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THE EFFECTS OF COMMUNICATION AND INFORMATION AVAILABILITY IN AN EXPERIMENTAL STUDY OF A THREE-PERSON GAME*

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This study investigated the effects of six communication/information conditions on the outcomes reached by three-person groups playing a characteristic function game. The game was played by a monopolist and two weaker players. The conditions consisted of six combinations which varied the amount of information available to the players and their ability to communicate with one another. The investigation focused on the effects of the independent variables and the relationship between the data and several game theoretic solution concepts. The results indicated that the monopolist's payoffs depended to a large extent on the communication/information conditions. Announcement of the payoff division and the availability of messages tended to reduce his payoffs. In conditions where no messages were allowed, the monopolist's payoffs increased over time. Although the data diverged significantly from the core, the situations which contributed to greater competition resulted in outcomes closer to the core. A comparison between von Neumann-Morgenstern solutions and the more general class of subsolutions indicated that subsolutions were more reflective of the behavior observed. In addition, the results over the entire set of conditions closely approximated the Shapley value, which has recently been shown to be a risk neutral player's expected utility for playing the game. Directions for future research were suggested.

The selection of a rational alternative in strategic situations has been discussed under the rubric of game theory since its inception in 1944 [8]. Since that time, several solution concepts[1] have been presented which indicate what are generally referred to as "stable" *sets* of outcomes. The mathematical derivation of theory, however, has far outdistanced behaviorists' attempts to test game theory's different outcome sets. The present paper is an attempt to address the problem of determining which circumstances promote different stable outcomes.

The solution concepts which have received the most attention include the class of *solutions* [21], the *Shapley value* [19], the *bargaining set* [2], and the closely related *kernel* [4] and *nucleolus* [17]. More recent work considers the *competitive bargaining set* [6], a subset of the bargaining set, and the class of *subsolutions* [15] which generalizes the class of von Neumann and Morgenstern (vN-M) solutions.

Previous Research

Kalisch, Milnor, Nash, and Nering [9] were the first researchers to study the bargaining of players in characteristic function games. Their study investigated several games and concluded that, in relation to the outcome sets of the relevant theories, the Shapley value received some support from the data and other solution concepts were neither supported nor rejected. The study also indicated that (1) personalities in face-to-face bargaining had a strong impact on the results, and (2) repeated trials with a fixed set of players would be necessary to observe the type of stability required for a test of the vN-M set.

A subsequent study by Maschler [12] investigated the applicability of the bargaining set and the kernel of three-person games. The overall results favored the bargaining set over the kernel. In addition, Selten [18] has summarized the results of several games where the players engaged in face-to-face bargaining.

More recent research has also investigated the bargaining set [7], [8] including the kernel and the competitive bargaining set, and vN-M solutions [3], [20]. In addition to considering the applicability of

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[1] The term "solution concepts" will be used throughout the paper to indicate the general sets which different theoretical positions propose as stable outcomes. Solution concept, then, should be differentiated from von Neumann and Morgenstern's solution set.

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game theory to behavior, these studies have consistently investigated several aspects of the communication opportunities of the game participants.

The studies conducted at the University of North Carolina [7], [8] have shown a marked increase in the sophistication and precision of the experimental research on games. These studies have used a computerized procedure which allows the game players to send and receive offers from other players who are identified only by a letter (A, B, or C). The standard procedure entails rotating the players through different positions of the same game, allowing the researchers to obtain results which are independent of the position each player holds while also allowing for learning to occur over trials.

In an experiment which resembles the present study, Kahan and Rapoport [8] used a class of characteristic function games which have the special property that $v(A) = v(B) = v(C) = v(ABC) = 0$ and $v(AB)$, $v(AC)$, and $v(BC)$ are all positive but not necessarily equal to one another. These games are called quota games, because quotas, ω_i, can be assigned to each player such that the payoffs to any two-person coalition satisfy: $v(ij) = \omega_i + \omega_j$, where $i, j = A$, B, and C, and $i \neq j$. The bargaining set, the kernel, and the competitive bargaining set all consist of outcomes such that, regardless of which coalition forms, the payoff to each individual is his quota.

Kahan and Rapoport [8] also manipulated a communication variable in each of the quota games they used. The players in one condition could send offers only when it was their turn and were not allowed to send secret messages. A second condition permitted secret messages but limited the players to sending their offers in turn. The final condition permitted subjects to send secret messages and to make offers at any time. The overall findings were consistent with the bargaining set, the competitive bargaining set, and the kernel. No differences were found for the communication variable.

Other studies, however, have found differences due to communication opportunities. Buckley and Westen [3] reported findings which indicated that the frequency with which coalitions failed to form increased when communication was restricted to the passing of written messages (versus face-to-face bargaining). Horowitz and Rapoport [7] found that in Apex games (where the Apex player must be either included in a winning two-person coalition or must be the only player excluded from a winning coalition composed of all the other players) the Apex player's payoffs were significantly larger in conditions where he made the first offer rather than the last.

The disparity in the data on the effects of communication opportunities may be related to the particular procedures used in the different experiments. However, the original points made by Kalisch *et al.* [9], that personalities affect the outcomes and that vN-M solutions could not be tested when players rotate between different positions, remain valid. In addition, the previous studies have tested only a small number of the communication variations which are possible and have also considered only a small number of the solution concepts which may be applicable. The present study focuses on four solution concepts, the core,[2] vN-M solutions, subsolutions, and the Shapley value, under six conditions which control communication and information availability. The design, therefore, allows for a more complete analysis of the effects of communication and information on several solution concepts.

The Game

The game in this study was presented as a market consisting of three players, each of whom is the owner of one shoe. At each period player A owns a right shoe while players B and C each own one left shoe. Single shoes have no value, but a *pair* of shoes (consisting of one right shoe and one left shoe) can be sold for 100 points. Thus, no player acting alone has the power to earn any income from the market, but any coalition of players which can assemble a pair of shoes has the power to earn 100 points.

This game can be modeled in characteristic function form where $N = (A, B, C)$ and $v(A) = v(B) = v(C) = v(BC) = 0$ and $v(AB) = v(AC) = v(ABC) = 100$. The set of outcomes of this game is the set X of all possible distributions of 100 points among the players.

Following standard game theoretic usage, an outcome $x = (x_A x_B x_C)$ *dominates* another outcome $y = (y_A y_B y_C)$ if there exists a coalition of players $I \subset N$ which prefers the outcome x to the outcome y and has sufficient power to assure to its

[2] For the game in question, the core is a unique point which coincides with the bargaining set, the kernel, and the competitive bargaining set. The relationships which are found between the core and the data will, therefore, apply to each of these solution concepts.

members the distribution of wealth they receive at x. Formally, x *dominates* y ($x \succ y$) if there exists a coalition $I \subset N$ such that for each player $i \in I$, $x_i > y_i$ and $\sum_{i \in I} x_i \leqslant v(I)$. Thus, there can be no domination by the grand coalition N, and, examining the characteristic function of our game, we see that all domination must be by the coalitions (A, B) and (A, C), since these are the only other coalitions whose characteristic functions are not equal to zero.

We define the *dominion* of an outcome x to be the set of all outcomes which are dominated by the point x and denote it by $D(x) = \{y \in X \mid x \succ y\}$. We define the dominion of a set of outcomes $S \subset X$ to be the set of outcomes dominated by some point in S and denote it $D(S) = \bigcup_{x \in S} D(x)$. The complement of this set, i.e., the set of outcomes which are undominated by any point in S, is denoted by $U(S) = X - D(S)$.

The domination relation can be interpreted intuitively as a "force" acting on the game; if an outcome x dominates an outcome y, then there is a coalition of players with both the incentive and the power to "move" the game from y toward x.

One set which can be considered stable with respect to domination is the set of outcomes which are undominated by any other outcome. This set, called the *core* of the game, can be denoted by the set of outcomes $C = U(X)$. For the special case of games in characteristic function form, the core is equal to the set $C = \{x \in X \mid \sum_{i \in I} x_i \geqslant v(I)$ for all coalitions $I \subset N\}$. This set may be empty; most games which have been studied experimentally have, in fact, an empty core.

For this particular game the core is nonempty and consists of the single outcome $C = (100, 0, 0)$, at which player A receives 100 points, and players B and C receive zero. Any outcome y outside of the core is unstable in the sense that it can be dominated by some other outcome x; i.e., if y is outside of the core, then there is some coalition of players which prefers x to y and has the power to enforce x.

In this game the core coincides with the unique competitive equilibrium of the market. In general, it can be shown that the core of any market game contains every competitive equilibrium. There is a considerable body of theory (e.g., [1], [5]) which supports the intuitive notion that competitive equilibria result from very competitive play.

A more comprehensive notion of stability is a vN-M *solution* which is defined to be any set of outcomes $S \subset X$ such that (1) no x in S dominates any y in S; and (2) every z outside of S is dominated by some x in S. Equivalently, a solution is a set S such that $S = U(S)$.

Von Neumann and Morgenstern interpreted solutions as "standards of behavior" which, once they became generally accepted, would create expectations which would be self-enforcing. The solutions of this particular game are all the arcs of the form $Z(p) = (p, f(p), g(p))$, $0 \leqslant p \leqslant 100$, where f and g are continuous, nonnegative and nonincreasing functions such that $p + f(p) + g(p) = 100$. Every solution of a game contains the core, and for this game, every solution also contains a point at which player A receives zero. A vN-M solution of this game can be viewed as arising from bargaining by players B and C acting cooperatively against player A.

Another kind of stable set, which can be viewed as somewhat intermediate between the core and a vN-M solution, is the *subsolution* [14] which can be defined to be a set of outcomes $S \subset X$ such that

$$\text{(I)} \quad S \subset U(S), \quad \text{and}$$
$$\text{(II)} \quad S = U^2(S) \equiv U(U(S)).$$

It can easily be shown that every solution is a maximal subsolution, and that every subsolution contains the core. For this game, the subsolutions are the arcs of the form $Z(p)$ for $0 \leqslant c \leqslant p \leqslant 100$, where $Z(p)$ is defined as before.

The most significant difference between solutions and subsolutions as stable standards of behavior for the game in question[3] is that in order to be a vN-M solution, a standard of behavior must include the possibility that player A will receive zero whereas the class of subsolutions includes standards of behavior in which player A is assured of receiving some strictly positive amount. For example, consider the arc $Z(p) = (p, 1 - p/2, 1 - p/2)$ where p varies between 0 and 100; this arc is a solution and therefore includes the possibility that player A will receive $p = 0$. A related subsolution, for example, might not permit p to drop below some strictly positive value c.

A different approach to the study of games involves assessing the worth of a game to a player *before* the game is played. It has recently been shown [16] that the Shapley value represents a risk neutral player's cardinal utility function for playing the game. For this game the Shapley value is (66.7, 16.7, 16.7).

The play of the game was divided into several trials (see the next section) in such a way that the characteristic function of the game played was actually a multiple of the characteristic function described here.[4] Differences in the ability to communicate with the other players and differences in the amount of information held by the players can alter the complexion of the game, especially as it is perceived by the players. Situations where the left shoe players cannot communicate with one another or where they have little information about the negotiations should be advantageous to the monopolist [10]. If he can alienate the left shoe players so that they do not form a blocking coalition, he can reap larger and larger payoffs. If, however, the left shoe players are given some information about the negotiations, they may be able to cooperate against the monopolist and block his power plays.

Method

Participants

The participants in this experiment were 117 male undergraduates enrolled in the introductory organizational behavior course at a large midwestern university. The participants did not receive any monetary payoffs. All of them, however, did receive credit toward a course requirement for participating.

Design

Three factors were manipulated: (1) secret or announced payoff divisions; (2) announced messages, secret messages, or no messages at all; and (3) secret or announced offers. A complete factorial design (i.e., 2 payoff division conditions by 3 message conditions by 2 offer conditions) would have resulted in twelve conditions. However, many of the conditions were either conceptually impossible, allowed for a repetition of information, or actually announced repetitive information. The six conditions which resulted in distinctly different situations were (1) secret payoff division-no messages-secret offers; (2) announced payoff division-no messages-secret offers; (3) announced payoff divisions-no messages-announced offers; (4) announced payoff divisions-secret messages-secret offers; (5) announced payoff divisions-secret messages-announced offers; and (6) announced payoff divisions-announced messages-announced offers.

The six conditions can be intuitively arranged[5] from condition (6) which gives the

[3] The more general relationship between solutions and subsolutions is discussed in Roth [14].

[4] The characteristic function of a game is simply a summary of some of the game's features. Thus, games which are quite different from one another may share the same characteristic function. This study investigates the sensitivity of the outcomes of the game to some of these differences.

[5] The ordering is intuitive in every case except between condition (3), announced payoff division-no messages-announced offers, and condition (4), announced payoff division-secret messages-secret offers. Before conducting the study, it was a moot point whether the opportunity to pass messages or the

players the most information, and might therefore be expected to allow the most cooperation between the left shoe players and result in outcomes furthest from the core, to condition (1), which allows little opportunity for such cooperation, and might be expected to yield outcomes near the core.

Procedure

Each of the three players was seated behind partitions which shielded him from the other players and from the experimenter. The participants were given written instructions which were also read aloud by the experimenter. The instructions presented the game (described earlier) and the following (summarized) information: "Your task is to bargain among yourselves to determine who will sell their shoes and how the sellers will divide their payoff. We will repeat this procedure several times, with each player assuming the same position each time." The players were then instructed in the mechanics of the experiment. Each player filled out offer slips which consisted of the choice of a bargaining partner and a proposed payoff division totalling 100 points. The players sent their offer slips through a slot in the partitions to the experimenter. After all the players had submitted offer slips, each player could accept at most one of the offers. An agreement was reached when an offer was accepted. However, in the case of more than one acceptance, each player was bound to the offer he had made. In other words, if a person made an offer which was accepted, he was held to that offer, even if he had accepted an offer for another agreement. In cases where two players accepted each other's offers but the payoff divisions were different, the average of the two payoff divisions was recorded. This procedure was repeated for 12 completed trials or until time ran out. The players, however, were not told how many trials would be completed.

In the groups where the payoff division was secret, the experimenter only announced the positions of the players who had reached an agreement. When the payoff division was announced, the experimenter also revealed the number of points each player had received from the agreement.

When secret messages were allowed, any of the players could write any message he wished to any of the other players. Messages were delivered in the same way that offer slips were delivered. When the messages were announced, the experimenter announced who had sent the message, who was to receive it, and the contents of the message.

The announced offers conditions were very similar to the announced messages conditions. The sender, the recipient, and the contents of each offer were announced. In addition, all acceptances and rejections were announced.

Each group completed 12 trials; there were six groups in each of the 6 conditions. No group experienced more than one condition. Each player held the same position throughout the entire session. At the end of the experiment, the players were debriefed and were dismissed after all of their questions were answered.

Results

The results which follow report on the analysis of the data for 36 of the 39 groups which participated in the study (see the Appendix). Three of the groups (one in condition (4), two in condition (6)) took such a long time negotiating that they had to be excused before 12 trials could be completed. One of these groups required 33 rounds to come to its *first* agreement! Even more surprising is the fact that the left shoe players in this group did *not* reach an agreement between themselves to thwart

knowledge of the other players' offers would lead to greater or less cooperativeness within the game. The final ordering, then, was arbitrary.

the monopolist. Rather, the monopolist would not accept an offer that did not yield him at least 70 of the 100 points. In the other two groups, both in condition (6), the left shoe players again did not reach an agreement. However, each pair of left shoe players continued to demand a coalition which included all three players. In addition, there were a large number of messages in these groups, and the fact that the experimenter was required to read them all slowed progress considerably.

The analyses will be presented in two sets. The first set will present the results of analyses of variance to depict the effects of the communication and information variables. The dependent variable in this analysis was *A*'s payoffs. The second set attempts to elucidate the "pattern" of the results, so that meaningful comparisons could be made between the data and vN-M solutions and subsolutions.

The conditions (6) by trials (12) analysis of variance on *A*'s payoffs, where trials was a repeated measure, resulted in three significant effects: (1) Conditions, $\mathbf{F}(5, 30) = 3.09$, $\mathbf{p} < 0.03$; (2) Trials, $\mathbf{F}(11, 330) = 2.28$, $\mathbf{p} < 0.02$; and (3) Conditions × Trials, $\mathbf{F}(55, 330) = 1.35$, $\mathbf{p} < 0.07$. Table 1 (which aggregates trials into four trial blocks to increase readability) indicates that the monopolist's payoffs increased from the first to the second trial block, and did not significantly increase thereafter. Trend analysis also resulted in a significant linear trend: $\mathbf{F}(1, 30) = 4.60$, $\mathbf{p} < 0.05$. Other trends were not significant.

TABLE 1

Mean Payoffs for the Monopolist in each Condition and Trial Block, and the Results of Simple Main Effects for Trials for Each Condition[a]

	Trials						
Condition	1–3	4–6	7–9	10–12	F	p <	Mean
1	68.3_c	74.8_{bc}	80.8_{ab}	83.0_a	5.23	0.01	76.7_a
2	58.0_b	64.4_{ab}	67.3_{ab}	71.0_a	3.88	0.01	65.2_{ab}
3	62.7_b	70.6_{ab}	74.4_a	72.8_{ab}	3.87	0.01	70.1_a
4	54.1	58.5	58.6	54.7	1.96	ns	56.5_b
5	63.2	61.2	62.7	58.4	2.05	ns	61.4_{ab}
6	60.1	60.6	68.3	57.6	2.60*	0.05	59.2_{ab}
Mean	61.1_b	65.0_a	67.0_a	66.3_a	2.28	0.01	64.8

[a] Cells with common subscripts, within each condition or for either of the "Mean" columns, are *not* significantly different from one another at the 0.05 level using the Newman-Keuls test.

* *Post hoc* tests revealed no significant differences between trial blocks for Condition 6.

The main effect for conditions revealed that the monopolist's payoffs were greatest when the payoff was not announced or when the offers were announced (counter to expectation). His payoffs were least in the condition where secret messages were allowed, and were fairly low in all of the message conditions.

The significant interaction was analyzed further using simple main effects of trials for each of the conditions. The results (see Table 1) indicate that the interaction can be accounted for primarily by conditions (1), (2), and (3), the conditions where communication was not available. *Post hoc* tests of the simple main effects indicate that the monopolist's payoffs increased over trials in each of the no message conditions.

The monopolist's mean payoff, over all trials and all conditions, was 64.8 points. It should be noted that the Shapley value for *A* indicates that he might expect 66.7 points in this game, and that the data tended to substantiate such an expectation.

The Left Shoe Players' Demands

Because positions B and C were identical except for their label, the analysis of the demands of the left shoe players differentiated between the left shoe player in each group who accumulated the higher total payoff (designated "B") from the left shoe player who accumulated the lower total payoff (designated "C"). The analysis treated players as a factor in a $2 \times 6 \times 12$ anova (players by conditions by trials). The only significant effect was for trials [$\mathbf{F}(11, 660) = 8.73$, $\mathbf{p} < 0.00001$], indicating that the left shoe players reduced their demands over trials. Although the trials by "B"/"C" interaction was not significant, the means for each of the players for each of the trials indicated that "B," the more successful of the two players, demanded less than "C" on each trial. The fact that he was included in over sixty percent of the agreements may have resulted from his lower demands.

Coalitions Between the Left Shoe Players

A coalition for the left shoe players was observed whenever both B and C made an identical offer for the three-person coalition, and each left shoe player accepted the other's offer. Given this operational definition, relatively few coalitions formed between them.[6] More left shoe coalitions formed in conditions where messages were possible (a total of 37 in conditions (4), (5), and (6), and 6 in conditions (1), (2), and (3)). The number of three-way coalitions which were proposed by the left shoe players showed similar results: 139 in the no message conditions, 212 in the message conditions. Finally, the number of three-person coalitions in the no message conditions totalled 4 (out of 216 possible); in the message conditions the total was 18 (again, out of 216).

Comparisons with Theory

There were substantial variations in the "patterns" taken by the negotiations within the groups. In an attempt to depict the data with some precision, the payoffs received by the players in position A were averaged for each condition. In addition, average payoffs were computed for players "B" and "C" (defined as above) for each group. The points which resulted defined an arc which is contained in a vN-M solution and, consequently, also in a subsolution. However, the arc does not extend lower than a payoff of 54.5 for the monopolist. This observation is consistent with the hypothesis that the standard of behavior is a subsolution in which player A will not accept too low an offer.

To obtain an even clearer picture of the offers and demands that were minimally acceptable to A, an additional analysis used the following two variables: (1) the minimum demand made by A versus the smallest offer he accepted from the left shoe players; and (2) the lowest acceptable offer versus the second lowest acceptable offer. The lowest/second lowest variable was used to guard against the relatively frequent situations where A demanded very little on the first trial but thereafter increased his demands, and where A sent an offer for the three-person coalition only to indicate to the left shoe players that they could do better if they worked exclusively with him.

The analysis, then, was a $2 \times 2 \times 6$ anova (minimum demand/offer by lowest/second lowest by conditions). The results revealed significant conditions and lowest/second lowest main effects [$\mathbf{F}(5, 30) = 2.72$, $\mathbf{p} < 0.04$, and $\mathbf{F}(1, 30) = 23.77$, $\mathbf{p} < 0.00003$, respectively], and two effects which approached standard significance levels: the demands/accepts variable [$\mathbf{F}(1, 30) = 1.99$, $\mathbf{p} < 0.175$]; and the conditions $\times$ lowest/second lowest interaction [$\mathbf{F}(5, 30) = 2.41$, $\mathbf{p} < 0.061$]. The means for

[6] A study by Maschler of a game with a similar characteristic function [11], [12] was conducted under rules which allowed the players to meet face to face, outside of the laboratory. He reported a high incidence of cooperation among the weak players.

the interaction are shown in Table 2. A direct parallel between A's payoffs and his minimally acceptable offer is readily apparent: the "tougher" A was in accepting offers, the higher were his payoffs. This result yields further support for a level of aspiration model [13] in n-person bargaining. Of the other findings, the lowest/second lowest main effect revealed that A would generally accept or demand one relatively low offer, but that he would not accept or demand another one. The marginal demands/accepts effect showed that A's minimum demand was lower ($\bar{X} = 50.4$) than the lowest offer he was willing to accept ($\bar{X} = 53.0$). The conditions by lowest/second lowest interaction depended to a large extent on the large difference between the lowest and the second lowest offers accepted in condition (3) (see Table 2).

TABLE 2

The Means for the Monopolist's Minimally Acceptable Offer for the Conditions × Lowest / Second Lowest Interaction

	Minimally Acceptable Offer		
Condition	Lowest	Second Lowest	Mean
1	64.6	69.7	67.2_a
2	48.3	55.7	52.0_{ab}
3	46.9	60.9	58.9_{ab}
4	42.4	45.1	43.8_b
5	49.4	52.1	50.8_{ab}
6	41.4	43.9	42.6_b
Overall Mean	48.8	54.6	51.7

Note. Cells sharing a common subscript are not significantly different from one another at the 0.05 level of significance using the Newman-Keuls test.

Discussion

At first glance, the data points are quite similar to the Shapley value but very different from the core. Statistical tests are not even necessary to determine the significance of the differences from the core payoff of 100. In addition, in only one group did player A consistently attain payoffs which were close to the core (in condition (3), his payoff at the twelfth trial in one group reached 99.7). However, agreements when communication was not possible were *closer* to the core than agreements where communication was possible. Indeed, the analysis of A's payoffs indicated movement toward the core (i.e., increases for A) in the conditions where communication was not possible. An increased number of trials might reveal the extent to which this movement would continue. The initial expectation that communication opportunities would increase cooperation between the weaker players was generally supported. Removing the ability to communicate tended to increase competition between the left shoe players and increase payoffs for the monopolist.

Because both the vN-M solutions and the class of subsolutions encompass the entire payoff space, no single outcome can be observed to strictly contradict their "predictions." The data patterns indicate that the results fall on an arc which is part of a solution, and that different communication conditions promote different outcomes in the solution. In addition, the analysis concerned with the monopolist's minimally acceptable offer indicated that he would not accept offers which ranged below 40 of the 100 points. This supports subsolutions over vN-M solutions, which always include the possibility that player A will receive zero.

The results yielded several other interesting points. The fact that player A did very well in condition (3), where offers were announced, was somewhat surprising. Instead of aiding the left shoe players, the added information tended to increase player A's payoffs. Future research may substantiate either of two possible explanations for this result: (1) the left shoe players were able to build tacit agreements to hold down player A's payoffs when they learned how poorly they were doing in condition (2); and/or (2) each left shoe player, as he heard the recent offer made by his counterpart, attempted to better that offer on the very next trial. This process did occur in the group whose payoffs closely approximated the core in condition (3).

The present results can also be interpreted as additional information on the elusive concept of power. Player A was very powerful: he had to be included in any agreement which was reached. He did not hold as much power as a dictator because he could not receive the payoff without a partner. However, he did hold a monopoly. He was not subject, for example, to the possibility of being shut out entirely, which is the case for an Apex player [7]. Player A's power is also evidenced by the fact that the core for the game gives the entire payoff to him and none to the other players. Yet, in several of the conditions in the present study, player A received payoffs which averaged only slightly more than fifty percent. Other variables which were not investigated here may have influenced the magnitude of A's payoffs. Social psychological theories (e.g., [10]), for instance, predict that the payoffs of a monopolist or a dictator will increase as the size of the group increases. Recently completed research [14] on larger groups indicates not only that the monopolist's payoffs are larger with larger groups, but also that their payoffs rapidly approach the core. In addition, the effects of communication and information conditions similar to those used in the present study were found to have effects comparable to those reported here.

Other variables also merit study. The effects of face-to-face bargaining, personality characteristics, and perceived status may all impinge upon the results in an n-person game. However, the differences in games beg for further research more than any of these. A taxonomy of games which incorporates both the strategic and psychological systems which lie behind the facade of the characteristic function is a necessity in the near future of the experimental study of games. Do the results of the present game, for instance, generalize to games where no player holds a monopoly? To games between experienced players? The questions are nearly endless. A synthesis of the mathematical and the psychological points of view might make future research more meaningful to both areas.

To summarize, then, it appears that the ability to communicate helped foster greater cooperation between the weaker players. It was difficult to establish trust without communication or information of some kind and, even with some information, the monopolist often reaped most of the payoffs. The monopolist in most cases would not accept offers below a certain criterion, supporting an implication from subsolutions. Finally, as the bargaining continued, the payoff configurations did move closer to the core in the most competitive conditions.[7]

Appendix

An enumeration of the agreements in each of the conditions for each of the trials.

[7] The authors gratefully acknowledge the constructive comments of Louis R. Pondy and an anonymous reviewer, and the support the first author received from the Center for Advanced Study at the University of Illinois during this project.

Trials

Condition	Group No.	1	2	3	4	5	6	7	8	9	10	11	12
No. 1	1	75–25 AB	80–20 AB*	75–25 AB*	80–20 AC	75–25 AB*	80–20 AC	$77\frac{1}{2}$–$12\frac{1}{2}$ AC	80–20 AB	85–15 AC	80–20 AC*	85–15 AB	85–15 AC
Secret payoffs—no	2	50–50 AB	70–30 AC	60–40 AB	70–30 AC	60–40 AC	70–30 AB	70–30 AB	75–25 AC	70–30 AC	75–25 AB	75–25 AC	76–24 AB
messages—secret offers	3	85–15 AB	$87\frac{1}{2}$–$12\frac{1}{2}$ AB	95–5 AC	95–5 AC	$87\frac{1}{2}$–$12\frac{1}{2}$ AB*	85–15 AB*	90–10 AC*	90–10 AC	90–10 AC*	95–5 AB	90–10 AC*	90–10 AB
	4	75–25 AC	75–25 AC	75–25 AC	80–20 AB	$80\frac{1}{2}$–$19\frac{1}{2}$ AB	85–15 AC	90–10 AC	96–4 AB	96–4 AB	91–9 AB*	90–10 AC	90–10 AC*
	5	50–50 AB	40–20–40 ABC	80–20 AC*	75–25 AC	70–30 AC*	51–49 AB*	80–20 AC*	80–20 AC	83–17 AC	82–18 AC*	90–10 AB	85–15 AC*
	6	$57\frac{1}{2}$–$42\frac{1}{2}$ AB*	50–50 AC	50–50 AC*	70–30 AB	65–35 AB	65–35 AC	67–33 AB*	65–35 AC	70–30 AB	70–30 AB*	70–30 AB	75–25 AB*
No. 2	7	50–50 AB	50–50 AB	50–50 AC	50–50 AB	50–50 AB*	60–40 AC	60–40 AC	66–34 AC	50–50 AB	60–40 AC	55–45 AC	60–40 AC
Announced payoffs—no	8	$55\frac{1}{2}$–$44\frac{1}{2}$ AB	$47\frac{1}{2}$–$52\frac{1}{2}$ AB	55–45 AB	60–40 AB	$62\frac{1}{2}$–$37\frac{1}{2}$ AB	$62\frac{1}{2}$–$37\frac{1}{2}$ AB	$42\frac{1}{2}$–$57\frac{1}{2}$ AC	$54\frac{1}{4}$–$45\frac{3}{4}$ AC	$49\frac{1}{2}$–$50\frac{1}{2}$ AC	50–25–25 ABC	65–35 AB	65–35 AB
messages—secret offers	9	70–30 AB	75–25 AC	80–20 AC	80–20 AC	70–30 AC*	80–20 AB	80–20 AC	80–20 AC	80–20 AC	85–15 AB	85–15 AB	80–20 AB*
	10	55–45 AB	60–40 AC	$57\frac{1}{2}$–$42\frac{1}{2}$ AC	60–40 AC	61–39 AC	70–30 AB	$62\frac{1}{2}$–$37\frac{1}{2}$ AB	65–35 AB	$62\frac{1}{2}$–$37\frac{1}{2}$ AB	60–40 AB	60–40 AB	60–40 AB
	11	60–40 AB*	65–35 AC	$63\frac{1}{2}$–$36\frac{1}{2}$ AB*	$67\frac{1}{2}$–$32\frac{1}{2}$ AC	72–28 AB	$73\frac{1}{2}$–$26\frac{1}{2}$ AB	$77\frac{1}{2}$–$22\frac{1}{2}$ AC	81–19 AB	$85\frac{1}{2}$–$14\frac{1}{2}$ AC	85–15 AC	$87\frac{1}{2}$–$12\frac{1}{2}$ AB	90–5–5 ABC
	12	50–50 AB	60–40 AC*	40–30–30 ABC*	55–45 AB*	60–40 AC	65–35 AC	65–35 AC	70–30 AB	80–20 AB	70–30 AC*	80–20 AB	80–20 AB*

Condition	Group No.	Trials 1	2	3	4	5	6	7	8	9	10	11	12
No. 3	13	75–25 AC	65–35 AB*	51–49 AB*	65–35 AC	75–25 AB	85–15 AB	90–10 AC	75–25 AC*	76–24 AB	$76\frac{1}{3}$–$23\frac{2}{3}$ AB	70–30 AB*	79–21 AC
Announced payoffs—no	14	10–90 AB	90–10 AC*	12–88 AB*	$77\frac{1}{2}$–$22\frac{1}{2}$ AB*	87–13 AB*	50–50 AC	65–35 AB	$62\frac{1}{2}$–$37\frac{1}{2}$ AC	83.3–16.7 AB	60–40 AC	55–45 AB	84–16 AC
messages—announced offers	15	100–0 AC	50–50 AC*	70–30 AC	60–40 AB*	60–40 AB	60–40 AB	65–35 AC	65–35 AC	65–35 AC*	65–35 AC	65–35 AC*	65–35 AC*
	16	60–40 AC*	61–39 AB*	65–35 AC	61–39 AB	$72\frac{1}{2}$–$27\frac{1}{2}$ AC	70–30 AB	75–25 AC	70–30 AB	$77\frac{1}{2}$–$22\frac{1}{2}$ AC	75–25 AC	70–30 AC*	70–30 AB*
	17	50–50 AC	60–40 AC	70–30 AC	55–45 AC	55–45 AC	55–45 AC	61–39 AC	55–45 AC*	60–40 AC	55–45 AB	$61\frac{1}{2}$–$38\frac{1}{2}$ AC	$61\frac{1}{2}$–$38\frac{1}{2}$ AC
	18	70–30 AC	80–20 AB	90–10 AB	90–10 AB	96–4 AC	96–4 AC	97–3 AB	98–2 AC	99–1 AB	$99\frac{1}{2}$–$\frac{1}{2}$ AC*	$99\frac{1}{2}$–$\frac{1}{2}$ AC	99.7–.3 AC
No. 4	19	55–45 AB	55–45 AB	55–45 AB	55–45 AB	55–45 AB	55–45 AB	55–45 AB	60–40 AC	65–35 AB	65–35 AB	65–35 AB	70–30 AC
Announced payoffs—secret	20	50–50 AB	50–50 AC	50–25–25 ABC*	50–50 AC	55–45 AB	60–40 AB	65–35 AC	65–35 AC	65–35 AC	65–35 AC	65–35 AC	$66\frac{2}{3}$–$33\frac{1}{3}$ AC
messages—secret offers	21	50–50 AB	75–25 AC	70–30 AB	60–40 AC	70–30 AB	70–30 AB*	60–40 AC	70–30 AB	70–30 AB	70–30 AC	70–30 AC	70–30 AC
	22	50–50 AB*	50–50 AC	50–50 AB*	65–35 AC	60–40 AC	50–50 AB	40–60 AB	40–60 AB	40–60 AB	50–50 AC	20–20–60 ABC*	20–20–60 ABC*
	23	60–40 AC	70–30 AB	60–40 AC	55–45 AB	60–40 AB	65–35 AC	65–35 AC	$67\frac{1}{2}$–$32\frac{1}{2}$ AC	70–30 AB	70–30 AB	40–30–30 ABC	33–33–33 ABC*
	24	33–33–33 ABC	25–75 AC	65–35 AB	55–45 AB	50–50 AB	$62\frac{1}{2}$–$37\frac{1}{2}$ AC	$57\frac{1}{2}$–$42\frac{1}{2}$ AB	50–50 AC	50–50 AB	50–50 AB	45–55 AC	50–50 AB

		Trials											
Condition	Group No.	1	2	3	4	5	6	7	8	9	10	11	12
No. 5	25	65–35 *AB**	60–40 **AC***	55–45 **AC***	55–45 *AC*	60–40 **AB**	60–40 *AB*	65–35 **AC**	65–35 **AC***	65–35 *AC**	65–35 **AC**	65–35 **AC**	70–30 **AC**
Announced payoffs—secret messages—announced offers	26	60–40 *A***B**	55–45 *A***B**	$52\frac{1}{2}$–$47\frac{1}{2}$ **AC**	60–40 *AB*	60–40 *AC*	57–43 *A***B**	34–33–33 **A***BC*	56–44 *A***B**	60–40 *A***C**	30–35–35 *AB***C***	30–35–35 *A***BC**	33–33–33 *A***BC**
	27	50–50 *AC**	50–50 *AC**	50–50 *A***B***	55–45 *AC*	40–30–30 *ABC**	50–50 *A***C**	50–50 **AC**	50–50 **AC**	50–50 **AC**	50–50 *A***B**	50–50 **AB**	50–50 *AB*
	28	$62\frac{1}{2}$–$37\frac{1}{2}$ **AB**	70–30 *AB*	80–20 **AC**	80–20 **AC**	80–20 **AC**	52–48 *A***B***	52–48 **AB**	52–48 **AB**	52–48 **AB**	52–48 **AB**	52–24–24 *ABC*	52–48 **AB**
	29	76–24 *A***B***	50–50 *A***B**	50–50 *A***B**	50–50 *A***B**	50–50 *A***B**	50–50 *A***B**	50–50 *A***B**	80–20 **AC**	80–20 *AC*	50–50 **AB***	50–50 **AB**	80–20 *AC*
	30	100–0 *A***B**	75–25 **AB***	76–24 *AC**	80–20 **AB**	80–20 **AB**	83–17 **AB**	85.3–14.7 **AB**	$92\frac{1}{2}$–$7\frac{1}{2}$ **AB**	90–10 **AC**	90.1–9.9 **AB**	$91\frac{1}{2}$–$8\frac{1}{2}$ **AB**	91–9 **AB**
No. 6	31	75–25 *A***B**	50–50 **AC**	$37\frac{1}{2}$–$62\frac{1}{2}$ **AC**	50–50 *A***B**	60–40 *AB*	$62\frac{1}{2}$–$37\frac{1}{2}$ **AC**	50–50 *A***B**	65–35 *AC**	60–40 *AC**	50–50 *A***B***	50–50 **AB**	50–50 *AB*
Announced payoffs—announced messages—announced offers	32	50–50 *A***C**	50–50 **AB***	50–50 *A***B***	50–50 *A***C**	55–45 *AC*	51–49 *AB**	50–50 *A***C***	51–49 *AC*	50–50 *AB**	50–50 *AB**	50–50 *A***C**	50–50 *AC*
	33	$57\frac{1}{2}$–$42\frac{1}{2}$ **AB**	60–40 *A***C**	62–38 *A***B**	62–38 *AC*	62–38 *AC*	65–35 *AB*	70–30 *AC**	75–25 *AB*	80–20 *AC*	82–18 *A***B**	85–15 *A***B**	100–0 *AC*
	34	60–40 *A***B***	55–45 *A***C**	40–60 *AC**	45–55 *A***C**	51–49 **AC**	55–45 *AC*	55–45 *AC*	50–50 **AC**	60–40 *AB**	56–44 **AB**	60–40 **AC**	55–45 **AB**
	35	75–25 *A***B***	75–25 *AC*	65–35 *AC*	$66\frac{2}{3}$–$33\frac{1}{3}$ *AB**	$66\frac{2}{3}$–$33\frac{1}{3}$ *AC*	80–20 *AC*	90–10 *A***B**	40–30–30 *A***BC***	40–30–30 *ABC**	40–30–30 **ABC**	40–30–30 **ABC**	40–30–30 **ABC**
	36	80–20 *AB*	70–30 *AC*	70–30 *AB*	70–30 *AC*	70–30 **AB**	70–30 **AB**	80–20 *A***C**	33–33–33 **ABC***	50–50 *A***B**	55–45 *AC*	55–45 *AC*	70–30 *AB*

Note: Boldface letters denote the player(s) who originated the accepted offer. Asterisks indicate agreements which were not formed on the first attempt (within a trial).

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