from the expected value (which is 0) under the null hypothesis that in the parent population of which the block is a sample $C_1 = C_2 = C/2$; and that the distribution of the random variable C_1 is binomial.

Note that the value of Q is indeterminate if all the outcomes in a block are either CC or DD. We could in such instances set $Q = 0$, since neither player has a predominance of C's or D's over the other. However, such blocks may also be due to the "lock-in" effect, as can be readily surmised from the fact that the frequency of occurrence of such blocks is much greater than can be accounted for statistically, assuming the choices of the two subjects to be independent.

Therefore we shall calculate our average Q's in two ways: (1) including the pure CC or DD blocks, for which we set $Q = 0$, and (2) excluding such runs. Obviously the Q's will be larger in the second case. We shall call this modified index Q*.

Table 4 shows the values of Q and Q* averaged for each of the five games.

TABLE 4

Game	Q Men	Q Women	Q* Men	Q* Women
XIII $P=-3$	1.1	1.5	1.4	1.8
XIV $P=-5$	0.8	0.8	1.1	1.1
XV $P=-10$	1.1	1.0	1.2	1.1
XVI $P=-20$	1.1	1.2	1.6	1.4
XVII $P=-40$	1.4	2.5	1.9	3.1
Mean	1.1	1.4	1.4	1.7

Note that the theoretical expected value of Q is approximately 0.8 (that is, the mean of the absolute value of a normally distributed variable, whose mean is zero and whose standard deviation is one). We surmise that pre-emption (or the concomittant appeasement) is reflected in the excess of Q and of Q* over the expected value. This excess is somewhat attenuated in Q (compared with Q*) by the lock-in effect, which tends to diminish skewness.

We note also that except for the reversal $Q(5) < Q(3)$, skewness tends to increase with the magnitude of P, which makes intuitive sense, because retaliation becomes more difficult as $|P|$ increases. Note especially the high values of Q and Q* in Game XVII observed in women. One is tempted to conjecture that women tend especially to pre-empt (or yield to pre-emption) when the risk associated with retaliation becomes very high.

Whether the initial reversal is real is an interesting question. Note that it occurs both in men and in women. If it is real, then the effect may be related to the one discussed above with regard to a similar reversal in C.

The "Appeasement Failure" Index

The final variable we shall examine is the "appeasement failure" index defined as

$$M = \frac{(1\text{-}y)\ (1\text{-}z)}{yz} \tag{9}$$

The significance of this ratio is the following. Consider a unilateral run of any length. In this situation one player, whom we shall call the pre-emptor, keeps on playing D, while the other, whom we shall call the appeaser, plays C. Presumably the latter has given in to the former's bid for the T payoff. He does not venture to retaliate with D for fear of receiving the worst payoff, P. We now ask what is likely to happen when the run ends, i.e., when one or the other player or both change their strategy. One of three events can happen: (1) the appeaser finally "rebels" by switching to D (even though he punishes himself by doing this), while the pre-emptor continues with D; (2) the pre-emptor "repents" by changing to C, while the other player continues with C; (3) the changes take place simultaneously so that the players switch roles. Ignoring for the time being the last mentioned outcome, let us consider the ratio of frequencies of the other two outcomes, namely how much more frequently does a unilateral run end in DD than in CC? Formally this ratio is represented by (9). We modify the definition somewhat by considering only unilateral runs of length two or longer.

The correspondingly modified ratios M for each game in the male and female populations are shown in Table 5.

TABLE 5

Game	M Men	M Women
P = −3	.85	2.15
P = −5	1.46	1.87
P = −10	1.24	1.74
P = −20	.45	1.47
P = −40	.52	.28
Mean	.90	1.50
Weighted* Mean	.84	1.15

*The weighted mean is obtained from the ratio of the total number of unilateral runs (in all five games) ending in DD to the total number of such runs ending in CC

From Table 5 we note that M roughly decreases as the magnitude of P increases. That is to say, as the punishment becomes more severe the pre-emptor is more likely to become "converted" sooner than the appeaser quits appeasing. This effect may be due either to the appeaser's increasing reluctance to retaliate or to the pre-emptor's greater readiness to respond to the other's cooperation (in view of the greater punishment associated with the expected retaliation).

We now inquire what happens after a switch occurs, i.e., the players have switched roles. Our data indicate that following a switch the DD outcome is on the average (using weighted means) 1.5 times more frequent than CC in the male population and 3.7 times more frequent in the female population. If unweighted means are used, the corresponding ratios are 2.6 and 4.0. Evidently the "disappointment" of the relenting pre-emptor in finding himself suddently in the appeaser's role is stronger than the appeaser's desire to establish cooperation.

THE TIME COURSES OF THE VARIABLES

So far we have examined the data from a static point of view, comparing the central tendencies across games and populations. Let us now examine the data from the dynamic point of view, i.e., with respect to the trends, if any, in the several parameters in the course of the iterated plays. For this purpose we combine the data obtained from the five games. However, we keep separate the data obtained from the male and female populations for purposes of comparison.

The Initial Trend

The variable to be examined first is the running mean frequency of C, averaged over 15 successive plays (overlapping), i.e., 1-15, 2-16, 3-17, etc. We wish to see whether the initial "learning" leads to an increase or a decrease of cooperative choices. The comparison between the male and female population is shown in Figure 3.

We see that there is a distinct difference between the initial time courses. That of men remains almost constant. That of women shows a distinct decline. Note, however, that men and women start with almost the same C frequencies.[1]

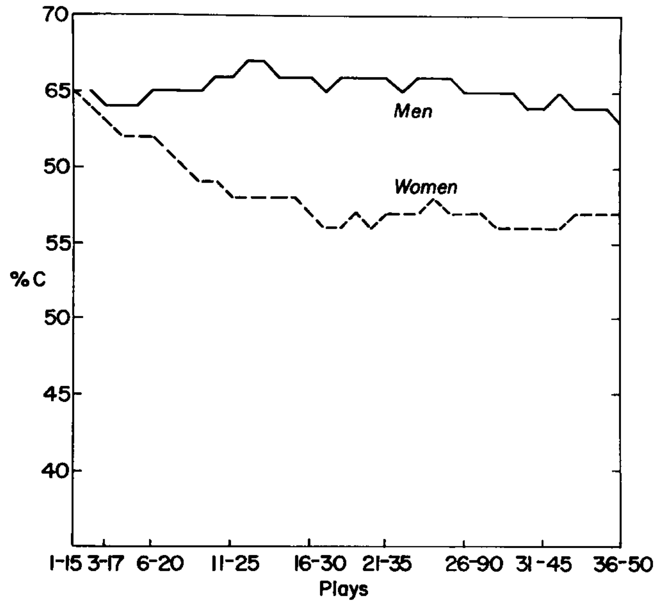


Figure 3

The Gross Trends in C, CC, CD + DC and DD

We shall next take a grosser view of the over all time courses of our variables, namely our time unit will now be the 50-play block.

From Figure 4 we see that on the whole the frequency of C choices increases. That is, both populations (considered as a whole) seem to be predominantly learning to cooperate in the iterated game of Chicken, so that the initial downward trend is reversed at some point.

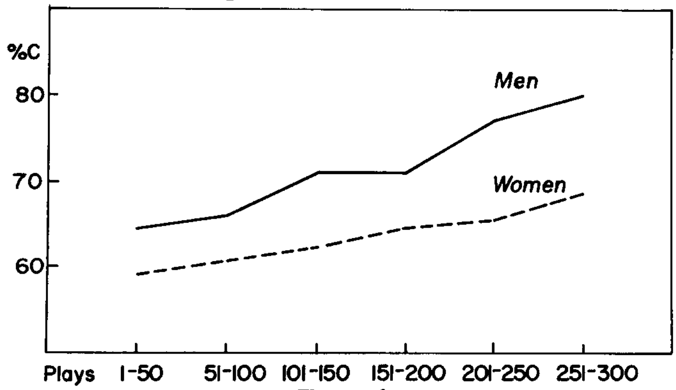


Figure 4

Figure 5 shows the average time courses of CC, CD + DC and DD. We see that on the whole the frequency of CC increases at the expense of CD + DC, while DD remains constant or, perhaps, is slowly decreasing. The trends, where they occur, are somewhat more pronounced in the male population than in the female.

The Trends in x, y, z, w

Figure 6 shows the average time courses of the conditioned probabilities, x, y, z and w. We see that to the extent any trends are discernible they are upward in x and perhaps in z, and very slightly downward in w. No trend is discernible in y. If

(continued on page 23)

1. This result was remarkably consistent throughout the experiments on Prisoner's Dilemma. Whatever sex differences were observed were revealed only in the course of long iterated runs.

(continued from page 14)
these trends are real they would indicate that on the whole both populations are learning to continue cooperating when they are in CC (learning *not* to pre-empt), and also learning to continue defecting when in DD (learning not to give in in the deadlock). They also seem to be learning to respond with cooperation to the other's cooperative choice. The rate of learning of the *conditional* choices (if it occurs at all) is considerably smaller than that of the simple choices (cf. Figures 5 and 6).

Figure 7 shows the time courses of Q and Q*.

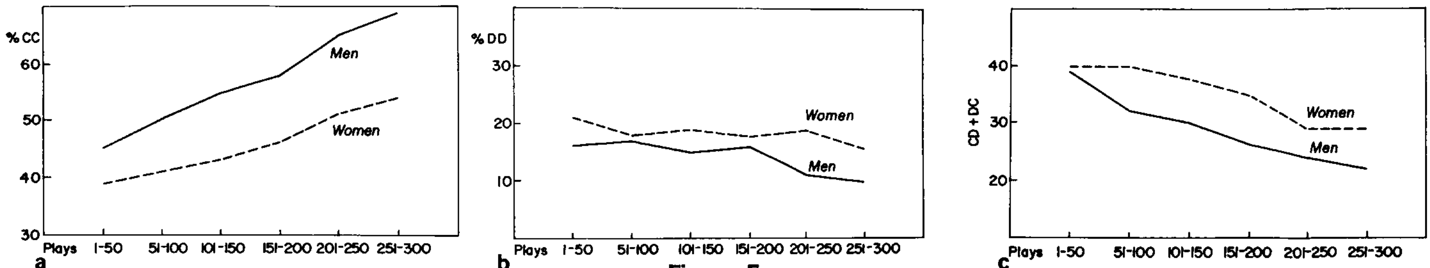


Figure 5

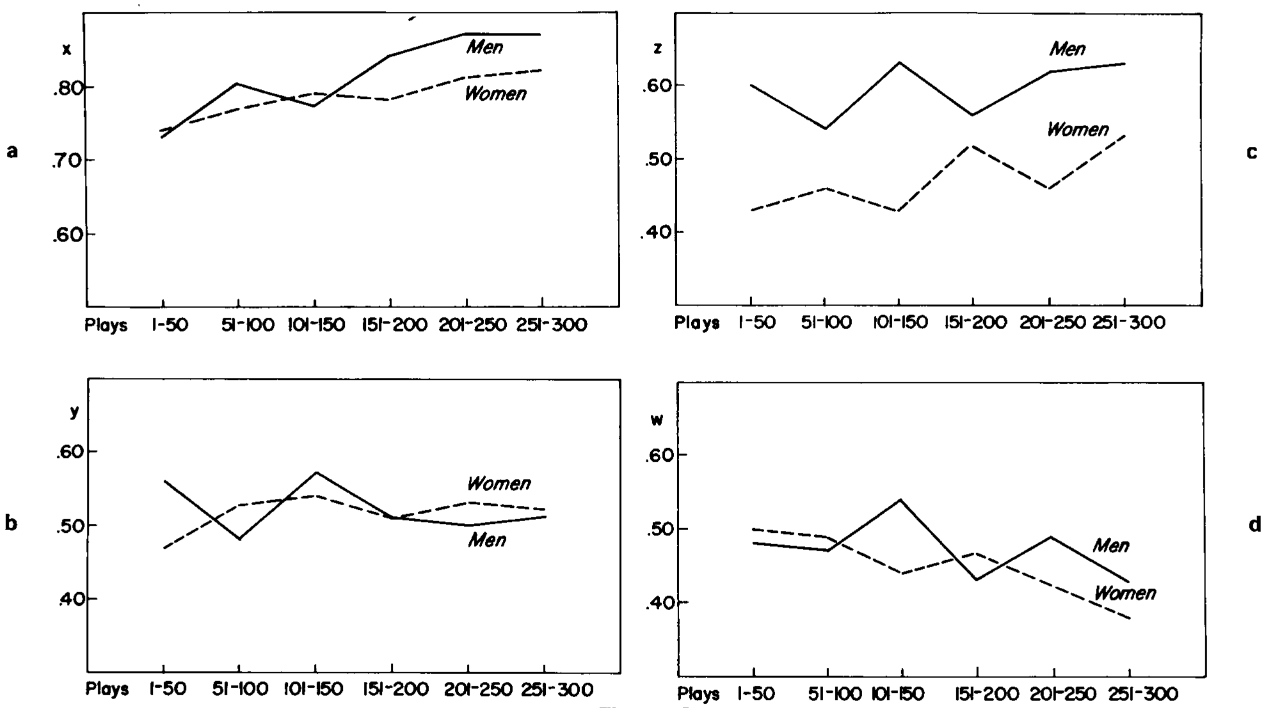


Figure 6

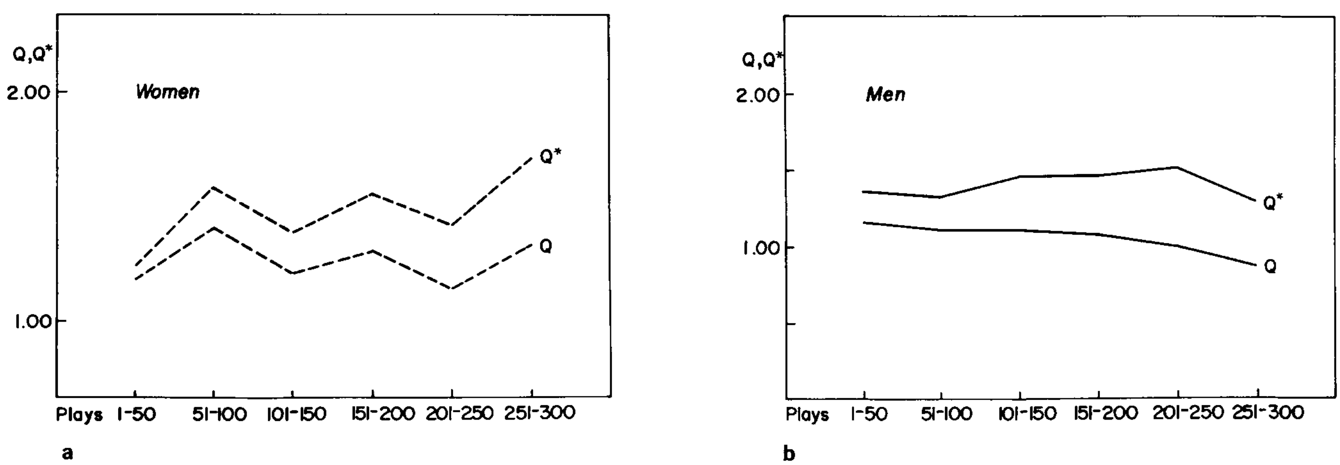


Figure 7

We see from Figure 7 that there is no discernible learning effect in Q except possibly toward the end in women. We note also that both Q and Q* are larger in women throughout. Apparently the pre-emption-appeasement episodes are more frequent in the female population.

COMPARISON OF CHICKEN WITH PRISONER'S DILEMMA

We have already pointed out that while the pressure to choose D in Prisoner's Dilemma is unconditional (operates regardless of whether the other player is assumed to have chosen C or D), it is not unconditional in Chicken (can be rationalized only if the other player is assumed to have chosen C). One could therefore conjecture that on the whole Chicken will exhibit more C choices than Prisoner's Dilemma.

However, there are other factors to consider. It is conceivable that just because in Chicken retaliation is more costly than acquiescence there is additional motivation to choose D. The point is that while in Prisoner's Dilemma there is little prospect of *getting away* with a long stretch of rewarded D's (since the other player actually stands to gain by retaliating), there is such a prospect in Chicken (since the other player stands to lose by retaliating). On the face of it, therefore, one cannot say *a priori* which game will exhibit the larger C. Let us look for the answer in data.

For comparison we have chosen two games of the Prisoner's Dilemma type. The payoff matrices are shown in Figure 8.

	C_2	D_2
C_1	1, 1	−2, 2
D_1	2, −2	−1, −1

Game IV

	C_2	D_2
C_1	5, 5	−10, 10
D_1	10, −10	−1, −1

Game XI

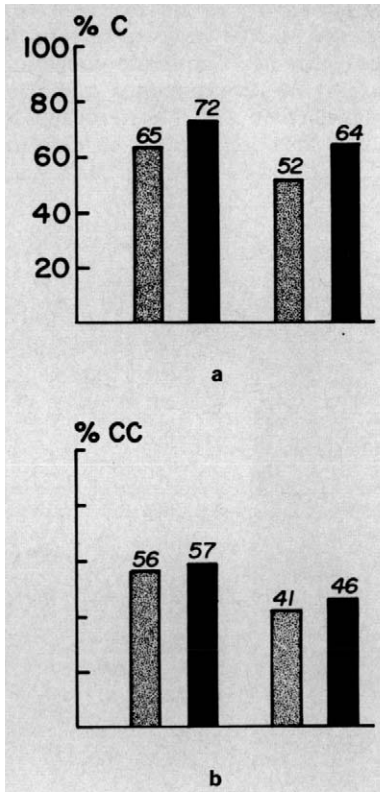
Figure 8

Games IV and XI[2] are "closest" to the games of Chicken with which they are compared. In Game IV, R, T and S are identical numerically with the corresponding payoffs in Games XIII-XVIII. In Game XI, R, T and S are all multiplied by a factor of 5, so that their ratios are equal to the corresponding ratios in game IV. Previous analysis of the data obtained from Games IV and XI (from male and female populations) showed that these two games are indeed very similar to each other. We shall therefore combine the data from these two games.

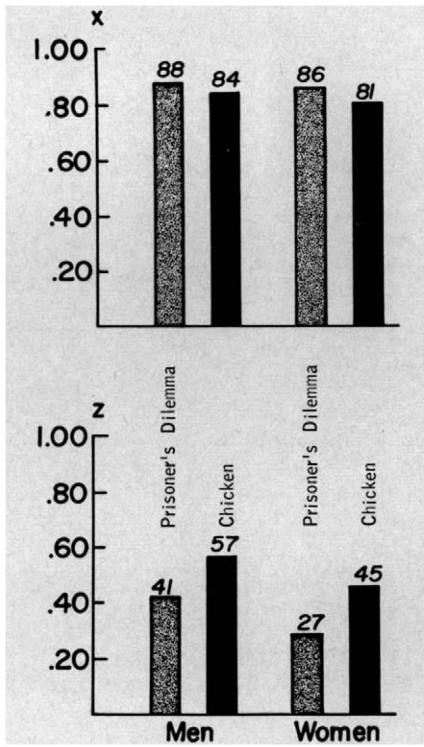
Our subjects playing Prisoner's Dilemma (Games IV and XI) were 20 male pairs and 20 female pairs.

Figure 9 shows the comparison of C, CC, (CD + DC) and DD frequencies. We see that there is more overall cooperation in Chicken than in Prisoner's Dilemma with numerically identical or proportional R, T and S. We conjecture, therefore, that the pressure to defect based on the possibility of being able to "get away with it" is not as strong as the direct pressure to defect based on the dominance of D. From Figures 9a, 9b and 9c we see that the increase in the C frequency observed in Chicken compared with Prisoner's Dilemma is due primarily to the increase in the frequencies of the unilateral outcomes (CD and DC) at the expense of DD.

The increase of CC frequencies (Figure 9b) is comparatively slight in women and negligible in men. We can therefore conjecture that Chicken shows more cooperation than Prisoner's Dilemma primarily because of the severity of the punishment for double defection. There is no evidence in the data shown in Figure 9 either for or against the conjecture that the tempta-



Figure

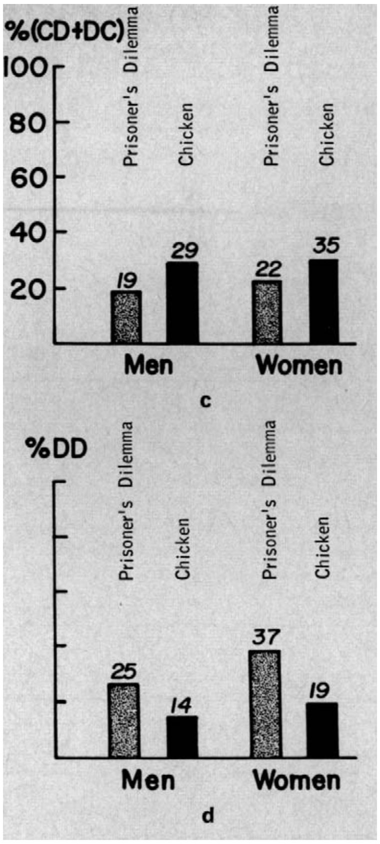


Figure

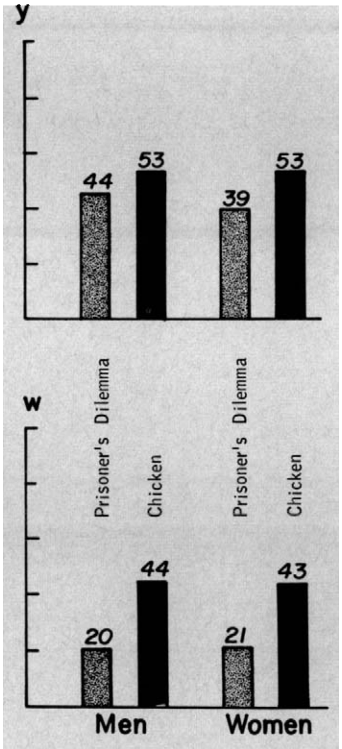
tion to pre-empt is strengthened by the prospect of "getting away with it."

However, evidence for just this conjecture does appear when we compare the two games with respect to the conditional frequencies, x, y, z and w. This comparison is shown in Figure 10.

2. Again our notation follows that of an established series.



9



10

The implication of the comparison is clear. The mean values of x in Chicken are actually *smaller* than those in Prisoner's Dilemma. Note that the gain ratio (T/R), is the same in all our games. If we consider instead the gain difference, i.e., T − R, we see that in Game XI, this difference (T − R = 5) is actually greater than in all the Chicken games (T − R = 1). Thus we might expect that in terms of the temptation to increase one's payoff by defecting to D from CC, the effect should be equal or greater in the composite Prisoner's Dilemma game. We observe the opposite. Thus our conjecture that the prospect of getting away with it does play a part in Chicken (which it does not in Prisoner's Dilemma) in contributing to the D frequencies. Clearly this tendency is more than offset by other tendencies, as can be seen in the comparisons between the other conditional frequencies. Specifically, all three of the remaining conditional frequencies, y, z and w, are larger in Chicken than in Prisoner's Dilemma. The greatest difference is in the values of w. The reason seems clear: there is a strong pressure to escape from the larger punishment associated with DD in Chicken.

The differences in y can be attributed to the "appeasement" pressure in Chicken, namely a reluctance to retaliate, that is, to switch to D from unilateral C. Again this is understandable in view of the greater punishment for DD.

Most interesting is the difference in z. Why should the pre-emptor in Chicken "repent" more frequently than in Prisoner's Dilemma? It cannot be because he is more *sure* that retaliation will eventually occur. In fact retaliation is actually less certain in Chicken, as can be surmised from the larger magnitude of P and seen directly in the larger value of y. It must therefore be the magnitude of the prospective punishment associated with retaliation, which induces the pre-emptor to retreat from D to C more frequently in Chicken than in Prisoner's Dilemma. In other words, within the range of the payoffs examined the magnitude of the punishment for DD is a more effective deterrent than the certainty of the punishment.

At this point one might be tempted to speculate on the relevance of this result to some current theories of deterrence. Penologists sometimes argue that certainty of conviction is a more powerful deterrent of crime than the severity of punishment. Something of this sort may also be at the basis of the various theories of "measured response," which have supplanted the shortlived doctrine of "massive retaliation" in the thinking of American strategists.

Our results with Chicken seem to show the opposite: more severe punishment seems to be a more effective deterrent than more certain punishment. It goes without saying that a generalization from a laboratory game played for pennies to real life problems, some of global magnitude, is foolhardy, and we are contemplating nothing of the sort. Our only purpose in drawing the analogy is to point out that even in the simplest conceivable situation, like the 2 x 2 laboratory game, fine distinctions must be made before one ventures to state general principles like "Certainty of punishment is a more effective deterrent than magnitude of punishment" or vice versa.[3]

Aside from the problem of finding a common measuring stick (a "trade off") between severity of punishment and certainty of punishment, the very notion of deterrence needs to be specified more precisely. In our games, for example, the magnitudes of both x and z are measures of deterrence. The former is a measure of the extent to which a player is "behaving," presumably for fear of retaliation; the latter is a measure of the extent to which a player "stops misbehaving" for fear of retaliation. (On the other hand, |w| is not a measure of deterrence because this parameter refers to a state in which the player is *already* being punished. As for y, it is a measure of the player's propensity to continue to be exploited.)

3. Nothing in our arguments implies any conclusion concerning the deterrence potential of progressively more severe punishments when the degree of certainty remains constant (in real life).

We see that the sort of deterrence which keeps a player "behaving" is more effective in Prisoner's Dilemma than in Chicken. Here the certainty of retaliation seems to be the stronger factor. On the other hand the kind of deterrence which induces a player to "stop misbehaving" (to quit D, although rewarded, for fear of retaliation) is more effective in Chicken than in Prisoner's Dilemma. Here severity seems to be the stronger factor. We will note, in passing, that the "punishment" is always actually experienced in our games, unlike some of the "punishments" which are hypothesized in theories of nuclear deterrence, for example.

Figure 11 shows the comparison of M in the two composite games.

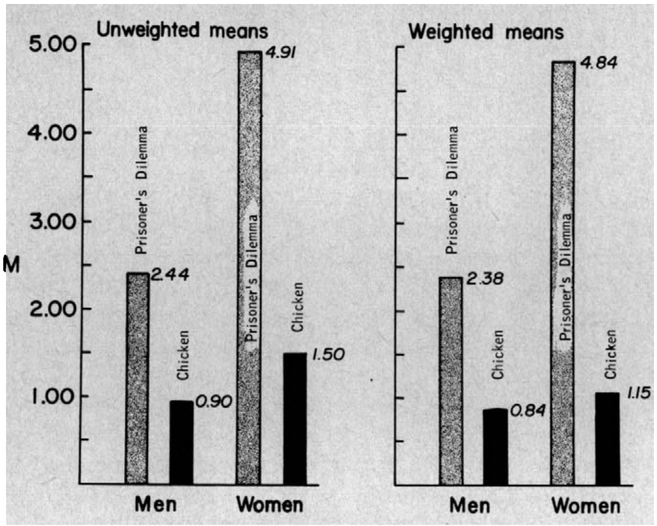


Figure 11

It should be noted that the psychological interpretation of M in Prisoner's Dilemma has a meaning different from the corresponding meaning in Chicken. A unilateral run in Chicken is analogous to "appeasement," inasmuch as it represents "giving in" to the pre-emptor. In Prisoner's Dilemma, on the other hand, a unilateral run does not represent "giving in." It has more of the flavor of a "pacifist" response. The unilateral cooperator could get more by defecting, even if the other player continues to defect. Thus the unilateral runs in Prisoner's Dilemma are more akin to "martyrdom" or at least to "teaching by example." Thus in the context of Prisoner's Dilemma M stands for the "failure of martyrdom" index, while in Chicken it stands for the "failure of appeasement" index.

From Figure 11 we see that appeasement in Chicken is more likely to succeed than martyrdom in Prisoner's Dilemma. We see also that both appeasement and martyrdom are more likely to succeed when men play men than when women play women. Comparison of skewness is shown in Table 6.

The second column shows the expected fractions of blocks in which $|C_1 - C_2|$ falls within the given number of standard deviations (column 1) from the expected value (zero) of $(C_1 - C_2)$. The third column shows the observed fractions in Prisoner's Dilemma (data of men and women combined). The fourth column shows the observed fractions in Chicken. We see that the distribution of Prisoner's Dilemma blocks is only slightly more heavily weighted at the extremes than the normal distribution. This bias is more pronounced in Chicken. The blocks with large deviations give evidence of the pre-emption-appeasement effect. An analogous effect in Prisoner's Dilemma (which would be interpreted as "martyrdom-exploitation") is not nearly as pronounced.

It remains to compare the time courses of the variables in the two composite games. From these we may get an impression of what is being learned in each of the games. For this

TABLE 6

Fraction of Blocks	Normal Distribution	Prisoner's Dilemma	Chicken
Indeterminate		.23	.20
$< 1\sigma$	.68	.63	.60
$< 2\sigma$	.95	.83	.79
$< 3\sigma$	.99	.93	.87
$< 4\sigma$	1.00	.99	.92
$< 5\sigma$		1.00	.96
$< 6\sigma$			.97
$< 7\sigma$			.98
$< 8\sigma$			.98
$< 9\sigma$			.99
$< 10\sigma$			.99
$< 11\sigma$			1.00

purpose we lump the data obtained from male and female populations. In the interest of increasing the number of subjects we shall also include data obtained from mixed pairs (i.e., men playing against women) playing Games IV and XI. Thus our Prisoner's Dilemma population will now comprise 60 pairs. (Previous analysis of the data obtained from mixed pairs indicates that on all of the variables examined here their performance falls squarely between the performances of male pairs and that of female pairs.)

The initial trends are compared in Figure 12.

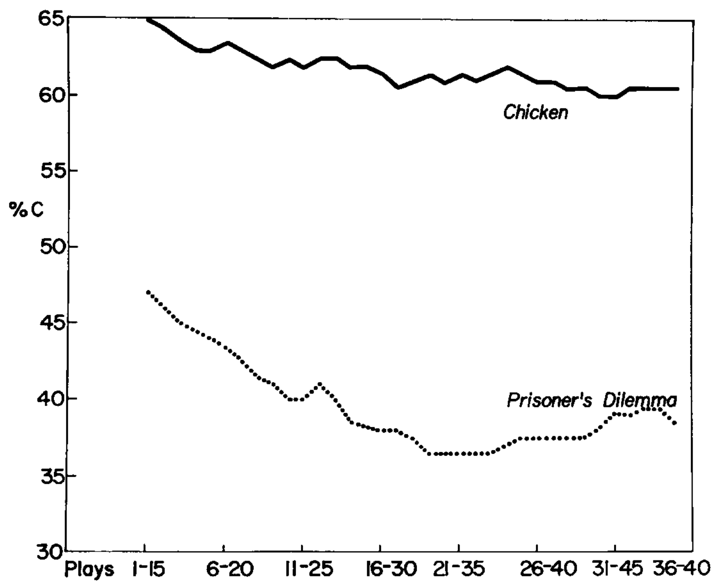


Figure 12

Note that the downward trend is much more pronounced in Prisoner's Dilemma than in Chicken. The slight downward trend observed in Chicken is due entirely to the female population, here combined with the male (cf. Figure 3).

The time courses of C, CD, (CD + DC) and DD are shown in Figure 13.

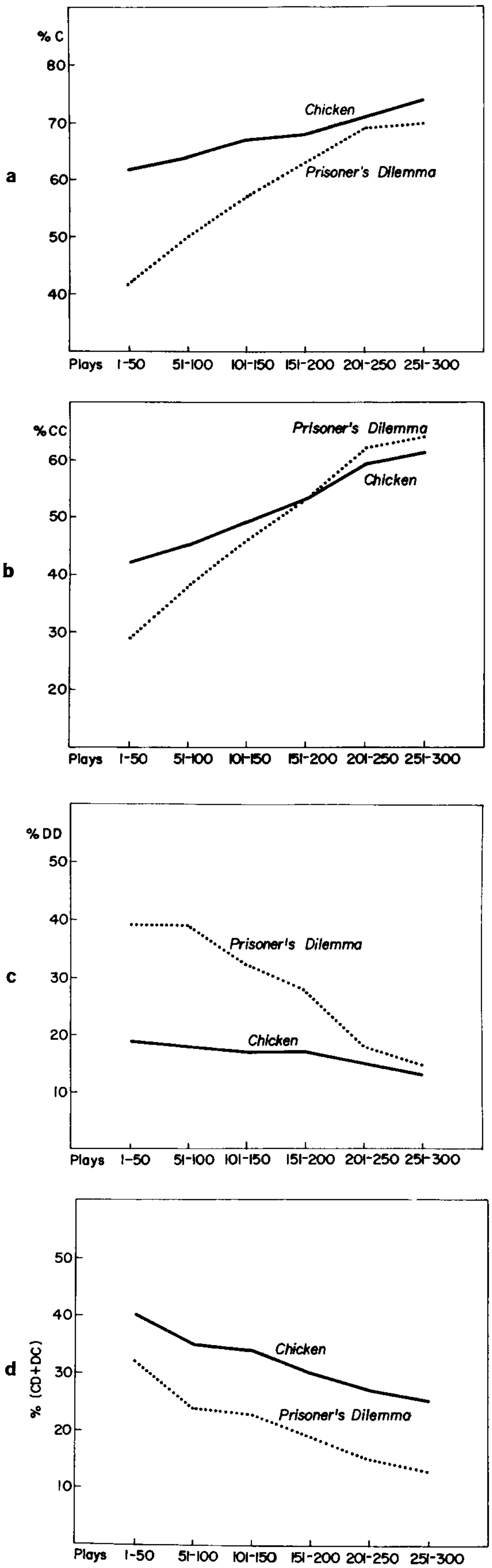


Figure 13

Here we have clear evidence of learning. Briefly the C frequencies increase, largely through the increase of cooperation (CC) and at the expense of DD and of the unilateral outcomes. The *rate* of learning seems to be greater in Prisoner's Dilemma than in Chicken. Note, however, that in Chicken the CC frequencies are higher than in Prisoner's Dilemma and the DD frequencies are lower already in the first 50 plays. Consequently there is less "room" for improvement in Chicken. On the other hand the unilaterals tend to decline more rapidly, at least at the start, in Prisoner's Dilemma. This is to be expected since in Prisoner's Dilemma there is a gain, not a cost, associated in switching to D when one has received the "sucker's payoff."

The comparison of the time courses of x, y, z and w is shown in Figure 14. The clearest evidence of learning is with regard to x. The rate of learning is less rapid in Chicken than in Prisoner's Dilemma, which accounts for the larger values of x observed in the latter game. Note that *initially* Chicken shows a larger x (i.e., fewer defections from CC). We note also that the most pronounced differences between the two games, i.e., the values of y, z and w, hold throughout the entire time course.

The time courses of Q and Q* are compared in Figure 15.

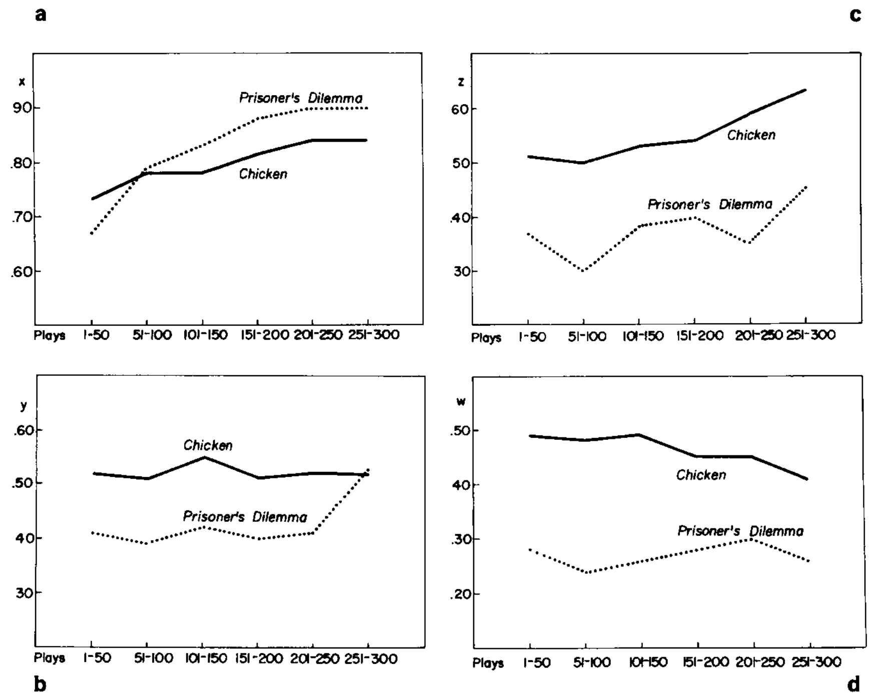


Figure 14

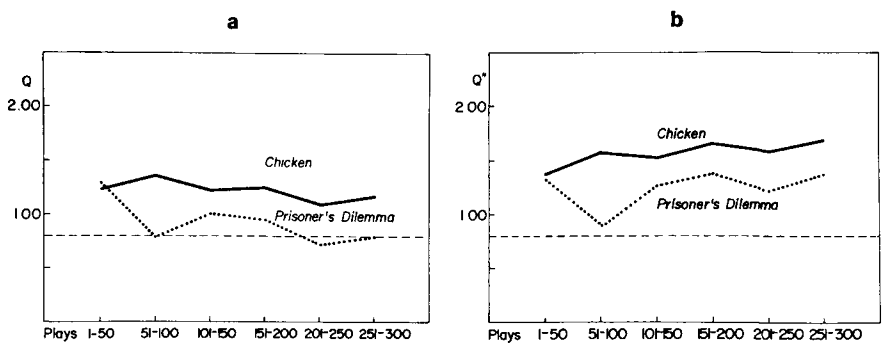


Figure 15

The dotted line represents the expected value of Q (and of Q*) under the null hypothesis that the difference $(C_1 - C_2)$ is subject only to independently statistical fluctuations of C_1 and C_2 around a common mean value.

Note that from the second block on the value of Q in Prisoner's Dilemma (Figure 15a) practically coincides with the expected value (0.8) under the null hypothesis. However, when the "lock-in" effect is factored out some skewness remains (Figure 15b). This is perhaps due to the difference in the "inherent" cooperative propensities between pairs of players randomly selected from a population in which these propensities are distributed. (Our null hypothesis was, in effect, an assumption that the propensities of each individual fluctuated statistically around the same mean value.) In Chicken, Q is considerably above expectation and so is Q* *a Fortiori*. These values are also consistently above the corresponding values in Prisoner's Dilemma. This corroborates further our conjecture that the pre-emption-appeasement effect is operating in Chicken, which is the fundamental difference between Chicken and Prisoner's Dilemma.

REFERENCES

Kahn, Herman. *On Escalation: Metaphors and Scenarios*. New York: Praeger Publ. Co., 1965.

Rapoport, Anatol, and Chammah, Albert M. *Prisoner's Dilemma: A Study of Conflict and Cooperation*. Ann Arbor: University of Michigan Press, 1965.

The Effects of Advisors on Business Game Teams

WILLIAM H. STARBUCK
ERNEST KOBROW

The authors test the consequences of adding coaches to teams of graduate students playing a business management game. Dr. Starbuck is Visiting Associate Professor of Social Relations at The Johns Hopkins University, and Associate Professor of Administrative Sciences and Economics at Purdue University. Mr. Kobrow was formerly a research associate at Purdue, and is presently pursuing graduate study at Tulane University

■ During the summer of 1963 a group at Purdue University conducted a fairly elaborate study of business game play. The study was motivated primarily by a desire to learn more about small group decision-making, but their was a secondary interest in pedagogical technique. The latter led us to assign "advisors" – advanced doctoral students who had shown exceptional promise in their academic work and who had strong interests in pragmatic business decision-making – to some of the student teams. This paper discusses the consequences of adding advisors to the teams.

PROCEDURES

Eighty-eight graduate students were randomly assigned to eighteen teams, two teams having four members and the rest five. The students were candidates for masters degrees in industrial administration, and had nearly completed their course of study at the time the game was played.

The eighteen teams were divided into three industries of six teams each. Teams within an industry competed directly with one another, but there was no competition between industries. Three teams from each industry were assigned an advisor, and three were permitted to make decisions as they pleased. Each of the three advisors was assigned one team from each of the three industries. The advisors were told that their primary function was to encourage and facilitate the use of rational, quantitative decision models by the players, but that they could serve as generalized resources to the extent that their teams solicited such help.

The teams played the UCLA Executive Decision Game (Version 3), making two decisions a week for six weeks. It was announced initially that the teams would make fifteen decisions; but the game was terminated after twelve decisions to thwart end-game strategies. Two hours of the regular class schedules were allotted for each decision, but teams could spend more or less time as they saw fit. Although participation was required as part of a concurrent course in business policy, no specifications were laid down for what constituted adequate participation; game activities had no effect on the students' course grades.

Aside from the sheer fun of the game, the primary reward for participation was monetary. Before the teams began to play a formula was announced by which the fictitious profits in the game could be translated into dollars. The formula was based on the profits achieved by undergraduate teams in a previous play of the same game, and was intended to pay an average team about \$55. In fact, the graduate students achieved nearly three times the profits we had forecast, with earnings ranging from \$85 to \$179.

RESULTS

The advisors were surprised and disappointed that their teams made almost the same profits as the unadvised teams. The advised teams earned \$1,315 and the unadvised teams

AUTHOR'S NOTE: This study was supported in part by National Science Foundation grants G24199 and GS-370. Faculty and graduate students who have contributed to this study include John Dutton, Clarke Johnson, Donald Rice, Vernon Smith, John Walter, Norman Weldon, John Wertz, and especially Ronald James and Donald King.