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Ultimatums in two-person bargaining with one-sided uncertainty: Demand games

Amnon Rapoport*, James A. Sundali, Darryl A. Seale

Department of Management and Policy, 405 McClelland Hall, University of Arizona, Tucson, AZ 85721, USA

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Abstract

The demand game is a noncooperative two-person ultimatum game with one-sided uncertainty in which the Sender knows the value of the shared surplus (pie) but the Receiver only knows its probability distribution (Mitzkewitz and Nagel, 1993). We study experimentally the effects of systematic changes in the variability of the pie distribution on the Sender's proposals and Receiver's (binary) responses. In accordance with a behavioral theory that we propose, we find that (i) the Sender's proportional share of the pie increases as the Receiver's uncertainty about the pie increases, and (ii) for a given pie distribution, the Sender's proportional share decreases as the actual pie size increases.

JEL classification: C72; C92

Keywords: Ultimatum game; Experimental economics; Two-person bargaining; Uncertainty

1. Introduction

In ultimatum games (for reviews of experimental studies see Güth et al., 1982, Güth and Tietz, 1990 and Roth, in press) a Sender announces how much of a pie, whose size is common knowledge, he proposes to give to the Receiver. If the Receiver accepts, each receives the share proposed. If not, each receives nothing.

Recent studies by Croson (1992), Mitzkewitz and Nagel (1993), Straub and Murnighan (in press), Kagel et al. (in press) and Rapoport et al. (in press) have extended previous

* Corresponding author; Tel.: 602-621-9325; fax: 602-621-4171; e-mail: uamnon@ccit.arizona.edu.

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research by investigating ultimatum games with one-sided uncertainty on the part of the Receiver. Essentially, two reasons have motivated this research. First, it has been noted by Croson that the assumption of complete information underlying the previous research is often unrealistic. Second, when the ultimatum game is played under uncertainty, the notion of "fairness," which has played a major role in several explanations of the results of ultimatum games with complete information, becomes ambiguous. If the buyer does not know the seller's exact share of the surplus, fairness considerations based on equality may no longer be invoked.

Mitzkewitz and Nagel (M&N) designed a two-person bargaining game in which the Sender knows the pie size but the Receiver only knows the probability distribution of the value of the pie. When the Receiver is the uninformed party, two types of ultimatum games are possible: an *offer game* where the Receiver is informed of his possible share, and a *demand game* where the Sender announces the share of the pie he requests for himself. In the finite version of the ultimatum game under complete information, there are two subgame-perfect equilibrium solutions. In one of them the Sender demands the entire pie for himself, and in the other he asks for the entire pie minus Δ. When the ultimatum game is played under incomplete information, the appropriate solution concept is the sequential equilibrium of Kreps and Wilson (1982). This equilibrium yields the following solution: In the offer game the Sender proposes Δ, regardless of the size of the pie, and the Receiver accepts any positive offer. In the demand game, the Sender requests the entire pie minus Δ, and the Receiver grants the Sender his demand.

The main purpose of the present study, and the previous investigation of offer games by Rapoport and Sundali (RS) is to assess the effects of *Receiver's uncertainty* about the pie size on both the Sender's offers and Receiver's responses. Our second purpose is to compare the previous results on offer games to the present results on demand games. The comparison is aided by the fact that both studies shared the same experimental procedure and recruited subjects from the same population. The comparison focuses on several findings reported by Mitzkewitz and Nagel in their study of the offer and demand games.

There exists a growing body of experimental evidence, that can no longer be ignored, showing systematic differences in competitive and cooperative behavior between men and women. A recent experiment by Eckel and Grossman (1992) uncovered gender differences in a variant of the ultimatum game with complete information. Intrigued by these results, the third purpose of the present study is to assess the effects of gender in ultimatum games with incomplete information.

The remainder of the paper is organized as follows. Section 2 proposes a behavioral theory to account for the effects of the variability of the pie size distribution on the Sender's offers and Receiver's responses. Section 3 describes the experimental procedure. The results of the present study are presented and discussed in Section 4, which focuses on the effects of the variability of the pie distribution, gender, and experience gained in playing the game. Section 5 compares the results of the present study on demand games with the results of the RS study on offer games, and Section 6 compares the results of both these studies with those reported by Mitzkewitz and Nagel. Our conclusions are summarized in Section 7.

2. Theory

Assume that the Sender makes an offer to divide a pie worth \$k, which is distributed uniformly over the interval $[a,b]$. The distribution of k is common knowledge, but only the Sender knows the exact value of k. He proposes to take x for himself and give the Receiver y, where $x+y=k$. The Receiver only knows x. Using a between-subject design, the present experiment includes three conditions:

$$\text{Condition } 0-30: a=0, b=30$$

$$\text{Condition } 5-25: a=5, b=25$$

$$\text{Condition } 10-20: a=10, b=20$$

The three uniform distributions have different support but the same expected value: $\mu=15$.

Let γ_R denote one minus the minimum proportion of pie that the Receiver would be willing to accept. It is natural to assume that $0.5 \leq \gamma_R \leq 1.0$. Let $p(x,\gamma_R)$ denote the Receiver's probability, given his knowledge of the distribution of the pie and the Sender's demand, that the Sender's proportional share of the pie is "generous," namely, that $x/k \leq \gamma_R$. For a uniform distribution of the pie

$$p(x,\gamma_R) = p[(x/k) \leq \gamma_R] = \left\{ \frac{b - x/\gamma_R}{b-a} \right.$$

Fig. 1 plots the values of $p(x,\gamma_R)$ as a function of the demand x for each condition separately. The upper part of the figure depicts the value of $p(x,\gamma_R)$ for $\gamma_R=0.5$ and the lower part for $\gamma_R=0.8$. For example, in Condition 0–30 $p(12,0.5)=0.2$ whereas $p(12,0.8)=0.5$.

We propose below a behavioral model to characterize the cognitive processes of the two bargainers in the demand game and then derive and test several qualitative predictions. The model shares several features with the dynamic reasoning process proposed by Güth (1993) to describe the cognitive processes of bargainers in the ultimatum game. It also resembles the informal characterization of the thought processes proposed by Mitzkewitz and Nagel, and the belief structures incorporated in the model of Rabin (1993).

The model postulates the following steps.

Step 1. The Sender views the demand game as either a distributional task or a strategic game. Senders who view the game as a distributional task in which both parties are entitled to equal shares always demand $x=y=k/2$. Senders viewing the game strategically move to the next step.

Step 2. The model then assumes that the Sender believes that the Receiver will reject an offer if he believes that the probability that this offer is "generous" is too low. In symbols, a Sender who views the demand game strategically is assumed to believe that the Receiver will reject any demand x, if $p(x,\gamma_R) \leq \alpha_R$, where $0<\alpha_R<1$. Not knowing the value of α_R (which may vary from one Receiver to another), the Sender estimates it to be α_S.

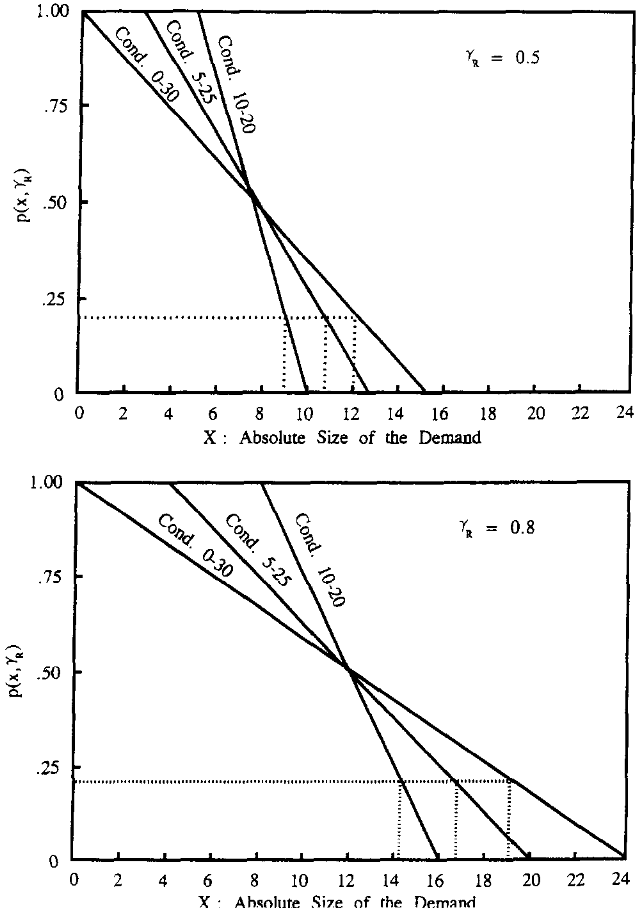

Fig. 1. The Receiver's probability that the demand is "generous" by condition.

Step 3. Having estimated α_S, the Sender determines his best response, x', which is the solution of the equation

$$p(x, \gamma_S) = \frac{b - x/\gamma_S}{b - a} = \alpha_S \tag{1}$$

subject to the following two constraints:

1. $x \leq k$,
2. $x = \max(x', \gamma_S k)$,

where γ_S $(0.5 \leq \gamma_S \leq 1.0)$ is a parameter value denoting the Sender's proportional share. Condition (1) is a feasibility constraint stating that the Sender cannot demand an absolute share exceeding the actual size of the pie. Condition (2) asserts that the Sender will demand at least his proportional share of the pie.

Given these two constraints, the predicted demand is given by

$$x^* = \begin{cases} k, & \text{if} k \leq x' \\ x', & \text{if} x' < k \leq x'/\gamma_S \\ \gamma_S k, & \text{if} x'/\gamma_S < k \leq b, \end{cases} \tag{2}$$

where x' is the solution of Eq. (1) :

$$x' = [b - \alpha_S (b - a)] \gamma_S. \tag{3}$$

To illustrate Eqs. (2) and (3), consider the case where α_S=0.2 and γ_S=0.5. Eq. (3) yields in this case x'=12, x'=10.5, and x'=9 for Conditions 0–30, 5–25, and 10–20, respectively (see top part of Fig. 1 where α_S is denoted by a broken line). The model predicts the following demands in Condition 0–30: x=k, if $k \leq 12$, x=12, if $12<k\leq 24$, and x=$k/2$, if $k>24$. The corresponding demands in Condition 5–25 are: x=k, if $k\leq 10.5$, x=10.5, if $10.5<k\leq 21$, and x=$k/2$ if $k>21$. Finally, the predicted demands in Condition 10–20 are x=9, if $k\leq 18$, and x=$k/2$, if $k>18$. Note that the inequality $k\leq x'$ is not realized in Condition 10–20 in this case.

Step 4. After being informed of the Sender's demand x, the Receiver rejects the Sender's demand if $p(x,\gamma_R)\leq\alpha_R$, otherwise he accepts it.

To recapitulate, the behavioral model characterizes the behavior of the two players in terms of two parameters. Like the model proposed by Rabin, it explicitly incorporates the beliefs that each player has about the parameters that determine the other player's behavior. The first parameter, α_R, denotes the rejection threshold for the Receiver's probability that the Sender's demand is "generous." The second parameter, γ_S, is the relative share of the pie that the Sender demands for himself. The first parameter value is assumed to be estimated by the Sender by α_S, and the latter parameter value is assumed to be estimated by the Receiver by γ_R. The model recognizes two classes of Senders – "fair" and "strategic." The former are assumed to demand $k/2$ always. The latter are assumed to follow the cognitive processes in Steps 2 and 3. In particular, the "strategic" Sender is assumed to determine his best response, given his estimate α_S, subject to the constraints of feasibility and demanding at least some fixed proportion of the pie. Having observed x, the Receiver is assumed to reject the demand if the probability that it is "generous" falls below his rejection threshold α_R. Note that the two players are not treated symmetrically by the model. The Receiver is assumed to be largely passive; his (binary) decision depends on his threshold parameter value α_R. In contrast, the "strategic" Sender is assumed to estimate the Receiver's rejection threshold and then form his best response.

The model is mute with respect to the estimates of α_R and γ_S. Assuming that the values of α_S and α_R are drawn from distributions that overlap, it follows that rejections will occur with some positive frequency even if $\gamma_S\neq\gamma_R$.

To complete the model, we add two assumptions.

Assumption 1. The parameters α_R, α_S, γ_R, and γ_S are independent of the parameters of the pie distribution and the Sender's demand.

Assumption 2. $\alpha_R \leq 0.5$ and $\alpha_S \leq 0.5$. This assumption implies that the Receiver will not reject any demand if the probability that the demand is "generous" exceeds 0.5. The same applies to the Sender's estimate of the Receiver's rejection threshold.

Implications. The behavioral model implies several qualitative predictions which we test below. The first implication concerns the effect of the uncertainty about the pie distribution on the Sender's demand. The second implication concerns the effect of the pie size on the relative share demanded by the Sender. First, note that Eq. (3) can be rewritten as

$$x' = [b(1 - 2\alpha_S) - 2\mu]\gamma_S, \text{ where } \mu = (a + b)/2.$$

Since μ and γ_S are fixed, x' increases in b as long as $\alpha_S \leq 0.5$ (see Assumption 2). Second, Eq. (2) implies that if

$$[b - \alpha_S(b - a)]\,\gamma_S < k \leq [b - \alpha_S(b - a)]$$

x^* is a fixed constant which does not depend on k. Therefore, as the pie size k increases within this interval, the model implies that x^*/k will decrease. The model predicts that:

1. the Sender's proportional share is a nondecreasing function of the Receiver's uncertainty about the pie size;
2. for a given condition, the proportional share demanded by the Sender is a nonincreasing function of the pie size.

These two predictions are illustrated in Fig. 2 for the case α_S=0.2 and γ_S=0.5 (top panel) and the case α_S=0.4 and γ_S=0.5 (bottom panel). To compare the three uniform pie distributions (which have the same mean but different support) to one another, the results are displayed in terms of the percentage point (0–100) of each distribution. Fig. 2 plots the predicted proportion of the pie demanded by the Sender as a function of $(k-a)/(b-a)$ for each condition separately. Both panels show that the Sender demands the same or higher proportion of the pie as (1) its size decreases and (2) the range of the uniform distribution increases.

The third and final implication concerns rejections by the Receiver. As stated above, if the distributions of α_S and α_R overlap, resulting in cases where $\alpha_S > \alpha_R$, rejections will occur with positive frequency.

3. Method

3.1. Subjects

The subjects were students and employees of the University of Arizona who, in response to advertisements published in the student daily newspaper, volunteered to participate in a two-person bargaining experiment lasting approximately three hours. Subjects were told to expect payoffs between \$10 and \$50, contingent on their performance. Forty subjects, 20 males and 20 females, were assigned to each of the three conditions.

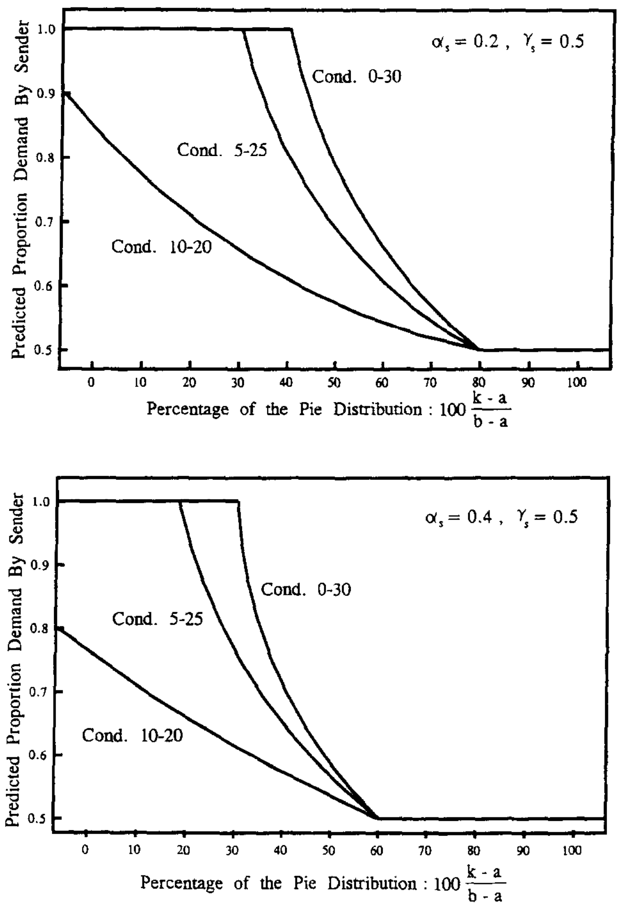

Fig. 2. Predicted percentage of pie demanded by Sender as a function of the percentage point of the pie distribution.

Procedure

During each session, twenty subjects were seated in a large classroom (Room A) and handed written instructions.[1] After the subjects read the instructions, one of the three experimenters explained the basic design of the study, repeated the instructions about the payment schedule, and answered questions about procedure.

The twenty subjects were then divided randomly into two equal size groups of Senders and Receivers. The Receivers remained in Room A while the Senders were transferred to a second large classroom (Room B). In each room the subjects were seated as far apart from one another as possible, and not allowed to communicate or exchange information in any manner.

[1]The instructions can be obtained from the authors upon request.

A randomly chosen Sender was brought to Room A and seated about 10 meters in front of the ten Receivers. A large box containing 101 poker chips, each designating a different pie value, was placed in front of the Sender. The distribution of the pie values was displayed prominently in large numbers on the board behind the Sender so that all the Receivers could see it. The distribution was also stated in the instructions. One of the two experimenters in Room A vigorously mixed the chips. The Sender picked randomly one of the chips from the box, recorded its value (k) on a Proposal Form, and returned the chip to the box. The Sender then recorded the two shares x and y, such that $x+y=k$, and copied the value of x on a 3×5 index card. The second experimenter in Room A delivered this card to one of the ten Receivers in the room, who copied the demand x, and responded by writing "yes" or "no" on his Response Form. In addition, the Receiver recorded his best estimate of the pie. The experimenter then destroyed the index card, and the same procedure was repeated. For each Sender, the order of the demands presented to the Receivers was determined randomly. On each trial, the Sender did not know who would receive his demand.[2]

Once the Sender completed making ten demands, (without receiving feedback about the Receiver's response), he was escorted out of Room A and seated in another classroom (Room C). A different Sender was then escorted to Room A, and the procedure was repeated.[3]

When the last Sender completed his round of ten demands, Phase 1 of the experiment was concluded. The experimenters collected the Proposal and Response forms and switched the subjects between the classrooms without giving any information about Phase 1. Phase 2 was identical to Phase 1 with the roles of Senders and Receivers switched. The subjects were not instructed to anticipate Phase 2. Each session lasted approximately 2 1/2 hours.

Individual payoffs were determined as follows. At the end of the experiment, three trials were chosen randomly, two where the subject was assigned the role of Sender, and

[2] A possible criticism of the design is that the last statement " On each trial, the Sender did not know who would receive his demand" is not perfectly correct, as the probability of the Sender identifying the recipient of his proposal increased with trials. Although this criticism is technically correct, in actuality this problem did not arise. The Sender did not face the Receivers directly; rather, he was seated with his profile to the Receivers facing a small desk at which he recorded his proposals. In no case did the Sender attempt to identify the recipient of his current proposal.

[3] In a time when deliberate attempts are made to maintain anonymity in ultimatum games with complete information (e.g. Hoffman et al., in press), face-to-face designs may seem undesirable. We opted for this design because of three major reasons. First, in order to compare the demand game to the offer game previously studied by RSP, we had to use the same design. Second, in both the present study and previous study of RSP, pies were sampled randomly from a commonly known distribution. Although we had access to a modern computer laboratory, we opted for a design in which the pie was sampled *publicly* in front of all the Receivers. Consequently, we did not have to assume that the Receiver believes the instructions that pies are drawn randomly; he could observe the random sampling procedure with his own eyes. Third, under the present design the Receiver observed that the demands were delivered, one at a time, in a random order. He had no reason to suspect that the demands were being manipulated by a computer. Recall that we had the Sender sitting approximately 10 meters from the Receivers, who were scattered in a large classroom. In addition, the subjects were not familiar with one another and their behavior was closely monitored by the two experimenters in Room A. As a result, nonverbal communication was highly unlikely. In our judgment, the advantages of this design in the present study, though not in general, offset its potential shortcomings.

one where he played the role of Receiver. Each subject was then paid according to his outcome on these three trials. Show up fees were not given. Payoffs varied considerably among subjects. The mean payoff per subject over the three conditions was $26.56.

4. Results

4.1. Sender's demands

We first assessed the proportion of Senders viewing the game as a distributional task.[4] To do so, we counted the number of Senders who proposed an equal split of the pie on at least eight of ten trials. Only 1 of the 120 Senders (in Condition 5–25) satisfied this criterion. When this criterion was relaxed to at least five out of ten trials, the number of "fair" Senders increased to 5 (4.2%). These results correspond to those of Straub and Murnighan, who reported that very few of their subjects were "consistently fair." Since the proportion of "fair" Senders was so small, we combined the "fair" and "strategic" Senders in all subsequent analyses.

We calculated for each Sender the proportion of the pie he demanded for himself ($d=x/k$), and then averaged the ten proportions. The resulting individual mean proportion demands (denoted by $\bar{d}$) were then subjected to a 3×2×2 condition by gender by phase analysis of variance. The ANOVA yielded two significant main effects, one due to condition ($F_{(2,119)}=18.79$, $p<0.0001$) and the other to gender ($F_{(1,119)}=19.63$, $p<0.0001$). None of the three two-way or single three-way interaction effects nor the main effect due to phase was significant ($p>0.05$).

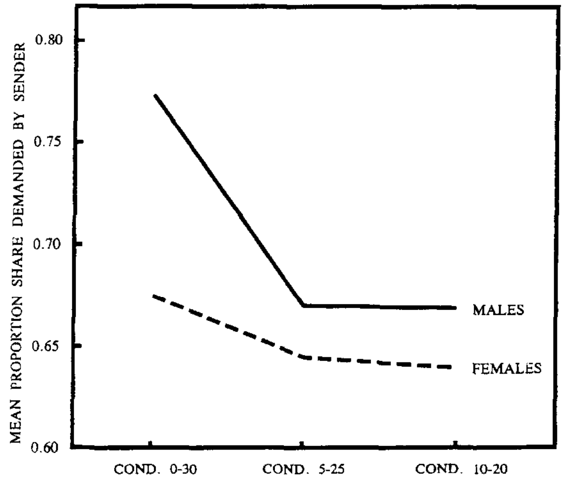

Fig. 3. Sender's mean proportion demand by gender of Sender and pie size condition.

[4]For Senders viewing the game as a distributional task but believing that their role confers greater property rights, the distributional split need not be equal. With the exception of the very few "fair" Senders offering equal splits, we found no Sender proposing the same proportional split (e.g. 60–40) on at least eight of the ten trials.

Fig. 3 displays the means of the $\bar{d}$ values by condition and gender. Mean proportion demands averaged over subjects are seen to decrease as the amount of uncertainty about the pie size decreases. Similar results were reported by RS for the offer game. Averaged over gender, the mean proportion demand decreased from 0.724 for Condition 0–30, through 0.658 for Condition 5–25, to 0.652 for Condition 10–20. Post hoc analyses (Tukey's standardized test and Bonferroni t-test) show that the significant condition effect is due to the difference between Condition 0–30 on the one hand and Conditions 5–25 and 10–20 on the other. Fig. 3 also shows that in all three conditions male Senders requested a higher proportion of the pie than female Senders. These results are consistent with those reported by Eckel and Grossman. Fig. 3 suggests the existence of a condition by gender interaction, with the difference in mean proportion demand between males and females diminishing as the uncertainty about the pie size decreases. Although the interaction effect uncovered by the ANOVA is not significant ($F_{(2,119)}=2.73$, $p<0.07$), the associated probability value is sufficiently low to render this interaction a subject of further investigation.

Our previous investigation of offer games (RS, in press), which used the same experimental design, reported a significant main effect due to phase (switching role of Senders and Receivers), with Senders in Phase 2 offering a smaller proportion of the pie than Senders in Phase 1. Although an opposite trend was observed in the present study, with Senders increasing[5] the proportion demand in Phase 2, the difference between phases was not significant. Consequently, the results will be reported across phases in all subsequent analyses.

In each of the three conditions individual differences in $\bar{d}$ were substantial. The individual mean proportion demands varied between 0.484 to 1.000 in Condition 0–30, 0.503 to 0.931 in Condition 2–25, and 0.499 to 0.951 in Condition 10–20. Fig. 4 portrays the frequency distributions (each based on 20 observations) of the Sender's mean proportion demand for all six conditions by gender combinations. Inspection of Fig. 4 reveals that the mode of the distribution shifts to 0.5 as the uncertainty about the pie size decreases. This trend holds for both male and female Senders. In terms of their mean, mode, and skewness, the frequency distributions for Condition 10–20 already resemble the frequency distributions of proportion demands observed in ultimatum games with complete information (see, e.g. Güth et al., 1982).

To assess the effect of pie size on mean proportion demand, we divided the observed pie values in each condition into 10 equal interval classes, each including 10% of the theoretical distribution. (The sizes of the intervals are \$3, \$2, and \$1, for Conditions 0–30, 5–25, and 10–20, respectively.) Fig. 5(A, B, and C) portray the mean proportion demands across the ten equal size pie value classes. The means are drawn separately for each condition, and within each condition they are displayed separately for male and female Senders. With the exception of the lowest pie size class in Condition 0–30 ($0\leq k\leq 3$), the mean proportion demands are seen to decrease slowly with pie size. Similar results were reported by Straub and Murnighan, who used a wider range of pie sizes.

[5]The phase effect in the demand but not in the offer games is similar to the effect of role-switching in the alternating offer game reported by Binmore, Shaked, and Sutton (1985).

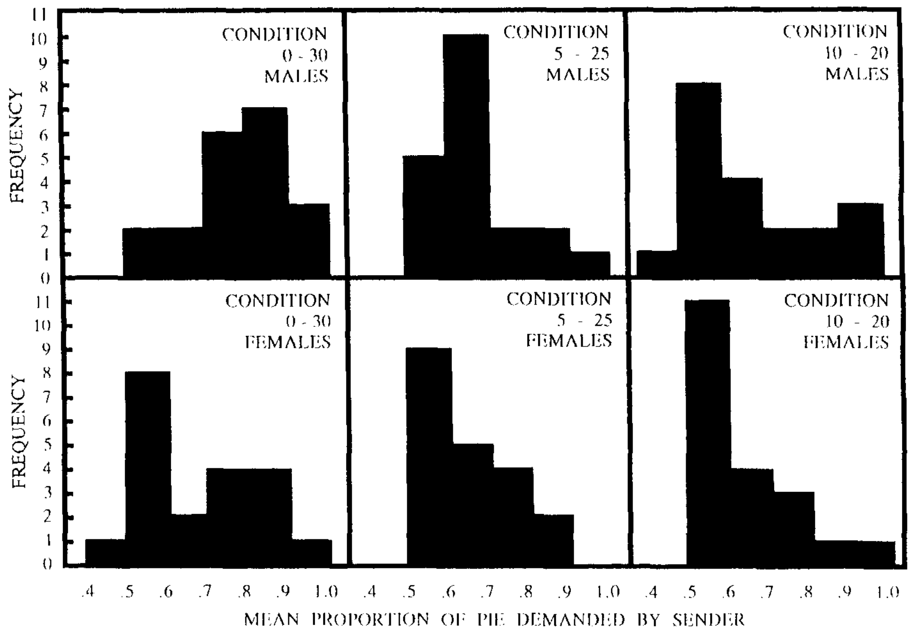

Fig. 4. Mean proportion demands of individual Senders by pie size condition and gender.

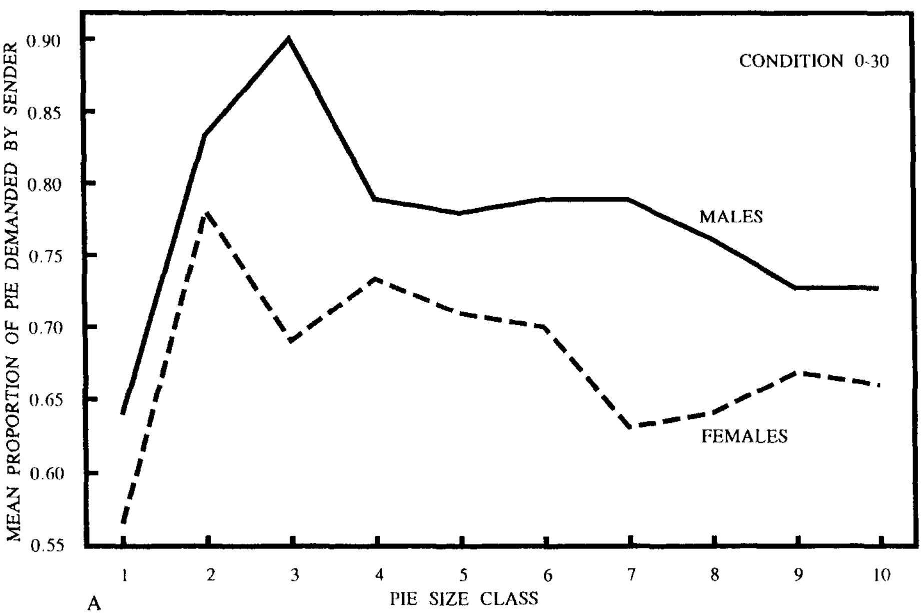

Fig. 5. (*Continued*)

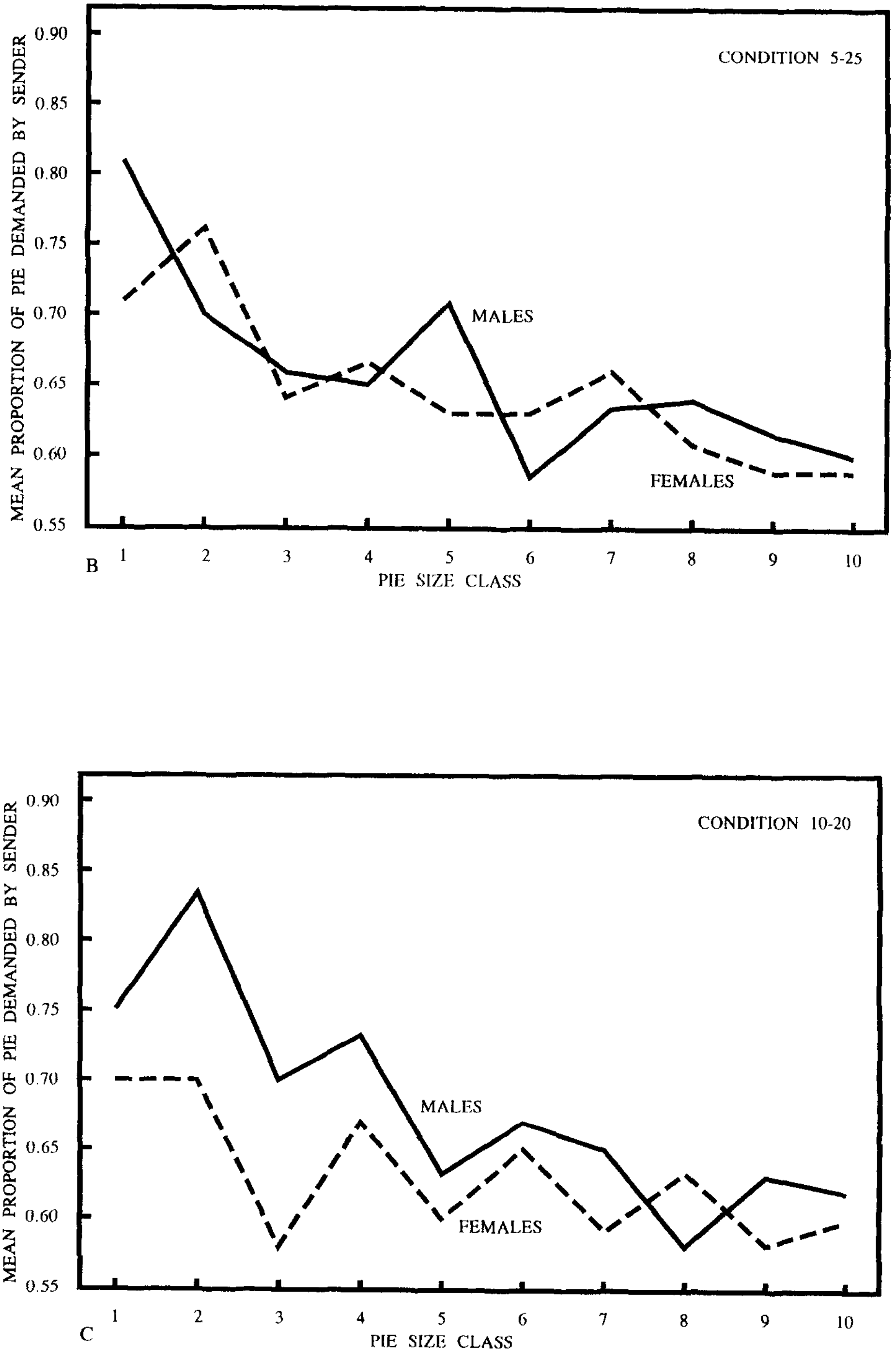

Fig. 5. Sender's mean proportion demand as a function of pie size.

Table 1
Slopes and intercepts of the linear regression of percentage demand on observed pie value

	Condition 0–30		Condition 5–25		Condition 10–20	
Statistic	Male	Female	Male	Female	Male	Female
Slope	−0.78	−0.58	−0.89	−0.69	−2.09	−1.09
Standard error	0.16	0.17	0.17	0.19	0.41	0.33
Intercept	93.16	79.02	79.28	75.04	98.76	79.88
Standard error	2.99	3.24	2.53	3.08	6.33	5.00

To test for the significance of the linear trends in Fig. 5, we regressed the percentage demands (100*d*) on the observed pie values. The regressions were computed separately for each condition by gender combination. Since Fig. 5 (A) suggests a strong departure from linearity for pie values between 0 and $3, the regression analysis for Condition 0–30 included only observed pie values equal to or larger than $3. Table 1 presents the slopes and intercepts of the linear regression lines and their associated standard errors.

Each of the six slopes in Table 1 is negative and significantly different from zero ($p<0.0001$). These results support the prediction about the effect of pie size on the proportion demand. The effect of gender is also evident: in each condition the slope of the regression line is steeper for males than females (and the intercept of the regression line is higher for males than females). The percentage demand decreases in pie size gradually: an increase of 10% in the observed pie value is associated with a decrease of 2.34, 1.78, and 2.09 in the percentage demand for male Senders in Conditions 0–30, 5–25, and 10–20, respectively. The corresponding percentages for female Senders are 1.74, 1.38, and 1.09.

4.2. Receiver's response

Altogether 180 of a total of 1200 demands (15%) were rejected. The percentage of rejections does not differ much from the percentage of rejections typically observed (between 15% and 20%) in ultimatum games with complete information (Roth, in press). Of the 180 rejections, 94 occurred in Phase 1 and 86 in Phase 2, suggesting that experience gained in playing the game as Senders had no effect on the subjects when assigned the role of Receivers. The support of the pie distribution had only a small effect on the percentage of rejections. The Sender's demands were rejected 60 (15%), 49 (12.25%), and 71 (17.75%) times in Conditions 0–30, 5–25, and 10–20, respectively.

However, the percentage of rejections varied considerably between male and female Receivers. In Condition 0–30, males rejected 39 of the demands (19.5%) compared to 21 rejections (10.5%) by the females. This difference is statistically significant ($z=2.48$, $p<0.05$). The same pattern was observed in Condition 5–25 with male Receivers rejecting 33 demands (16.5%) and females rejecting only 16 demands (8%). This difference between the proportions is also significant ($z=2.59$, $p<0.05$). In contrast, in Condition 10–20 female Receivers rejected 43 demands (21.5%) compared to 28 (14%) by males. This difference, too, is significant ($z=1.90$, $p<0.05$). We observe, then, a mixed pattern of rejections by males and females, with males rejecting approximately twice as many

Table 2
Number and percentage of rejections of Sender's demands by condition and gender

Condition 0–30

Gender	Rejections	Pie size class 0–2	2–5	5–8	8–11	11–14	14–17	17–20	20–30	Total
Male	Number	6	5	5	1	7	2	5	8	39
Receivers	Percentage	40	23	18	3	28	6	33	30	
Female	Number	4	1	2	0	2	4	1	7	21
Receivers	Percentage	22	4	8	0	8	13	8	28	
All	Number	10	6	7	1	9	6	6	15	60
Receivers	Percentage	30	15	16	1	18	9	22	29	

Condition 5–25

Gender	Rejections	Pie size class 0–4	4–6	6–8	8–10	10–12	12–14	14–16	16–25	Total
Male	Number	0	6	2	3	2	7	5	8	33
Receivers	Percentage	0	15	6	19	5	20	23	80	
Female	Number	2	2	1	2	3	0	3	3	16
Receivers	Percentage	17	5	3	6	8	0	20	43	
All	Number	2	8	3	5	5	7	8	11	49
Receivers	Percentage	13	11	4	10	6	12	22	65	

Condition 10–20

Gender	Rejections	Pie size class 0–7	7–8	8–9	9–10	10–11	11–12	12–13	13–20	Total
Male	Number	1	0	0	1	3	2	7	14	28
Receivers	Percentage	6	0	0	3	9	18	39	54	
Female	Number	1	1	5	4	7	3	5	17	43
Receivers	Percentage	6	4	14	15	18	25	38	57	
All	Number	2	1	5	5	10	5	12	31	71
Receivers	Percentage	6	2	7	9	15	22	39	55	

demands as females in Conditions 0–30 and 5–25, and females rejecting approximately 50% more demands than males in Condition 10–20.

To test the effect of x on the probability of rejection, we divided the Sender's demands in each condition into eight classes of size \$3, \$2, and \$1 in Conditions 0–30, 5–25, and 10–20, respectively. Due to the relatively low number of very small or very large demands, the two extreme classes of each frequency distribution have different intervals. Table 2 presents the number of rejections and the corresponding percentage of rejections by pie size class for each condition separately. Within each condition, the results are presented separately for male Receivers, female Receivers, and all Receivers. The class boundaries are shown at the top of each section of the table.

Although male and female Receivers differed from one another in the percentage of rejections, inspection of Table 2 shows that the shapes of the rejection functions are similar. To view these patterns more clearly, the percentages of rejections for each class were computed across gender. The results (Fig. 6) show that the frequency distributions

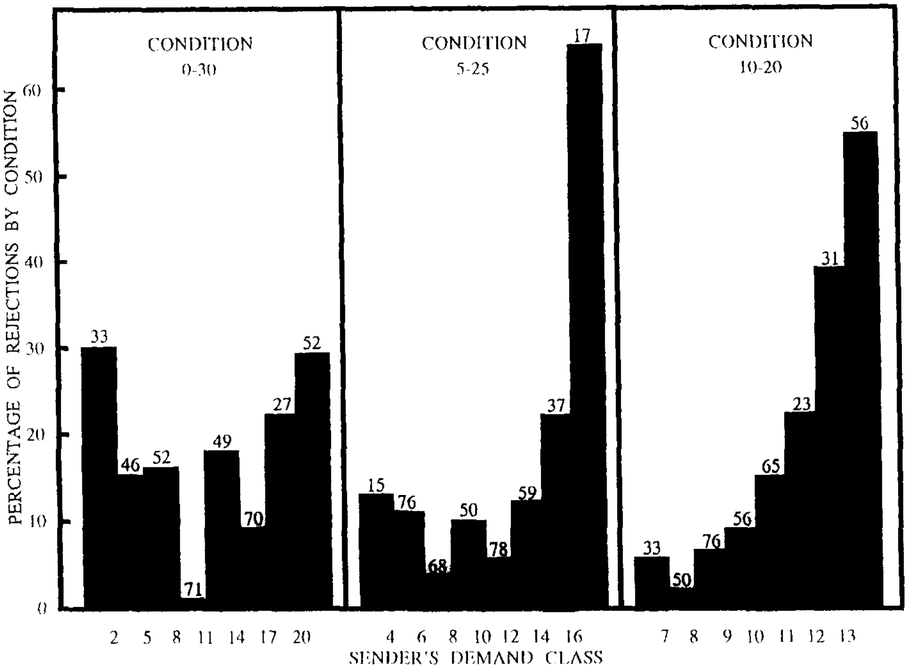

Fig. 6. Percentage of rejections as a function of Sender's absolute demand.

of percentage of rejections are not all monotonic. The frequency distribution for Condition 0–30 is U-shaped with small (0–2) and large (20–30) demands being rejected approximately 30% of the time. As the variance of the pie distribution decreases, the percentage of rejections of small demands decreases rapidly whereas the percentage of rejections of large demands (more than 2/3 of the pie) increases. Thus, as the uncertainty about pie size decreases, the relative frequency distribution of rejections resembles more closely the one observed in ultimatum games with complete information (see, e.g. Güth and Tietz, 1990).

Analyses of individual data show many violations of "monotonicity," where a Receiver rejects a demand x_j and later accepts a larger demand x_k ($x_j<x_k$), even though the prior belief about the distribution of pie sizes is identical in both cases. One possible, though not very likely explanation, is that the Receivers change their criteria for rejection as a function of the number of proposals they have observed. To test this learning hypothesis, we classified the number of rejections in each condition in terms of the trial t ($t=1,\ldots,10$) on which they were made. We then tested the null hypothesis of no association between frequency of violations and trial number. The test results did not justify rejection of the null hypothesis (χ^2 (9)=7.33, 3.04, and 5.48 for Conditions 0–30, 5–25, and 10–20, respectively, $p>0.5$). Similar results were obtained when the frequencies of rejection were combined over the three conditions (χ^2 (9)=8.83, $p>0.3$).

Yet another possible explanation for the high frequency of violations of "monotonicity" is that the Receivers update their threshold parameter γ_R as a function of the

Table 3
Means and standard deviations of predicted, observed, and estimated pies

Pies		Condition 0–30	5–25	10–20
Predicted	Mean	15.00	15.00	15.00
	SD	8.66	5.77	2.89
Observed by Sender	Mean	15.58	14.53	15.14
	SD	8.77	5.93	2.96
Estimated by Sender	Mean	15.50	14.47	15.21
	SD	8.35	5.37	2.89

demands they have observed. If the Receivers update γ_R, then those who have observed lower demands in the past are more likely to reject a higher demand than those observing higher demands. To test this learning hypothesis, we regressed the Receiver's response (accept/reject) on trial t on the mean demand observed by this Receiver on trials 1 through t. The test results rejected the null hypothesis of no linear relationship in each of the three uncertainty conditions ($F_{(1,398)}=4.2$, $p<0.05$; $F_{(1,398)}=11.6$, $p<0.001$; $F_{(1,398)}=17.5$, $p<0.001$; for Conditions 0–30, 5–25, and 10–20, respectively). In each case, Receivers who had faced lower demands in the past were more likely to reject a higher demand than those who observed higher demands. We repeated the analyses with a logistic procedure, which essentially yielded the same results.

4.3. Receiver's estimates

Recall that on each trial, the Receiver was asked to estimate the size of the unknown pie. The estimates did not constitute an integral part of the bargaining process; they were not disclosed to the Sender and they had no effect on payoffs. Nevertheless, the actual estimates summed over the Receivers were surprisingly accurate. Table 3 presents the means and standard deviations of the (i) theoretical (uniform) distribution of the pie, (ii) pies observed by the Sender, and (iii) pies estimated by the Receiver. Each statistic is based on 400 observations. Table 3 shows that the means, and to a lesser extent the standard deviations, of the estimated pie distributions track the corresponding statistics of the observed pie distributions for the three conditions very accurately.

The Receiver's estimates were gathered in part to explain the rejection results. A Receiver would be expected to reject a demand more readily if he believed that his relative share of the pie was unacceptably small. To test this conjecture, we computed for each Receiver and each trial a derived score $z=1-x/k_R$, which will be referred to as the *Receiver's estimated proportion share*. We then divided the z values (one for each trial) into nine classes and counted for each z class the frequency of rejections. Table 4 presents the proportion of rejections and the associated number of responses (acceptances and rejections) by z class. The frequencies are averaged across gender and presented for each condition separately. As expected, the proportion of rejections decreases as the estimated proportion share increases. The major exception occurs in the bottom z class ($0.52\leq z\leq 1.00$), where the proportion of rejections increases. These rejections are

Table 4
Proportion of rejections as a function of Receiver's estimated proportion share

	Condition					
Estimated	0–30		5–25		10–20	
Prop. Share	Prop.	n	Prop.	n	Prop.	n
0–0.065	0.360	75	0.517	29	0.632	19
0.065–0.130	0.121	33	0.100	10	0.533	15
0.130–0.195	0.028	36	0.208	24	0.533	15
0.195–0.260	0.173	52	0.350	40	0.319	47
0.260–0.325	0.219	32	0.062	48	0.140	43
0.325–0.390	0.133	30	0.033	60	0.158	76
0.390–0.455	0.024	41	0.038	52	0.103	68
0.455–0.520	0.026	76	0.009	110	0.021	97
0.520–1.000	0.200	25	0.222	27	0.050	20
		400		400		400

mostly due to the cases where the Sender demanded a very small absolute share and the Receiver rejected it even though he believed that he was receiving more than 50% of the pie.

Another reason for gathering the Receiver's estimates was to relate the behavior of the same subject in his dual role as Sender and Receiver. Recall that demands were made anonymously; no knowledge of the intended Receiver, and no information about the outcome was given. In principle, the subjects could assume different bargaining postures in the two phases, demanding a relatively high proportion of the pie when playing as Senders but expecting relatively large proportions of the pie when playing as Receivers. This type of behavior is often observed on the road when the same individual demands the right-of-way both when he navigates his car or crosses the road on foot. However, if bargainers are characterized by the parameters α and γ and expect others to be similarly characterized, Senders who demand a relatively large proportion of the pie should expect to receive a relatively small proportion when assigned the role of Receivers (see Güth et al., 1982).

For each subject i we compared two scores: $\bar{\bar{d}}_i$, which is the mean of the ten proportion demands he made as Sender, and z_i, which is the mean Receiver's estimated proportion share over the ten demands he observed as a Receiver. A product-moment correlation was then computed between the $\bar{\bar{d}}_i$ and z_i scores. The correlations assumed the values -0.44 ($p<0.0004$) for males, -0.55 ($p<0.0001$) for females, and -0.49 ($p<0.0001$) for both males and females ($n=120$). These correlations indicate that Senders who demanded a relatively large proportion of the pie for themselves expected others to do the same when they (the Senders) assumed the role of Receivers. Similarly, Receivers who believed that they were getting a relatively large proportion of the pie moderated their demands when they assumed the role of Senders. Since roles were interchanged between phases, the correlations reported above do not depend on the particular order by which the two roles were assigned. For similar results about the relationship between players' decisions and their expectations about others' behavior in the Prisoner's Dilemma game, see Dawes et al. (1977).

5. Comparison of offer and demand games

The previous study of offer games by RS used the same three pie size conditions and drew subjects from the same population. As a result, differences in the behavior of Senders and Receivers between the two studies cannot be attributed to differences in design, procedure, or subject population. The previous study of offer games included only twenty (rather than forty) subjects in each condition. In addition, RS did not record the gender of their subjects.[6] Consequently, in the subsequent comparison of offer and demand games the gender factor will be suppressed.

Our first comparison concerns the proportion of the pie that the Sender kept for himself. The Sender's proportion shares, averaged over ten trials, were subjected to a 2×3×2 experiment (offer vs. demand) by condition (0–30, 5–25, 10–20) by phase (1,2) ANOVA. The left hand panel of Table 5 shows the results. The ANOVA yielded a significant main effect due to experiment with Senders in the demand game requesting on the average a higher proportion of the pie (0.68) than Senders in the offer game (0.64). The other significant main effect was due to condition. For each of the two experiments, the Sender's mean proportion share decreased as the variance of the pie size decreased. The means of the Sender's proportion share for Conditions 0–30, 5–25, and 10–20 were 0.69, 0.63, and 0.59 in the offer game and 0.72, 0.66, and 0.65 in the demand game. Although the main effect due to phase was not significant, this finding is qualified by the two significant two-way interaction effects involving the phase factor. In the offer games, experience in playing the game as Receivers decreased the Sender's mean proportion share from 0.66 in Phase 1 to 0.62 in Phase 2. The same experience in the demand games increased the Sender's mean proportion share from 0.66 in Phase 1 to 0.69 in Phase 2. The significant phase by condition interaction effect shows that the effect of experience depends on the Receiver's uncertainty about the pie. In Condition 0–30, when the uncertainty assumes its highest value, experience in playing the game increased the Sender's mean proportion share from 0.69 in Phase 1 to 0.73 in Phase 2. In contrast, the Senders decreased their mean proportion share in Condition 5–25 from 0.65 in Phase 1 to 0.64 in Phase 2 and in Condition 10–20 from 0.64 in Phase 1 to 0.62 in Phase 2.

To assess the effect of pie size on the Sender's proportion share in both studies, we divided the pie distribution into ten classes of equal (10%) intervals. The Sender's proportion shares were then subjected to a 2×10×3 experiment by pie size class by condition ANOVA. The ANOVA results are displayed on the right hand panel of Table 5. The significant main effects due to experiment and condition have already been discussed above. Although the main effect due to pie size class is not significant, this result is qualified by the two significant interaction effects involving pie size class. Fig. 7 displays the nature of the experiment by pie size class interaction. It shows that in each condition (with the exception of the lowest pie size class in Condition 0–30 of the demand game) the Sender's mean proportion share increases in pie size in the offer game and decreases in the demand game. In each condition, the two functions intersect at about the 70th percentile of the pie distribution.

[6] RSP used mixed groups of twenty subjects per session with slightly more males than females.

Table 5
Results from two ANOVA tests on the Sender's proportion share

Experiment by condition by phase				Experiment by condition by pie size class			
Source	DF	F Value	p	Source	DF	F Value	p
Experiment (E)	1	27.6	0.0001	Experiment (E)	1	22.5	0.0001
Condition (C)	2	40.6	0.0001	Condition(C)	2	33.8	0.0001
Phase (P)	1	0.4	0.53	Pie Size (PS)	9	1.6	0.11
E×C	2	1.1	0.35	E×C	2	0.9	0.39
E×P	1	17.0	0.0001	E×PS	9	10.0	0.0001
C×P	2	6.1	0.002	C×PS	18	2.2	0.003
E×C×P	2	2.1	0.13	E×C×PS	18	0.9	0.64

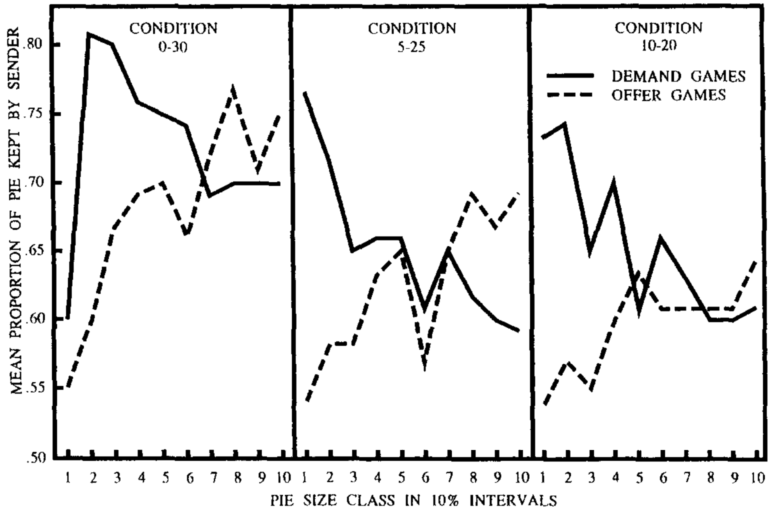

Fig. 7. Mean proportion of pie kept by the Sender in offer and demand games by pie size.

Although the Senders behaved quite differently in the two experiments, the Receivers responded in a very similar way. The overall percentage of rejections in the offer games was 18 compared to 15 in the demand games. Despite the very large number of games contributing to the calculation of these percentages (600 in the offer game and 1200 in the demand game), the difference between these two percentages is not significant (z=1.64, p>0.05).

The dependent variable in our next comparison was the Receiver's estimated proportion share, z. The derived z scores, one for each game, were subjected to a 2×3 experiment by condition ANOVA. The test uncovered two main effects, one due to experiment ($F_{(1,1794)}$=40.7, p<0.0001) and the other to condition ($F_{(2,1794)}$=30.7, p<0.0001). The experiment by condition interaction effect was not significant (F<1). Table 6 presents the means and standard deviations of the z scores by experiment and condition. In each experiment the Receiver increased the estimate of his proportional share as his uncertainty about the pie size decreased. Moreover, the Receivers estimated a higher proportional share in the offer (0.38) than the demand (0.33) game.

Table 6
Means and standard deviations of Receiver's estimated proportion share by experiment and condition

Experiment		Condition 0–30	5–25	10–20	Over conditions
Offer	Mean	0.34	0.39	0.41	0.38
Games	SD	0.13	0.11	0.09	0.11
Demand	Mean	0.29	0.35	0.36	0.33
Games	SD	0.21	0.15	0.14	0.17
Over	Mean	0.31	0.36	0.37	—
Games	SD	0.19	0.14	0.13	—

The Receivers' estimated proportional share corresponds very closely to the analysis of the actual demands. The Receivers estimated correctly that the Senders will demand a higher proportion of the pie in the demand than offer game, and that in each type of game the Sender's proportional share will increase as the uncertainty about pie size increases. Moreover, when the Receiver's estimated proportional share is added to the Sender's proportional share for each combination of experiment and uncertainty condition separately, the sum in each case does not deviate from unity by more than 0.03. It would be difficult to explain this high level of accuracy without postulating some "homegrown expectations" (Harrison and McCabe, 1992) shared by the Senders and Receivers.

6. Comparison with the M&N study

The present section combines the previous RSP study of the offer game and the present study of the demand game and refers to them jointly as the RSPS study. It first compares the M&N and RSPS studies in terms of their design characteristics, and then summarizes the similarities and discrepancies between their major results.

Rather than sampling a poker chip from a box containing 101 poker chips, as in the RSPS study, the Sender in the M&N study rolled an unbiased die with numbers from 1 to 6. As in the RSPS study, the Sender was informed of the roll of the die, whereas the Receiver only knew the probability distribution of the die. Offers and demands were restricted to multiples of 0.5; no such restriction was imposed in the RSPS study.

A major difference between the two studies concerns the method used to elicit offers/demands from the Sender and responses from the Receiver. The M&N study used the "strategy method" in which each agent (Sender or Receiver) is required to submit a complete strategy for the game *before* the die is rolled.[7] In particular, the Sender was required to submit in advance a single offer (or demand) for each of the six possible

[7]M&N are not the first to use the strategy method with the ultimatum game. A similar modification of the extensive form of the ultimatum game with complete information was developed independently by Carter and Irons (1991) and Harrison and McCabe (1992). Their modification calls for all subjects to enter complete strategies prior to play for *both* Senders and Receivers. The actual type that a subject is assigned to play in any period is known to be determined by Nature. Kahneman et al. (1985) also used the strategy method in a game very similar to the ultimatum game.

outcomes of the die. The Receiver was required to specify his response for each possible offer (demand). The smallest money unit of Δ=0.5 restricted the number of the Receiver's information sets, and consequently the number of elements in his strategy vector, to 13. In contrast, the RSPS study used the conventional "decision method," in which agents are required to make actual choices rather than specify strategies before the game commences.

We make no attempt to compare the two methods to each other which we view as complementary not contradictory. The advantage of the strategy method is that it renders individual strategies observable by revealing choices at information sets that do not arise in the course of play. The disadvantage is that it requires agents to respond to hypothetical rather than actual situations. A Receiver may behave differently when presented with an "insultingly low" offer than when asked to state what she would do if this offer were actually presented to her. The strategy method induces agents to state decision rules with fewer contradictions than the decision method.[8] As a result, we would expect considerably fewer violations of monotonicity under the strategy method.

A second major difference is that RSPS did not provide any information about payoffs during the entire game, whereas M&N informed the agents about their payoffs at the end of each trial. As a result, the RSPS study approximates more closely the case of a single-stage ultimatum game whereas the results of M&N are confounded with learning effects. Indeed, M&N reported significant changes in behavior over eight trials for both Senders and Receivers.

The third difference concerns the amount of uncertainty about the pie. The expected value and standard deviation of the theoretical pie distribution in the study of M&N are 3.5 and 1.71, respectively. If we rescale the pie distributions in Conditions 0–30, 5–25, and 10–20 by setting their expected values at μ=3.5, the respective standard deviations are 2.02, 1.35, and 0.67. None of these three conditions corresponds exactly to the one used by M&N. However, the mean results over Conditions 0–30 and 5–25 provide a satisfactory approximation.

A comparison of the M&N and RSPS studies yielded four major results (see also Nagel, 1994):

1. In both studies the Sender's mean proportion share is higher in the demand than the offer game.
2. In both studies the Sender's mean proportion share increases with pie size in the offer game and decreases in the demand game. Fig. 8 compares the Sender's mean proportion share between the two studies for each type of game. The Sender's mean proportion shares for the M&N study (right hand panel) were computed from the frequencies reported in Table 2 of their paper. Each mean is based on 320 responses. To compute the Sender's mean proportion shares for the RSPS study (left hand panel), we divided the pie distributions in Conditions 0–30 and 5–25 into six equal size classes (intervals of 16.7%) and performed the computation across the two conditions. Each mean is based on approximately 67 decisions in the offer game and 133 in the demand game. Note that the two functions for the offer and demand games intersect at

[8]The strategy method does not allow the agent to submit a mixed strategy in any given play of the game.

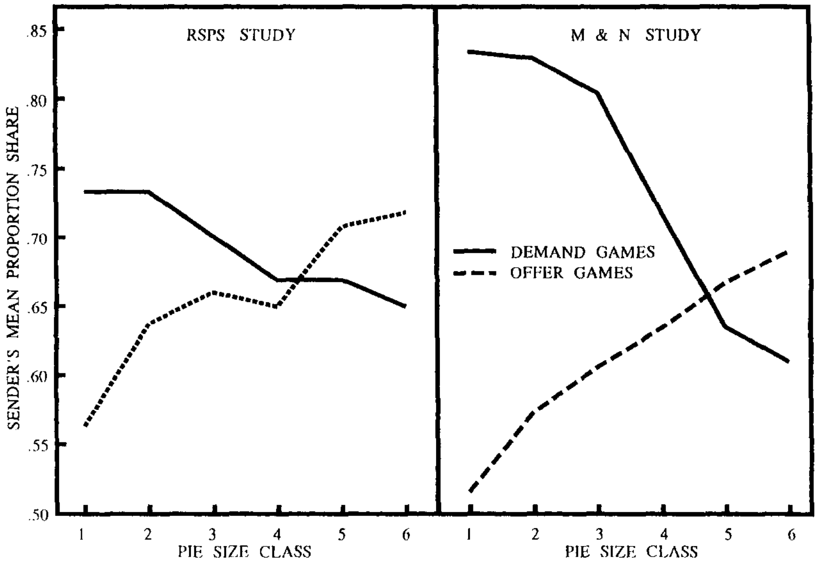

Fig. 8. Mean proportion of pie kept by the Sender as a function of pie size in the RSPS and M&N studies.

about the same point (between pie size classes 4 and 5) in both studies. The major difference is that the functions are steeper in the M&N study. This difference may be attributed to the differences between the decision and strategy methods or to different gender compositions in the two studies.

3. In contrast to the Senders, the Receivers behaved differently in the two studies. M&N reported that significantly more demands were rejected in the demand game than offers rejected in the offer game. We have found no such difference in our study (Section 5).
4. Our final comparison concerns the rate of rejection function. In the M&N study the proportion of offers rejected decreased with pie size in the offer game and the proportion of demands rejected increased with pie size in the demand game. Our results from Conditions 0–30 and 5–25 of the offer game agree with this finding. Offers smaller than $2 were rejected 78.3% of the time in Conditions 0–30 and 5–25, whereas only one out of a total of 56 offers between $5 and $7, and only one out of 101 offers that exceeded $7 in Conditions 0–30 and 5–25 was rejected. Similar to the M&N results, the proportion of demands rejected by the Receiver increased with the pie size in Condition 5–25 of the demand game. Monotonicity of the rejection rate function was not obtained in Condition 0–30 of the demand game (Fig. 6).

7. Discussion

Neither the sequential equilibrium solution predicting $x=k-\epsilon$ for all k, nor the fairness solution predicting $x=k/2$ account for the bulk of the results. The mean proportion of the pie demanded by the Sender averaged across the three uncertainty conditions is exactly two-thirds of the pie. As the uncertainty about the pie size decreases, the distribution of demands shifts in the direction of the distribution of demands observed in the ultimatum game with complete information. Analyses of the demands of individual Senders show only 86 equal split demands (7.2%) out of a total of 1200 demands, and only 77 demands (6.4%) in which the Sender demanded practically the entire pie for himself. Moreover, these "extreme" demands are spread unevenly over the Senders; 9 out of a total of 120 Senders are responsible for approximately 70% of these "extreme" results. One may insist on modeling the bargainers' behavior with strategic models that include arguments of utility functions that are not experimentally controllable in a description of the game (e.g. Bolton, 1991). The basic problem for testing such models is that there is no way to operationalize a common knowledge assumption about information that cannot be experimentally controlled. We agree with Güth that if we want testable models of two-person bargaining that account for the kinds of behavioral regularities observed in experiments we must turn to behavioral theories.

RSP proposed such a model to organize the results of the offer game.[9] The previous model was extended and modified in the present paper to the demand game. The model accounts for the major effect of uncertainty about the pie with Senders increasing their proportional share of the pie as the Receiver's uncertainty about the pie increases. It also accounts for the decrease in the Sender's proportional share as the pie size increases. There are two features of the results that are not accountable by the model, both in Condition 0–30. As shown by Fig. 5 (A), when the pie in Condition 0–30 was "small" (say $0 \leq k \leq 5$), the Senders (both males and females) demanded between 55 and 63% of the pie rather than asking for the entire pie. Fig. 6 shows that the distribution of percentage of rejections in Condition 0–30 was bimodal rather than monotonically increasing. We attribute both these results to the Receiver's desire to secure some minimal *absolute* share. Small demands signal small pies. Receivers who desire some minimal absolute share may, therefore, reject small demands if they believe that the remainder of the pie left for them is "too small." They may do so even if they believe that the Sender is "generous;" Table 4 shows a relatively large proportion of rejections when the Receiver's estimated proportion share *exceeds* 0.52 in both Conditions 0–30 and 5–25. We interpret the decrease in the Sender's proportional share in the lower end of the pie distribution in Condition 0–30 (and to a lesser extent in Condition 5–25) as an attempt by the Sender to leave the Receiver more than some minimal absolute share. Indeed, in more than 25 cases the Senders in Conditions 0–30 and 5–25 demanded for themselves less than 50 percent of small pies. However, as shown by Fig. 6, these attempts by the Sender were not always successful.

Gender is a variable that poses difficulties to traditional economic theory. Nevertheless, gender effects are important to anyone wishing to uncover and account for the different situational (Hoffman et al., in press), motivational, and personal variables that influence bargaining over the division of a shared surplus. In our study females made, in general, more equitable demands than males (Fig. 3), although the difference between them seems to decrease as the uncertainty about the pie is reduced. Our results are stronger

[9]This model accounts for both the uncertainty effect and pie size effects depicted in Fig. 7.

than those of Eckel and Grossman, who found only a small and statistically insignificant difference between males and females in the ultimatum game with complete information. The strongest effect reported by Eckel and Grossman is that females rejected significantly fewer proposals than males. We found the same results in Conditions 0–30 and 5–25, but not in Condition 10–20. Further research is needed with all male, all female, and mixed groups to ascertain whether these gender effects can be replicated.

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