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ULTIMATUM BARGAINING BEHAVIOR
A survey and comparison of experimental results *

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In an ultimatum bargaining game players 1 and 2 can distribute a positive amount of money in the following way: first, player 1 determines his demand which player 2 can then either accept or induce conflict, i.e. player 2 faces the ultimatum either to accept player 1's proposal or to have no agreement at all. Experimentally observed ultimatum bargaining decisions with amounts ranging from 0.50 to 100 German marks are statistically analysed. The demands of player 1 are compared with the acceptance behavior of player 2 with the help of consistency tests in which a subject has to decide in the position of both players. Finally, we consider ultimatum bargaining games with more than just one round where, except for the final round, nonacceptance does not cause conflict but another round of ultimatum bargaining for a smaller cake.

1. Introduction

In many bargaining situations it seems possible to terminate bargaining by imposing an ultimatum. Even if this possibility would not be used frequently, this still would have to be explained. Therefore one needs a theory of ultimatum bargaining behavior.

Bargaining games with the possibility to terminate bargaining by imposing an ultimatum are also interesting from a game-theoretic perspective. Since the solution of such games can be rather extreme, the game-theoretic solution is socially rather unacceptable. Therefore ultimatum bargaining is important for testing the predictive power of the game-theoretic solution. Richard H. Thaler (1988) even includes ultimatum bargaining in his list of 'Anomalies' and relates it to other

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social decision problems.

In all the studies which we consider, only two players, 1 and 2, negotiate how to distribute a given positive amount c of money. Thus, if one player wants to impose an ultimatum on the other, he only has to determine his own demand. The other player can then only either accept the residual amount or choose conflict which implies 0 payoffs for both players. In section 2 we consider one-round ultimatum bargaining games or subgames. Our statistical analysis of experimentally observed decision data compares and analyses all available results of one-round ultimatum bargaining games.

A disadvantage of these experiments is that we only know player 2's reaction to player 1's specific demand but not how he would have reacted to other demands by player 1. This can be avoided if, before knowing player 1's actual demand d_1, player 2 is asked for any possible demand d_1 whether he will accept it or not. In this way one observes not only player 2's acceptance decision but a complete acceptance strategy of player 2. In section 3 we compare the results of Güth et al. (1982) and Kahneman et al. (1986a,b) who both, although in slightly different ways, have tried to observe the complete acceptance strategy of player 2. Since player 2 determines his strategy independently from player 1's demand d_1, the same subject could assume the position of player 1 and the position of player 2. Güth et al. and Kahneman et al. both have exploited this possibility to compare how a given subject's demand d_1 as player 1 is related to his acceptance behavior as player 2.

Binmore et al. (1984,1985) performed experiments with two rounds of ultimatum bargaining: in the first round player 1 first determines his demand d_1 which 2 can then either accept or not, as before. But if 2 does not accept player 1's proposal this does not necessarily imply conflict. Instead there follows another round of ultimatum bargaining for a 'smaller cake' c' where now player 2 can first determine his demand $d_2 (0 \leq d_2 \leq c')$ which player 1 can then either accept or choose conflict. Their conclusions have inspired further experiments with more than one round of bargaining. In section 4 we compare the results of Binmore et al. with those of Güth and Tietz (1986), Neelin et al. (1988) as well as with the comparable decision data of Ochs and Roth (1989). The final remarks summarize the results and indicate lines of future research.

2. Strategic power versus distributive justice

The game-theoretic solution of one-round ultimatum bargaining games is rather obvious. If $d_1 < c$, player 2 should obviously accept player 1's proposal. Thus player 1 can ask for nearly all of c and leave only a crumb of the 'cake' c for player 2. Let $\epsilon(>0)$ be the smallest positive unit of money. If player 2 would not accept the demand $d_1 = c$ by player 1 the optimal demand of player 1 would be $d_1^* = c - \epsilon$ (otherwise $d_1 = c$ can also be an equilibrium demand). Since this demand will be accepted by player 2, the solution payoffs are $c - \epsilon$ for player 1 and ϵ for player 2, i.e. player 1 receives nearly the whole amount c. Due to this extremely 'unfair' distribution of rewards one-round ultimatum bargaining games are one of the most critical paradigms for testing the predictive power of the game-theoretic solution. Since ultimatum bargaining games are extensive games with perfect information (all information sets are singletons), the appropriate solution concept for such games is that of a subgame perfect equilibrium point (see Selten 1975).

In a simple reward allocation experiment (see, for instance, Mikula 1973; and Kahneman et al. 1986a,b) a subject has to allocate the total reward $c(>0)$ among two individuals who both contributed to obtain the total reward c. Viewed as a game the solution of such an allocation problem is clearly that the allocator takes all of c for himself, thereby leaving nothing for his partner. This similarity of the game-theoretic allocation explains why the two decision problems, ultimatum bargaining games and reward allocation problems, are often seen as closely related (see Thaler 1988; and Forsythe et al. 1988). The essential differences between the two decision problems are, of course, that the allocator in reward allocation does not have to fear a rejection by his partner and that reward allocation problems are neither presented as strategic games nor usually perceived as situations where egoistic motivations should dominate. The reward allocation experiments of Hoffman and Spitzer (1982,1985) are more complicated since the total reward depends on the allocation result and since players can agree on side payments.

In the study of Güth et al. (1982) the amount c varied from 4 to 10 German marks. Furthermore, all subjects played successively two games with different partners in order to observe whether experience affects ultimatum bargaining behavior. In table 1 the 'low rewards' data of

Table 1
The plays of ultimatum games.

Experiment	1st game			2nd game			3rd game		
	c	d_1	$\delta_2(d_1)$	c	d_1	$\delta_2(d_1)$	c	d_1	$\delta_2(d_1)$
Low rewards	4.00	2.00	1	4.00	3.00	0			
	4.00	4.00	0	4.00	3.00	0			
	4.00	4.00	1	4.00	3.00	1			
	5.00	2.50	1	5.00	3.00	1			
	5.00	3.00	1	5.00	4.00	0			
	5.00	3.50	1	5.00	4.99	0			
	6.00	3.00	1	6.00	3.00	1			
	6.00	4.00	1	6.00	3.80	1			
	6.00	4.80	0	6.00	5.00	0			
	7.00	3.50	1	7.00	4.00	0			
	7.00	5.00	1	7.00	4.00	1			
	7.00	5.85	1	7.00	5.00	1			
	8.00	4.00	1	8.00	5.00	1			
	8.00	4.35	1	8.00	6.50	1			
	8.00	5.00	1	8.00	7.00	1			
	9.00	5.00	1	9.00	4.50	1			
	9.00	5.55	1	9.00	4.50	1			
	9.00	8.00	1	9.00	6.00	1			
	10.00	5.00	1	10.00	6.00	1			
	10.00	5.00	1	10.00	7.00	1			
	10.00	6.00	1	10.00	7.50	1			
Auction winners	15.00	8.00	1	15.00	10.00	1	15.00	7.50	1
	15.00	8.00	1	15.00	10.00	1	15.00	9.00	1
	15.00	8.50	0	15.00	10.00	1	15.00	9.50	1
	15.00	9.00	1	15.00	11.00	0	15.00	10.00	1
	55.00	28.00	1	55.00	30.00	1	55.00	20.00	1
	55.00	35.00	1	55.00	35.00	1	55.00	36.00	1
	55.00	40.00	1	55.00	37.00	1	55.00	41.25	1
	55.00	45.00	1	55.00	50.00	0	55.00	45.00	1
	100.00	55.00	1	100.00	60.00	1	100.00	60.00	1
	100.00	55.00	1	100.00	65.00	1	100.00	70.00	1
	100.00	60.00	1	100.00	67.00	1	100.00	78.00	1
	100.00	61.00	1	100.00	70.00	1	100.00	81.00	0

Second round subgames									
Güth and Tietz	0.50	0.50	0	3.50	2.00	0			
	3.50	3.50	0	4.50	2.50	1			
	4.50	2.50	0	4.50	2.50	1			
	4.50	3.50	0	4.50	3.00	1			
	13.50	8.00	1	31.50	15.75	1			
	13.50	8.50	1	31.50	20.00	1			
	13.50	9.50	0	31.50	21.50	0			
	31.50	22.50	1						
	31.50	27.50	0						
Neelin et al.	$1.25	$0.25	0						
	$1.25	$0.50	1						
	$1.25	$0.60	1						
	$1.25	$0.62	1						
	$1.25	$1.00	0						
	$1.25	$1.20	0						
	$1.25	$1.20	0						
	$1.25	$1.24	0						
	$1.25	$1.25	0						
	Games 1–3			Games 4–6			Games 7–10		
Ochs and Roth [a]	12.0	6.00	1	12.00	6.00	1	12.00	7.80	1
	12.00	10.80	0	12.00	9.60	0	12.00	8.40	0
	12.00	11.88	0	12.00	11.88	0	12.00	8.40	0
	18.00	9.00	1	18.00	9.54	1	12.00	10.00	0
	18.00	9.36	1	18.00	9.90	1	18.00	9.00	1
	18.00	9.90	1	18.00	10.80	1	18.00	9.90	0
	18.00	9.90	1	18.00	13.50	0	18.00	9.90	0
	18.00	13.50	1				18.00	10.80	0
	18.00	14.40	0				18.00	13.50	0
Third round subgames [a]	5.00	4.00	0	11.00	5.50	1	5.00	2.50	1
	11.00	5.50	0	11.00	6.49	0	11.00	5.50	1
				11.00	9.35	0	11.00	6.60	1

[a] Normal amounts in $; note that subjects were paid only in one of ten games. (When comparing the various data sets of table 1 we therefore have to multiply these amounts by $\frac{2}{10}$ based on an exchange rate $1 for DM2.)

games with c ranging from 4 to 10 German marks were observed by Güth et al. (1982: tables 4 and 5). Due to random pairing the (sorted) results listed in table 1 usually are decision data of different subjects. We first indicate whether it was the 1st or 2nd game. For each game we give the amount c and the play, consisting of players 1's demand d_1 and player 2's acceptance decision $\delta_2(d_1)$. Here $\delta_2(d_1) = 1$ means that 2 accepts proposal d_1 whereas $\delta_2(d_1) = 0$ means that 2 chooses conflict.

The 'auction winners' (data) in table 1 are the plays observed by Güth and Tietz (1985, 1986) who auctioned the position of ultimatum bargainers before letting the auction winners play the ultimatum bargaining game. In their experiments subjects were first informed about the rules of second highest bid-price auctions and that it is a dominant strategy to bid the true value in such auctions. In a second highest price auction (see Vickrey 1961) the object is sold to the highest bid(der) at the price of the second highest bid. After these instructions all subjects participated in normal, 4-person, second highest bid-price auctions so that the authors could assess the proportion of subjects who accepted that bidding the true value is optimal. The share of inessential deviations from bidding truthfully (less than 5% of the true value) was 85%.

Once subjects were familiar with bidding in second highest bid-price auctions they were told that they were then going to bid for strategic positions. They were informed how to play ultimatum bargaining games with amounts c of 15, 55, and 100 German marks and then asked to bid either for the position of player 1 or for the one of player 2, i.e., we conducted an independent auction for both ultimatum bargaining positions and every single game. Afterwards the auction winners were determined and privately informed about the price (the next highest bid for the same position) which they had to pay for their strategic position. Then, knowing their own price but not the one of their opponent, the two auction winners played the ultimatum bargaining game. Denote by x_i player i's win in the ultimatum bargaining game and by p_i the price which i has to pay for his position i in the ultimatum bargaining game. The final win of the subject who became player i is $x_i - p_i$. These final payoffs were paid immediately after the game. As can be seen from table 1 three games were played successively. It should be noted that the decision data in the 1st, 2nd, and 3rd game for the amounts $c = 15$, 55, and 100 German marks usually came

Table 2
Average results of table 1.

Experiment	Repetition															
	1st game				2nd game				3rd game				All games			
	c	d_1	$\underline{d}_1$	δ_2	c	d_1	$\underline{d}_1$	δ_2	c	d_1	$\underline{d}_1$	δ_2	c	d_1	$\underline{d}_1$	δ_2
Low rewards	7	4.43	0.65	0.905	7	4.75	0.691	0.714					7	4.59	0.67	0.81
	(2)	(1.32)	(0.162)	(0.294)	(2)	(1.42)	(0.13)	(0.452)					(2)	(1.38)	(0.148)	(0.393)
	$N=21$				$N=21$								$N=42$			
Auction winners	56.67	34.38	0.603	0.917	56.67	37.92	0 676	0.833	56.67	38.94	0.656	0.917	56.67	37.08	0.645	0.889
	(34.7)	(20.6)	(0.086)	(0.276)	(34.7)	(23.1)	(0.083)	(0.373)	(34.7)	(26.9)	(0.127)	(0.276)	(34.7)	(23.8)	(0.105)	(0.314)
	$N=12$				$N=12$				$N=12$				$N=36$			
Second round subgames																
Güth and Tietz	12.94	9.56	0.761	0.333	15.93	9.61	0.595	0.714					14.25	9.58	0.688	0.5
	(10.9)	(8.81)	(0.156)	(0.471)	(13.5)	(8.36)	(0.062)	(0.452)					(12.21)	(8 62)	(0.149)	(0.5)
	$N=9$				$N=7$								$N=16$			
Neelin et al.	2.5	1.75	0.699	0.333									2.5	1.75	0.699	0.333
	(0)	(0.722)	(0.289)	(0.471)									(0)	(0.722)	(0.289)	(0.471)
	$N=9$												$N=9$			
	Games 1–3				Games 4–6				Games 7–10							
Ochs and Roth	3.2	2.11	0.673	0.667	3.09	2.04	0.674	0.571	3.07	1.97	0 656	0.222	3.12	2.04	0.667	0.48
	(0.566)	(0.475)	(0.179)	(0.471)	(0.594)	(0.432)	(0.166)	(0.495)	(0.596)	(0.328)	(0.117)	(0.416)	(0.588)	(0.419)	(0.156)	(0.5)
	$N=9$				$N=7$				$N=9$				$N=25$			
Third round subgames																
	Games 1–3				Games 4–6				Games 7–10							
Ochs and Roth	1.6	0.95	0.65	0	2.2	1.42	0.647	0.333	1.8	0.973	0.533	1	1.9	1.14	0.605	0.5
	(0.6)	(0.15)	(0.15)	(0)	(0)	(0.326)	(0.148)	(0.471)	(0 566)	(0.347)	(0.047)	(0)	(0.52)	(0.374)	(0.133)	(0.5)
	$N=2$				$N=3$				$N=3$				$N=8$			
All experiments	16.1	10.1	0.667	0.677	19.33	12.81	0.669	0.7	29.71	20.3	0.641	0 667	19.69	12.92	0.663	0.684
	(25.7)	(15.5)	(0.183)	(0.467)	(27.8)	(18.5)	(0.124)	(0.458)	(36.5)	(26.6)	(0.123)	(0.471)	(29.0)	(19.3)	(0.154)	(0.464)
	$N=62$				$N=50$				$N=24$				$N=136$			

Note: Standard deviations are given in parentheses.

from different groups of subjects since the strategic positions of each game were auctioned independently.

The next data set of table 1, named '2nd round subgames' (data), are the plays which were observed in the second round of two-round ultimatum bargaining games where no agreement has been reached in the first round. The first subset of decision data in the 1st and 2nd games gives the corresponding results of Güth and Tietz (1988a), and the second subset with observations only for the 1st game contains the results of Neelin et al. (1988). The data of Ochs and Roth (1989) are listed by aggregating the first three games, games 4 to 6, and games 7 to 10, respectively. The '3rd round subgames' are the corresponding data of Ochs and Roth (1989). We only included results of last-round subgames with equal discount factors for both players. The corresponding results of Binmore et al. (1984, 1985) were not available.

In table 2 we give the mean reward amount c, the mean demand d_1, the mean relative demand $\underline{d}_1$ ($\underline{d}_1 = d_1/c$), and the mean acceptance decision δ_2 individually for the different sets of experimentally observed data shown in table 1 as well as for their aggregates. It should be mentioned that all ultimatum bargaining games presented in tables 1 and 2 are strategically equivalent although they are embedded in different scenarios. When playing the ultimatum game the costs of strategic positions as well as the loss of efficiency implied by not reaching an agreement for the bigger pie in the first rounds are both sunk costs which do not have any impact on the optimal decision behavior.

If $N > 10$, the mean relative demanded shares $\underline{d}_1$ ranging from 0.6 to 0.69 do not vary dramatically. Nevertheless, table 2 reveals how strongly strategically irrelevant aspects can influence ultimatum bargaining decisions. This is most clearly demonstrated by the mean acceptance decision δ_2 varying from 0.22 in the 3rd games of the 2nd round subgames of the shrinking cake experiments to 0.92 in the auction winners experiments. Auctioning strategic positions seems to induce the most consistent kind of behavior.

Game theory predicts $\underline{d}_1$ to be nearly 1 and $\delta_2 = 1$ for $d_1 < c$ since $d_1 = c$ and $d_1^* = c - \epsilon$ are the only equilibrium demands. Contrary to this, $\underline{d}_1$ was consistently and significantly smaller than 1. Furthermore, the sometimes extremely low acceptance rates δ_2 in table 2 indicate that players 2 are often enough willing to sacrifice quite a monetary amount in order to punish player 1 for making an 'unfair' proposal (see

Güth (1988) who relates such a behavior to equity theory). A previous loss of efficiency by failing to reach an agreement on the bigger cake seems to increase this willingness to punish dramatically. Of course, in most last-round subgames of table 2 the mean amount c to be distributed has been rather low. The only exceptions are the second round subgames of Güth and Tietz (1988a) with $c = 12.94$ and $c = 15.93$ German marks as a result of the games with an almost unshrinking cake.

An attempt to explain the relative demand behavior of player 1 globally by a linear regression function of the amount c and the experience parameter 'game' fails. Dummy variables for the different experiments also do not influence demand behavior significantly.

For the 'auction winners' experiments it has been shown that the demand behavior was positively influenced by the bids in the auction (cf. Güth and Tietz 1985,1986). More globally, $\underline{b}_1$, i.e. the bid b_1 of player 1 divided by c, has a distinct influence on $\underline{d}_1$:

$$\begin{array}{llll}
\underline{d}_1 = & 0.372 + & 0.422\ \underline{b}_1, & R^2 = 0.400,\ N = 36 \\
\sigma & (0.059) & (0.088) & \\
t & 5.42 & 4.80 & \\
\alpha & < 0.001 & 0.001. &
\end{array} \qquad (1)$$

R^2 is the coefficient of determination and N the number of observations. σ denotes the standard deviation of the regression coefficients, t the corresponding t-statistic, and α the significance level.

For the last-round subgames let c_p denote the cake size of the second last round. The relation c/c_p is called the cake-shrinking parameter of the previous round. We have tried to explain the relative demand behavior $\underline{d}_1$ by the cake-shrinking parameter c/c_p, by the cake size c, the experience parameter 'game', the previous sacrifices (i.e. the amounts given up by turning down the previous offer), and the experimental dummies reflecting the various experimental procedures. None of the variables has a statistically significant influence.

Since δ_2 assumes only values of 0 and 1, the assumptions of the classical linear regression model with regresssand δ_2 are not fulfilled. The optimal separation function for acceptance decisions (see Hartung and Elpelt (1986: 140 f.) as well as Güth and Tietz (1988b) for details), which maximizes the number of correctly explained acceptance decisions, is given by

$$\delta_2(\underline{s}_2) = \begin{cases} 0 & \text{for } \underline{d}_1 \geq \underline{s}_2 \\ 1 & \text{otherwise,} \end{cases} \tag{2a}$$

with

$$\underline{s}_2 = 0.737 + 0.00262c. \tag{2b}$$

According to $\underline{s}_2$ player 2 is willing to accept a lower share if the cake is bigger. Function (2) explains 83% of the 136 observed acceptance decisions. Similar results can be obtained if the cake size parameter c is substituted by dummy variables for different experiments. The mean of the 93 accepted relative demands $\underline{d}_1^a$ is with 0.61 significantly smaller than the mean of the 43 rejected relative demands $\underline{d}_1^r$ (Mann-Whitney U test, $\alpha < 0.00001$).

Kravitz and Gunto (1988) as well as Güth et al. (1990) try to explore psychological reasons for ultimatum bargaining behavior. In the experiment of Kravitz and Gunto subjects do not play the ultimatum bargaining game properly. As player 2, subjects are confronted with predetermined demands (robot strategies) by player 1 where in two of three conditions the greedy proposal is supplemented by a nasty (the 'power comment') or a justifying (the 'need comment') remark. Subjects were paid a fixed amount unrelated to the offer and their reaction to it. Especially, in the case of the power comment subjects should have recognized that they were not faced with a real opponent. Before the experiment subjects were asked which demand they would choose as player 1, which proposal they considered as fair, and what they required as player 2 to accept. In a post-experimental questionnaire they were furthermore asked to rate the personality of their 'opponent' and the procedure of ultimatum bargaining on discrete bipolar scales.

Subjects in the Güth et al. (1990) experiment first answered the personality questionnaire 16PA, developed by Brandstätter (1988). In addition to some personal characteristics like sex, age, education, subjects were required to rate their personality on 33 discrete bipolar scales. We do not give a detailed description of this personality questionnaire as it is not related to ultimatum bargaining. The main reason for using it is an explorative attempt to explain ultimatum bargaining behavior by general psychological characteristics. To reduce the number of dimensions Güth et al. (1990) apply factor analysis and then use these factors to explain experimentally observed ultimatum bargaining decisions by these subjects. Psychological variables were useful in explaining the bidding and bargaining decisions but usually for different variables different factors were relevant.

For their ultimatum bargaining experiment Güth et al. (1990) uses the auctioning procedure of Güth and Tietz (1985, 1986) in a 2-factorial design: each of the amounts $c =$ DM18, DM32, and DM54 is played once in the usual way and once with an additional transfer payment to player 2 which equals the cake size c and which is paid independently of what happens in bargaining. Thus player 2 is sure to receive c in addition to what he earns in ultimatum bargaining. As a consequence, the game-theoretic solution gives both players nearly the same amount ($c - \epsilon$ and $c + \epsilon$, respectively) so that the game-theoretic solution is supported by the distribution standard of equal monetary rewards (see Homans 1961; and Güth 1988). Unfortunately, the hypothesis that player 1 will demand significantly more in case of the transfer payment had to be rejected.

Prasknikar and Roth (1989) compare ultimatum bargaining behavior with the experimental results for sequential best shot games (Harrison and Hirshleifer 1989). In a sequential best shot game player 1 first determines his contribution and then, knowing 1's decision, player 2 chooses how much he contributes. For both players the level of the public good is determined purely by the maximal individual contribution. The unique subgame perfect equilibrium point (Selten 1975) prescribes a 0 contribution by player 1, i.e. only player 2 has to bear the burden of providing the public good. In the experiment of Harrison and Hirshleifer (1989) the equilibrium payoff of player 1 and 2 was \$3.70 and \$0.42, respectively. Nevertheless their experimental results strongly support the game-theoretic prediction.

Since in the Harrison and Hirshleifer experiment a subject knew only his own payoff function, these best shot games can be viewed as games with incomplete information whereas ultimatum bargaining, as defined above, relies on complete information (i.e., all payoff functions are common knowledge). Prasknikar and Roth (1989) experimentally compare best shot games with and without complete information with ultimatum bargaining games. They confirm the conclusions by Harrison and Hirshleifer for best shot games with complete information. For best shot games with incomplete information the behavior is different from equilibrium behavior although it is moving in the direction of the equilibrium decisions. Most importantly, for both variants of best shot games the observed means are much closer to equilibrium behavior than for the ultimatum bargaining.

To explain the puzzling difference in the predictive power of game theory for best shot games and ultimatum bargaining Prasknikar and Roth (1989) explore the experimentally observed reaction behavior to non-equilibrium opening moves. Whereas in best shot games the game-theoretic opening move yields the highest payoff expectation, the best opening move in ultimatum bargaining is to leave a significant amount (about 40% of the cake) for player 2.

Equal positive contributions in best shot games are obviously inefficient since one of the two contributions is completely useless. If sharing the burden of providing the public good is impossible, fairness considerations cannot be applied. Furthermore, the very obvious aspect of efficiency requires extreme payoff distributions. The results of Hoffman and Spitzer (1982, 1985) demonstrate that the desire for efficiency can be a strong motivation. In ultimatum bargaining, efficiency does not have any impact on the payoff distribution since it only excludes conflict. Best shot games are therefore more complex than ultimatum bargaining games and more comparable to the 'complicated games' of Güth et al. (1982) which allow for efficient and inefficient payoff distributions.

3. Consistency of demand and acceptance behavior

In games without chance moves a (pure) strategy vector uniquely determines a play but many different strategy vectors might imply the same play. In the specific context of ultimatum bargaining games a play consists of players 1's proposal d_1 and 2's reaction $\delta_2(d_1)$ to this specific proposal by player 1. Whereas the choice of d_1 corresponds to choosing a strategy for player 1, the same is not true for player 2. A pure strategy of player 2 is a function $\delta_2(\cdot)$ which assigns to all possible demands d_1 by player 1 a decision $\delta_2(d_1) = 1$ or $\delta_2(d_1) = 0$. Thus the plays listed in table 1 give only a point information about the general decision behavior $\delta_2(\cdot)$.

An obvious way to observe the strategy $\delta_2(\cdot)$ instead of only a reaction $\delta_2(d_1)$ to one specific demand d_1 is to ask player 2 how he would react to all possible demands d_1 before being confronted with the specific decision d_1 of player 1, and to determine the result of ultimatum bargaining by the demand d_1 of player 1 as well as by the hypothetical decision behavior $\delta_2(\cdot)$ of player 2, i.e., if $\delta_2(d_1)=1$, player 1's proposal is accepted whereas for $\delta_2(d_1)=0$ conflict results. In the consistency test of Güth et al. (1982) every subject first had to determine his demand d_1 as player 1 and then this minimal acceptance payoff m_2 as player 2, presuming that the subject will only accept proposals d_1 with $c-d_1 \geq m_2$. Subjects were informed in advance that both their decisions d_1 and m_2 matter since every subject is engaged in two ultimatum bargaining games, once as player 1 and once as player 2.

Because of the experimental procedure Güth et al. (1982) were able to identify both decisions d_1 and m_2 of a given subject. There were 6 cases with $d_1+m_2>c$, 15 with $d_1+m_2=c$, and 17 with $d_1+m_2<c$. Apparently, subjects with $d_1+m_2>c$ consider themselves as exceptionally tough whereas subjects with $d_1+m_2<c$ would accept more ambitious demands d_1 than their own one. Subjects with $d_1+m_2=c$ seem to rely on a point solution, i.e., they consider one and only one agreement as acceptable. For instance, 7 of the 15 subjects with $d_1+m_2=c$ proposed the equal split of c. We will not investigate the individual decisions in further detail since we want to compare the results of Güth et al. (1982) with those of Kahneman et al. (1986a and b), who provide only aggregated data.

Kahneman et al. (1986) use ultimatum bargaining games to demonstrate the discrepancy between the 'assumptions of economics' like, for instance, profit maximization for firms and the actually observable decision behavior. In their 'Study 1: Resisting Unfairness', they tried to investigate how a subject as player 2 would react to 'unfair' payoff proposals by player 1. Their subjects also assumed both the position of player 1 and the one of player 2. First a subject had to decide as player 2 for any possible allocation of $c=\$10$ ranging from $d_1=\$0.50$ to $d_1=\$9.50$ in steps of $c=\$0.50$ whether he would accept it or not. Afterwards he had to allocate c as player 1 by choosing his demand d_1 out of $\{\$0.50,\dots,\$9.50\}$.

The experiment was conducted in a psychology and a commerce class where psychology students were matched with psychology stu-

Table 3
Mean offered share, proportion of equal splits, mean minimal demanded share, proportion of demanded shares > 0.15 of Kahneman et al. (1986: table 1) and Güth et al. (1982: table 7) as well as the corresponding results from table 1 whenever they are defined.

	Subject group			Consistency test		From table 1			All games
	Psych/ Psych	Psych/ Com	Com/ Psych			1st game	2nd game	3rd game	
Mean share offered to player 2	0.476	0.447	0.421	0.419	Low rewards	0.35	0.31	–	0.33
					Auction winners	0.40	0.32	0.34	0.35
					Last round sg.	0.29	0.36	0.38	0.33
					Mean	0.33	0.33	0.36	0.34
Proportion of equal splits	81%	78%	63%	43%	Low rewards	33%	14%	–	24%
					Auction winners	–	–	8%	3%
					Last round sg.	14%	18%	25%	17%
					Mean	18%	12%	13%	15%
Mean minimal demanded share by player 2	0.259	0.224	0.200	0.363		–	–	–	–
Proportion of minimal demanded shares > 0.015	58%	59%	51%	78%		–	–	–	–
					Low rewards	21	21	–	42
					Auction winners	12	12	12	36
					Last round sg.	29	17	12	58
Number of subjects	43	37	35	37	Total	62	50	24	136

dents (the 'Psych/Psych' column of table 3), psychology students as player 1 were facing commerce students being player 2 (the 'Psych/Com' column of table 3), and vice versa (the 'Com/Psych' column of table 3). The aggregate data given by Kahneman et al. (1986b: table 1) are the mean share $(c - d_1)/c$ offered to player 2, the proportion of equal splits $d_1 = c/2$, the mean minimal demanded share m_2/c, the proportion of minimal demands m_2 with $m_2 \geq 0.15c$, and the number of subjects. In table 3 we give these results in the first three columns mentioned above. The fourth column of table 3 contains the corresponding values for the consistency test of Güth et al. (1982: table 7). Whenever they are defined we also list the corresponding results of table 1 individually for the 1st, 2nd, and 3rd game as well as for all three games together. For the sake of completeness we specify the corresponding values separately for low-rewards, auction-winners, and last-round subgame experiments as well as for the whole set of data contained in table 1.

Table 3 reveals some surprising differences in the results. We focus our attention on the proportion of equal splits proposed by player 1. A similar analysis could be performed for the proportion of minimal demanded shares > 0.15 but the results of consistency tests could not be compared with those of normal ultimatum bargaining games.

There is no significant difference in the proportion of equal splits of the Psych/Psych and the Psych/Com group ($\alpha = 0.37$), but the average share of both these groups is significantly greater than the corresponding value of the Com/Psych group ($\alpha < 0.05$). Thus, psychology students tend to propose equal splits more often than students of business administration. However, the Com/Psych group has a significantly greater proportion of equal splits than the one observed in the consistency test of Güth et al. ($\alpha < 0.05$). We suppose that this is mainly due to the way of performing experiments (e.g. only a random sample of subjects was paid in the Kahneman et al. experiment).

But even the proportion of equal splits (43%) observed by Güth et al. (1982) is much higher ($\alpha < 0.001$) than the one in normal ultimatum bargaining games (15% in average). Thus, consistency tests seem to induce subjects to consider and to perceive the situation in quite a different way. Analysing the situation both from the viewpoint of player 1 and 2 apparently reduces the incentive to exploit the strategic advantage of player 1. Altogether this shows that subjects hardly ever apply game-theoretic reasoning to determine their behavior but that the extent of paying attention to strategic aspects can be strongly affected by the experimental environment whenever the monetary incentives are rather low.

Bolle (1988) uses consistency tests to explore whether high reward experiments can be substituted by low cost experiments with high potential rewards but a rather low reward expectation. The paper is mainly an attempt to justify experiments where not all subjects are paid according to their success but only a random sample. Bolle performed four different experiments: in the D2 experiment 12 pairs of subjects played for an amount c = DM2; in the P20 experiment with c = DM20 the monetary reward expectation was the same since only 1 of 10 pairs of subjects was actually paid. A similar distinction holds for the D20 and P200 experiment with a deterministic or probabilistic monetary reward expectation of DM20 per pair.

The proportion of equal splits with 62.5%, 50%, 41.7%, and 55% for the D2, P20, D20, and P200 experiment was always higher than the one of the consistency test by Güth et al. which already exceeded considerably the corresponding quota of 15% for usual ultimatum bargaining games. On the other hand, the proportion of minimal demanded shares (> 0.15) by player 2 with 79.2%, 80%, 66.7%, and 80% was always higher than the corresponding data of Kahneman et al. (1986b). One could say that Bolle's observations reveal a demand behavior of player 1 similar to Kahneman et al. and an acceptance behavior of player 2 corresponding to the results of Güth et al.

4. How to bargain for a shrinking cake?

The speciality of the bargaining situations analysed above is that there is just one round of ultimatum bargaining, i.e., one player proposes an agreement which the other can accept or not and then the game is over. The other extreme is the case of infinitely many rounds of ultimatum bargaining where in each round one player suggests an agreement which the other can accept or reject and where in the latter case a new round of ultimatum bargaining follows.

A model of the latter type has been rigorously analysed by Rubinstein (1982) who assumes that the two players take turns in being the proposer. Thus in all odd rounds $t = 1, 3, 5, \ldots$ player 1 would be proposing whereas in all even rounds $t = 2, 4, 6, \ldots$ this would be done by player 2. If no agreement is reached in finite time, both players receive nothing. In case an agreement to distribute c is reached in round t, player $i = 1, 2$ receives $x_i \rho_i^{t-1}$. Here x_i is the amount allocated to i and ρ_i with $0 < \rho_i < 1$ is player i's discount factor.

Thus the two players can only allocate the full amount c if they reach an agreement immediately, i.e. in round $t = 1$. Otherwise the 'cake', the amount which can be distributed, will shrink with each round not yielding an agreement.

Rubinstein (1982) has shown that the game-theoretic solution implies an immediate agreement according to which player 1 receives the share $(1 - \rho_2)/(1 - \rho_1\rho_2)$ of the amount c whereas 2's share is $\rho_2(1 - \rho_1)/(1 - \rho_1\rho_2)$. Thus the more patient player 1 is the more successful he will be. Furthermore, the special case $\rho = \rho_1 = \rho_2$ with $0 < \rho < 1$ illustrates that it is usually better to be first in proposing an agreement. For $\rho = \rho_1 = \rho_2$ the share of both player 1 and 2 is $1/(1 + \rho)$ and $\rho/(1 + \rho)$, respectively. Thus player 1's share approaches 1 for $\rho \to 0$ whereas for $\rho \to 1$ the solution agreement approaches the equal split of c.

The experiment of Binmore et al. (1984, 1985) deviates from the previous ultimatum bargaining experiments in the direction of the game model analysed by Rubinstein (1982). Instead of just one round Binmore et al. assume that there are two rounds of ultimatum bargaining. In the first round player 1 proposes d_1 with $0 \leq d_1 \leq c$ which 2 can accept or reject. If 2 rejects d_1 the second round follows where now player 2 can propose how to allocate the smaller cake c' with $0 < c' < c$ by choosing his demand d_2 with $0 \leq d_2 \leq c'$. In case that 1 rejects d_2 the game is over and both players receive nothing. Otherwise the payoff result is determined by the accepted proposal, i.e., players 1 and 2 receive d_1 and $c - d_1$, respectively, in case of an agreement in the first round and $c' - d_2$ and d_2 if an agreement is reached in the second round.

If the second round is reached, player 1 should accept any proposal d_2 satisfying $d_2 < c'$. Assuming that 1 will not accept the proposal $d_2 = c'$ leaving nothing for him player 2's optimal demand d_2 is therefore $d_2^* = c' - \epsilon$ where again ϵ denotes the smallest money unit. Anticipating this result for the second round, player 2, in turn, will accept any proposal d_1 with $c - d_1 > c' - \epsilon$ which shows that player 1 can demand $d_1^* = c - c'$ without having to fear a rejection by player 2.

Table 4
Relative opening demands $\underline{d}_1$ by player 1 in two-round ultimatum bargaining for a shrinking cake.

Interval for relative demands	Binmore et al. exp.			Güth and Tietz exp.					
	1st game	2nd game	both games	1st game		2nd game		Both games	
$c'/c=$	0.25	0.25	0.25	0.1	0.9	0.1	0.9	0.1	0.9
$\underline{d}_1 \leq 0.05$	–	–	–	–	–	–	–	–	–
$0.05 < \underline{d}_1 \leq 0.15$	–	–	–	–	– *	–	– *	–	– *
$0.15 < \underline{d}_1 \leq 0.25$	–	–	–	–	–	–	–	–	–
$0.25 < \underline{d}_1 \leq 0.35$	3	2	5	–	–	–	–	–	–
$0.35 < \underline{d}_1 \leq 0.45$	12	3	15	–	–	–	3	–	3
$0.45 < \underline{d}_1 \leq 0.55$	30	14	44	1	4	2	5	3	9
$0.55 < \underline{d}_1 \leq 0.65$	13	8	21	–	2	2	2	2	4
$0.65 < \underline{d}_1 \leq 0.75$	16 *	50 *	66 *	3	2	3	1	6	3
$0.75 < \underline{d}_1 \leq 0.85$	6	3	9	5	2	2	–	7	2
$0.85 < \underline{d}_1 \leq 0.95$	2	1	3	2 *	–	1 *	–	3 *	–
$0.95 < \underline{d}_1$	–	–	–	–	–	–	–	–	–
N	82	81	163	11	10	10	11	21	21

Table 4 (continued)

Interval for relative demands	Neelin et al. exp.	Ochs and Roth exp.							
		Games 1–3		Games 4–6		Games 7–10		All games	
$c'/c =$	0.25	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
$d_1 \leq 0.05$	–	–	–	–	–	–	–	–	–
$0.05 < \underline{d}_1 \leq 0.15$	–	–	–	–	–	–	–	–	–
$0.15 < \underline{d}_1 \leq 0.25$	–	–	–	–	–	–	–	–	–
$0.25 < \underline{d}_1 \leq 0.35$	–	–	–	–	–	–	–	–	–
$0.35 < \underline{d}_1 \leq 0.45$	–	–	– *	–	– *	–	– *	–	– *
$0.45 < \underline{d}_1 \leq 0.55$	2	11	18	8	20	9	26	28	64
$0.55 < \underline{d}_1 \leq 0.65$	1	18 *	6	19 *	4	30 *	6	67 *	16
$0.65 < \underline{d}_1 \leq 0.75$	33 *	1	–	3	–	1	–	5	–
$0.75 < \underline{d}_1 \leq 0.85$	4	–	–	–	–	–	–	–	–
$0.85 < \underline{d}_1 \leq 0.95$	–	–	–	–	–	–	–	–	–
$0.95 < \underline{d}_1$	–	–	–	–	–	–	–	–	–
N	40	30	24	30	24	40	32	100	80

Thus the game-theoretic solution predicts an immediate agreement determined by player 1's demand $\underline{d}_1^* = c - c'$.

In the experiment of Binmore et al. (1984, 1985) the initial cake was $c = 100$ pence and the smaller cake $c' = 25$ pence. Thus the solution payoffs of player 1 and 2 are 75 pence and 25 pence, respectively. Compared to the one-round ultimatum bargaining games, described and analysed in sections 2 and 3, the relation of equilibrium payoffs $c'/(c - c') = 1/3$ between player 2 and 1 in the Binmore et al. experiment is rather moderate. In the one-round ultimatum bargaining games the relation of equilibrium payoffs $\epsilon/(c - \epsilon)$ between players 2 and 1 is nearly zero.

Table 4 contains the experimental results of Binmore et al. (1985: fig. 1). The level of aggregation in table 4 is determined by Binmore et al. who do not list individual decision data. Whereas the main tendency (30 out of 82 observations) in the 1st game is to propose an equal split, the strong tendency (50 out of 81 observations) in the 2nd game is to play like a game theorist (Binmore et al. 1985: 1179). For Binmore et al. the equal division of c is an obvious and acceptable compromise for an unexperienced subject. However, once a subject is fully aware of the game structure, considerations of strategic power shoûld dominate.

The study of Binmore et al. has inspired further experiments with at least two rounds of ultimatum bargaining. Güth and Tietz (1985, 1986) have explored more extreme equilibrium payoff relations $c'/(c - c')$ for the different initial cake sizes $c = 15$, 35, and 55 German marks by using $c' = 0.1c$ and $c' = 0.9c$. In table 4 we have listed their results in the same way as those of Binmore et al. individually for the two values of the 'cake shrinking' parameter $c'/c = 0.1$ and $c'/c = 0.9$. The game-theoretic relative demand $\underline{d}_1^* = 0.9$ for $c'/c = 0.1$ and $\underline{d}_1^* = 0.1$ for $c'/c = 0.9$ was rarely observed. For $c'/c = 0.1$ only 2 out of 11 observations in the 1st game and 1 out of 10 in the 2nd game lie in the corresponding range $0.85 \leq \underline{d}_1 \leq 0.95$; for $c'/c = 0.9$ no observed value $\underline{d}_1$ coincides with the game-theoretic solution $\underline{d}_1^*$. Thus the conclusion of Binmore et al. that more experienced subjects confirm with the game-theoretic prediction is limited to rather moderate equilibrium payoff relations. As in one-round ultimatum bargaining games the game-theoretic solution looses nearly all its predictive power if it induces payoff results which are socially unacceptable.

Neelin et al. (1988) keep the equilibrium payoff relation 1/3 between player 2 and player 1 of Binmore et al. (1984, 1985) but vary the possible length of bargaining plays. The 'framing' of this experiment has been criticised by Binmore et al. (1988) (see Forsythe et al. (1988: table 1) for some differences in the experimental design of ultimatum bargaining experiments). With two possible rounds of ultimatum bargaining the initial cake $c = \$5$ shrinks to \$1.25, with three rounds it shrinks first to \$2.50 and then to \$1.25, whereas for five possible rounds the initial cake $c = \$5$ shrinks to \$1.70, then to \$0.58, then to \$0.20, and finally to \$0.07. Backward induction shows that in all cases the optimal opening demand is $d_1^* = \$3.75$, i.e. the equilibrium payoff relation (between players 2 and 1) is 1/3 regardless of whether bargaining can extend over two, three of five rounds.

For two rounds of ultimatum bargaining Neelin et al. confirm in a surprisingly clear way the major tendency in the 2nd game of the Binmore et al. experiment. It can be seen from table 4 that 33 out of 40 observations lie in the corresponding range $0.65 < \underline{d}_1 \leq 0.75$. Since all subjects participated in a trial session with four possible rounds of ultimatum bargaining, the subjects in the Neelin et al. experiment can be regarded as experienced.

But with more than two possible rounds of ultimatum bargaining the game-theoretic solution is a rather poor prediction. The general tendency observed by Neelin et al. (1988) is that the initial demands d_1 leave just the second round cake for player 2, i.e. d_1 is equal to c minus the second round cake. The means of the observed relative demands are 0.73, 0.53, and 0.66 for 2-round, 3-round, and 5-round ultimatum games, respectively (computed from Neelin et al. 1988: appendix 2). Only for two possible rounds of ultimatum bargaining such a behavior confirms the game-theoretic prediction $d_1^* = \$3.75$.

In a second experiment Neelin et al. (1988) allowed for more experience by letting subjects play the 5-round game four times, once for practice and three times for an initial cake of size \$15. Neither experience nor the increase of rewards changed the major conclusions described above.

The general observation by Neelin et al. that player 1 leaves the second round cake for player 2 in ultimatum bargaining games with at least two possible rounds seems to suggest the following limited rationality approach to ultimatum bargaining (see Güth and Tietz (1988) for another attempt): instead of backward induction underlying the game-theoretic solution concept of 'subgame perfect equilibrium points' (Selten 1975) subjects use a rather crude form of forward induction according to which player 1 rightly concludes that he can demand all of the difference between the initial amount c and the second round cake. However, he avoids a more detailed analysis of further strategic interaction by assuming that player 2 completely controls the situation once the second round of ultimatum bargaining is reached.

Unfortunately, the results of Güth and Tietz (1988a) show that subjects entertain such considerations only in very special situations, e.g. in situations where the equilibrium payoff relation is rather moderate. Neither the mean demanded share $\underline{d}_1 = 0.72$ for $c'/c = 0.1$ nor the one of $\underline{d}_1 = 0.57$ for $c'/c = 0.9$ confirm the hypothesis that player 1 leaves the second-round cake c' for player 2. Neelin et al. themselves have already expected that their hypothesis will not be confirmed in extreme situations where the equilibrium payoff relation is socially unacceptable.

But do the experimental results of Güth and Tietz (1988a) really reject the hypothesis that subjects rely on the limited rationality approach: 'Leave the second round cake for player 2'. In our view, the impressing results of Neelin et al. (1988) indicate that subjects first calculate the difference between the initial and the second round cake in order to derive an aspiration level. If the implied payoff distribution is either socially acceptable or such that player 2 will not dare to reject it, then this amount is really demanded. But if the cost of rejecting an unfair proposal is rather low for player 2, player 1 obviously gives up this initial aspiration level and applies other considerations to determine his demand. In this sense the empirical results of the shrinking cake experiments seem to provide a promising starting point for a limited rationality approach: subjects first apply a rather simple procedure like the 'leave the 2nd round cake for player 2' considerations. The recommendation of this procedure then has to pass an acceptability test. Only in case this test fails a more complicated procedure for analysing the situation is used, etc. We think that viewing decision making as a process of subsequent decision filters corresponding to an increasing degree of sophistication is probably the most fruitful way to derive a concept of limited rationality. It has been suggested by an anonymous referee that one should debrief subjects in order to test whether this corresponds to the intellectual process actually employed by the subjects.

Since our main intention is to compare the different experimental results of ultimatum bargaining behavior, we do not list and analyse the decision data which Neelin et al. observed for more than two possible rounds. In table 4 one can therefore find only the results for two possible rounds of ultimatum bargaining listed in the same way as the results of Binmore et al. (1984, 1985) and Güth and Tietz (1988a). Since the game was not repeated we cannot account for experience effects. Before playing the two-round games, subjects in the Neelin et al. experiment participated in a trial run with four possible rounds. From the instructions (see Neelin et al. 1988: appendix 1) we induce that the two-round games were the first decision problem that subjects had to face after their trial run.

The very systematic study of Ochs and Roth (1989) is based on a 4 by 2 factorial experimental design. All four constellations with approximate discount factors (0.4; 0.4), (0.4; 0.6), (0.6; 0.4), and (0.6; 0.6) for players 1 and 2 have been explored with two and three rounds of ultimatum bargaining. In table 4 we only included the results of games with two rounds of proposals and equal discount factors, since in games with unequal discount factors players 1 and 2 cannot divide a constant amount in later rounds in the same way as in the 'complicated' games of Güth et al. (1982). The results of Ochs and Roth are listed in the same way as the other results contained in table 4 where experience is reflected by summarizing the results of games 1–3, 4–6, and 7–10, respectively.

There is a weak tendency in the game-theoretic direction in the sense that most observations for the discount factor 0.4 lie in the interval for the game-theoretic relative opening demand $\underline{d}_1^* = 0.6$, and that the interval $0.45 < \underline{d}_1 \leq 0.55$ contains most observations if, due to the discount factor 0.6, the relative opening demand $\underline{d}_1^*$ is equal to 0.4. This influence of the discount factor or cake-shrinking parameter is highly significant ($\alpha < 0.001$). But similarly to the results of Güth and Tietz (1988a) for $c'/c = 0.9$ players 1 rarely go below the equal share of c with their demand d_1 if game-theoretic reasoning tells them to do so (the whole range $\underline{d}_1 \leq 0.45$ contains no observation in spite of $\underline{d}_1^* = 0.4$ for the discount factor 0.6).

Since payoffs were actually paid in only one of ten successive games, subjects in the experiment of Ochs and Roth faced a rather low probability that their decision will actually matter. Since experience did not have any significant influence, one might have preferred fewer repetitions with more significant payoffs. It is an interesting observation that the discount factor of player 1 influences the behavior in two-round bargaining games although the game-theoretic solution does not depend at all on this parameter. Ochs and Roth try to explain their observations by modifying the 'utility function'. Unlike our implicit assumption when determining the game-theoretic solution that players are solely motivated by monetary rewards they incorporate distributional concerns directly into the utility functions.

We strictly reject the idea to include results of analysing a social decision problem into the utility functions of the interacting agents. Utility functions are an instrument of describing individual characteristics needed to define a social decision problem. Furthermore, all our experiences from ultimatum bargaining experiments indicate that subjects do not 'maximize' but are guided by sometimes conflicting behavioral norms (see, for instance, the discussion of Güth (1988)). The utility approach necessarily neglects the dynamic nature of the intellectual process which subjects apply to derive their decision behavior as, for instance, indicated in our discussion of the Neelin et al. results.

Ultimatum bargaining with alternating offers and no announced upper bound for the number of rounds has been experimentally investigated by Weg et al. (1990). Of course, it will always be common knowledge that bargaining has to end after finitely many rounds. Actually, bargaining was not allowed to last for more than 20 periods. As Ochs and Roth, the authors used equal and unequal discount factors by providing tables showing the cumulative discounts up to 44 periods. The major conclusions are that the subgame perfect equilibrium point, i.e. the game-theoretic solution, is rejected and that norms of equality and equity seem to be more consistent with the experimentally observed decision data.

We now would like to compare the various data sets contained in table 4. '* ' indicates the interval containing the game-theoretic relative opening demand $\underline{d}_1^* = d_1^*/c$ by player 1. Whereas for Binmore et al. and Neelin et al. the * interval is one of the focal points, this is never true for the true for the Güth and Tietz results. As already indicated above, the corresponding results of Ochs and Roth depend crucially on the cake-shrinking parameter: If c'/c is 0.4, then the * interval is the main focal point. But if the cake-shrinking parameter is 0.6, the game-theoretic predicition has lost all its predictive power. In these cases the interval containing the equal split $\underline{d}_1 = 0.5$ becomes the main focal point. But even here still 16 of 80 players 1 (i.e. 20%) ask for more than half of the original cake. The distributions observed by Binmore et

Table 5
Average results of the first rounds of two-round ultimatum bargaining for a shrinking cake analogous to table 4.

	Binmore et al. exp.			Güth and Tietz exp.					
	1st game	2nd game	Both games	1st game		2nd game		Both games	
$c'/c=$	0.25	0.25	0.10.25	0.9	0.1	0.9	0.1	0.9	
c	3.50	3.50	3.50	18.64	18.00	18.00	18.64	18.33	18.33
	(0)	(0)	(0)	(13.00)	(11.9)	(11.9)	(13.0)	(12.5)	(12.5)
d_1	1.98	2.24	2.11	14.55	10.96	12.55	9.72	13.60	10.31
	(0.476)	(0.392)	(0.459)	(10.6)	(6.88)	(9.11)	(7.61)	(9.94)	(7.3)
$\underline{d}_1$	0.565	0.641	0.602	0.76	0.631	0.674	0.515	0.719	0.570
	(0.136)	(0.112)	(0.131)	(0.111)	(0.103)	(0.113)	(0.091)	(0.120)	(0.113)
$\delta_2(d_1)$	–	–	–	0.727	0.3	0.9	0.455	0.81	0.381
	–	–	–	(0.445)	(0.458)	(0.3)	(0.498)	(0.393)	(0.486)
N	82	81	163	11	10	10	11	21	21

	Neelin et al. exp.	Ochs and Roth exp.							
		Games 1–3		Games 4–6		Games 7–10		All games	
$c'/c=$	0.25	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6
c	10.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
d_1	7.25	3.45	3.21	3.55	3.14	3.54	3.13	3.52	3.16
	(0.605)	(0.292)	(0.206)	(0.305)	(0.194)	(0.273)	(0.198)	(0.292)	(0.202)
$\underline{d}_1$	0.725	0.575	0.535	0.591	0.523	0.591	0.522	0.586	0.526
	(0.061)	(0.049)	(0.034)	(0.051)	(0.032)	(0.046)	(0.033)	(0.049)	(0.034)
$\delta_2(d_1)$	0.775	0.9	0.75	0.9	0.833	0.9	0.844	0.9	0.813
	(0.418)	(0.3)	(0.433)	(0.3)	(0.373)	(0.3)	(0.363)	(0.3)	(0.39)
N	40	30	24	30	24	40	32	100	80

al. reveal most clearly double peakedness where the two focal points correspond to the equal split $\underline{d}_1 = 0.5$ and the game-theoretic relative opening demand $\underline{d}_1^* = 0.75$. Whereas for rather unexperienced players the main focal point of these two is the equal split interval, the opposite is true for more experienced subjects.

Table 5 contains more illustrative average results of table 4 as the average size c of the original cake, the average (relative) opening demand $d_1(\underline{d}_1)$, the average acceptance rate $\delta_2(d_1)$ of the opening demand d_1, and the number N of observations. All amounts have been expressed in German marks by evaluating 1 English pound ($\mathscr{L}$) by DM3.50 and 1 American dollar ($) by DM2. The amounts of Ochs and Roth have been divided by 10 to take account of the fact that subjects were paid in only one of 10 games. The values d_1 and $\underline{d}_1$ of Binmore et al. have been computed by setting $\underline{d}_1$ equal to the midpoint of the concerning interval in table 4. A '–' indicates that the corresponding observations were not available to us.

Güth and Tietz are the only ones who have varied monetary incentives. Furthermore, they have used the strongest average monetary motivation. Compared to the studies of Neelin et al. and Ochs and Roth there is a surprising variance in the average acceptance rates observed by Güth and Tietz. Whereas these range from 0.75 to 0.9 for Neelin et al. and Ochs and Roth, the corresponding interval for Güth and Tietz is from 0.3 to 0.9. Here one should, of course, keep in mind that Güth and Tietz have considerably fewer observations ($N = 10$ or 11 as compared to $N \geq 24$). But in our view the decisive reason for the extreme differences in the average acceptance rates is the fact that Güth and Tietz have imposed extreme cake-shrinking parameters c'/c. More specifically, the extremely low average acceptance rates have been caused by the almost unshrinking cake $c'/c = 0.9$.

The average relative opening demands $\underline{d}_1$ are consistently greater than 0.5 even in the cases with $c'/c > 0.5$ where $\underline{d}_1^* < 0.5$. Thus players 1 do not seem to trust game-theoretic reasoning when it yields them less than half of the initial cake. There is no significant effect of experience in the average data of Ochs and Roth. The observations of Güth and Tietz reveal a slight influence of experience in the sense that the mean demanded shares $\underline{d}_1$ decrease and that average acceptance rates $\delta_2(d_1)$ increase with more experience. Compared to this Binmore et al. have observed a significant increase of $\underline{d}_1$ with experience so that there is a puzzling difference in the effects of experience observed in the two experiments. It should be mentioned that, due to the games with $c'/c = 0.9$, Güth and Tietz observed quite a number of conflicts or nonefficient agreements and that all subjects could notice this (all players 1 were seated in one room and all players 2 in a neighboring room and games were played simultaneously). This common experience of conflicts or inefficient agreements could have induced subjects to be less demanding in the subsequent repetition. In the Binmore et al. experiment subjects had to rely purely on individual experiences.

A linear regression of the acceptance behavior of player 2 with the cake-shrinking parameter c'/c and the relative demand $\underline{d}_1$ of player 1 as regressors for the 262 first rounds of two-round games (withouth the data of Binmore et al. 1985) yields the following optimal separation function:

$$\delta_2(\underline{s}_2) = \begin{cases} 0 & \text{for } \underline{d}_1 > \underline{s}_2 \\ 1 & \text{otherwise,} \end{cases} \tag{3a}$$

with

$$\underline{s}_2 = 0.867 - 0.449\ c'/c. \tag{3b}$$

Other variables as the cake size c and the experience parameter 'game' have no significant influence. Function (3) explains 86.6% of the 262 acceptance decisions by player 2. The cake-shrinking parameter has significant impact on acceptance behavior. Observe that game theory predicts $\underline{s}_2 = 1 - c'/c$ and that the equal split solution implies $\underline{s}_2 = 0.5$. According to function (3) players 2 seem to determine their behavior by balancing the incentives to comply with both extreme principles. More specifically, the value $\underline{s}_2$ is always higher than the relative demand $\underline{s}_2 = 0.75 - 0.5c'/c$ implied by giving equal weights for both principles. The latter phenomenon could be justified by the hypothesis that players 2 want to allow for small deviations from a certain distribution norm, e.g. the one implied by equal weights for the game-theoretic and the fifty-fifty solution.

In the following we want to analyse the average demand behavior $\underline{d}_1$ over all 425 observations by some regressions. Postulating significance levels of $\alpha < 0.0001$ for the regression coefficients we obtain the following result:

$$\underline{d}_1 = 0.679 - 0.210\ c'/c, \quad R^2 = 0.126,\ N = 425. \tag{4}$$

The coefficient of determination can be improved by including the cake size c as regressor:

$$\underline{d}_1 = 0.659 - 0.242\ c'/c + 0.00488\ c, \quad R^2 = 0.189,\ N = 425. \tag{5}$$

Thus a bigger cake leads to higher relative demands. The highly significant influence of c (the partial correlation coefficient is 0.270) illustrates how important it is to vary the cake size c when exploring ultimatum bargaining behavior.

A further increase of R^2 to 0.266 is achieved if one substitutes c by the (0, 1) dummy variables for the experiments of Binmore et al. and of Ochs and Roth:

$$\underline{d}_1 = 0.769 - 0.225\ c'/c - 0.109\ \text{Binmore} - 0.0997\ \text{Ochs},$$

$$R^2 = 0.266,\ N = 425. \tag{6}$$

A corresponding dummy variable for the experiments of Neelin et al. has no significant influence. Compared to the results of Güth and Tietz and Neelin et al. the observations of Binmore et al. and Ochs and Roth indicate demands which ask for about 10% less of the cake. This can be revealed by separate regressions yielding similar coefficients for the cake-shrinking parameter c'/c.

An analysis of variance shows a sufficiently significant ($\alpha < 0.02$) interaction effect between the experience parameter game and c'/c. Separate regressions for the three experience conditions lead to

$$\underline{d}_1 = 0.656 - \underset{(\alpha < 0.005)}{0.137\ c'/c}, \quad R^2 = 0.039,\ N = 197,\ \text{for game} = 1, \tag{7a}$$

$$\underline{d}_1 = 0.698 - 0.246\ c'/c, \quad R^2 = 0.227,\ N = 156,\ \text{for game} = 2, \tag{7b}$$

$$\underline{d}_1 = 0.729 - 0.346\ c'/c, \quad R^2 = 0.420,\ N = 72,\ \text{for game} = 3. \tag{7c}$$

Eqs. (7) indicate a monotonic shift towards the compromise solution $\underline{d}_1 = 0.75 - 0.5c'/c$ implied by giving equal weights to the game-theoretic and the fifty-fifty solution. The asymptotic F-test (Amemiya 1985) for unequal variances shows with $F^2_{419} = 6.68$ that the structural change is highly significant ($\alpha < 0.002$). The increase of R^2 is accompanied by a reduction of the standard error from 0.125 to 0.092 to 0.041 underlining the importance of experiments in which subjects can learn successful behavior by experience. A theory of limited rational behavior, which can be classified as rational in the sense of goal-oriented behavior, should not be based only on experiments without repetitions. That experience influences the coefficient of c'/c is also demonstrated by a global regression which uses the product of c'/c and game (game = 1, 2, 3) as regressor instead of c'/c. Analogously to (6) we obtain

$$\underline{d}_1 = 0.665 + 0.0743 \text{ game} - 0.147 \text{ game} * c'/c - 0.118 \text{ Binmore}$$
$$- 0.112 \text{ Ochs}, \quad R^2 = 0.294, \ N = 425. \tag{8}$$

Better explanations can be obtained by separate investigations of accepted and refused demands. The gap $\Delta = |c'/c - 0.5|$ measures how the game-theoretic prediction deviates from the equal split solution and indicates the cognitive pressure due to these two competing behavioral norms. Using the gap Δ as an additional regressor yields the following result for the accepted relative demands $\underline{d}_1^a$:

$$\underline{d}_1^a = 0.728 - 0.140 \text{ game} * c'/c - 0.291 \text{ game} * \Delta + 0.0981 \text{ game}$$
$$- 0.176 \text{ Ochs}, \quad R^2 = 0.653, \ N = 211. \tag{9}$$

For the rejected relative demands $\underline{d}_1^r$ the regressor 'game $* \Delta$' is not significant. Eliminating this regressor yields

$$\underline{d}_1^r = 0.724 - 0.185 \text{ game} * c'/c + 0.097 \text{ game} - 0.133 \text{ Ochs},$$
$$R^2 = 0.724, \ N = 51. \tag{10}$$

The variable 'game $* \Delta$' indicates learning behavior in situations where Δ is large, i.e., when the two behavioral norms $\underline{d}_1^* = 1 - c'/c$ and $\underline{d}_1 = 0.5$ predict very different outcomes. From eqs. (9) and (10) one might therefore conclude that acceptance results from learning to make reasonable offers when Δ is large. In general, the mean accepted relative demand is significantly smaller with 0.586 than the mean rejected relative demand of 0.655 ($\alpha < 0.0001$).

5. Final remarks

Güth et al. (1982) examined experimentally ultimatum bargaining behavior in order to develop bargaining theory by first looking at the most basic bargaining situations and then trying to proceed with more complicated situations. Unfortunately, although ultimatum bargaining seems to be the most primitive form of negotiations, a satisfying descriptive theory of ultimatum bargaining is not yet available. As indicated by the results of sections 2 and 3 ultimatum bargaining behavior depends crucially on the experimental environment, i.e. on how the ultimatum bargaining game is embedded. Since a similar dependency on environmental aspects will be true for most (bargaining) experiments, we will not discuss this here in more detail.

One reason why ultimatum bargaining became a widely known experimental paradigm is that experimentally observed ultimatum bargaining behavior clearly contradicts the most obvious rationality requirements of game theory and also of economic theory. For somebody who always thougth that human decision making will be characterized at most by limited rationality, this controversy must be somewhat surprising. Apparently this debate is far from being settled.

Experimentally observed ultimatum bargaining behavior reveals how considerations of distributive justice seriously destroy the prospects of exploiting strategic power. Our analysis has indicated which factors influence demand and acceptance behavior in ultimatum bargaining experiments.

It could be shown that the cake-shrinking parameter had a distinct negative influence on $\underline{d}_1$ and δ_2 in first rounds. Its influence on the acceptance behavior in last-round subgames is still open. The strong effects of the dummy variables for the experimental procedure underline their importance. To explore the influence of experimental procedures one might consider to replicate previous experiments of other authors as closely as possible. This might, for instance, indicate whether the way of recruiting, advising, and introducing subjects is responsible for the differing results.

The empirical results for ultimatum bargaining behavior will help to explain decisions in other and probably more complicated situations of strategic interaction. What we have learned is that people are willing to sacrifice considerable monetary amounts in order to punish someone who has been too greedy and that they do so even if it will not be of any help for them in the future. As a consequence the usual backward induction procedure underlying the concept of subgame perfect equilibria is no reliable *behavioral* concept. Actual decision behavior is obviously a result of both forward and backward induction. This is clearly illustrated by the impressing results of Neelin et al. (1988) which indicate some crude form of forward induction.

In our view, this has important implications for the interpretation of many game-theoretic results as, for instance, the Folk Theorems of game theory (see Aumann 1981; Fudenberg and Maskin, 1986; and also the critical discussion of Güth et al. 1988). On the one hand, Folk Theorems apply the concept of subgame perfect equilibria, i.e. backward induction rationality. On the other hand, Folk Theorems allow to vary the decision behavior in strategically equivalent subgames in a forward induction manner as most clearly illustrated by tit for tat or grim strategies. What the empirical evidence of ultimatum bargaining experiments demonstrates is that people are really willing to punish as supposed by tit for tat or grim strategies. There is apparently a rather sound behavioral basis for establishing Folk Theorem-like behavioral conjectures. This explains the frequent use and wide acceptance of Folk Theorem-like arguments although Folk Theorems as normative statements are rather questionable (see Güth et al. 1988).

The study of Neelin et al. (1988) is interesting since it illustrates how backward induction fails to be used when extending the possible length of bargaining plays from two to more bargaining rounds. One should try to find out whether this result is still valid when the stakes are higher and/or when subjects can lose money as, for instance, in the experiments where positions were auctioned. Of course, one should also vary the equilibrium payoff distribution in order to see how the breakdown of backward induction is influenced by the payoff distribution which it determines.

There are plans to further explore ultimatum bargaining behavior which, as far as we know, go back to the basic situation of just one bargaining round. Eric van Damme has suggested to investigate situations where player 1 can allocate $c - d_1$ among several players and where he, furthermore, can select who of the other players determines whether his proposal is accepted or not. More specifically, player 1 can choose any payoff vector $x = (x_1, \ldots, x_n)$ with $x_i \geq 0$ for $i = 1, \ldots, n$ and $x_1 + \ldots + x_n = c$, where n (≥ 3) is the number of players, as well as the responder $r \in \{2, \ldots, n\}$. The main hypotheses concern how variations in the responder r's information about x influence the decision behavior of 1 and r. The responder, for instance, might know the whole vector x, or x_r only, the amount allocated to him, or x_1 and x_r.

Other attempts concern ultimatum bargaining experiments in which player 2 is only incompletely informed about the cake size c. Again there are various possibilities to define the rules of such games, especially the a priori beliefs of player 2 about the cake size c.

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