Timing and Virtual Observability in Ultimatum Bargaining and "Weak Link" Coordination Games

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Abstract

Previous studies have shown that simply knowing one player moves first can affect behavior in games, even when the first-mover's moves are known to be unobservable. This observation violates the game-theoretic principle that timing of unobserved moves is irrelevant, but is consistent with virtual observability, a theory of how timing can matter without the ability to observe actions. However, this previous research only shows that timing matters in games where knowledge that one player moved first can help select that player's preferred equilibrium, presenting an alternative explanation to virtual observability. We extend this work by varying timing of unobservable moves in ultimatum bargaining games and "weak link" coordination games. In the latter, the equilibrium selection explanation does not predict any change in behavior due to timing differences. We find that timing without observability affects behavior in both games, but not substantially.

I. Introduction

Research rooted in psychology is often a useful tool for informing game theorists about important elements missing from traditional models of games and behavior. One way this is accomplished is by showing how simple changes to the enviroment of a game, or the way a game is played, can affect behavior in ways that are not predicted by the theory. For instance, framing the prisoner's dilemna game as either the "Wall Street" or "Community" game produced substantial differences in behavior, revealing the influence of context (Ross and Samuels, 1993). These results often produce the need to modify theory to take into account missing elements, as Rabin (1993) did in using several examples of how intentions and beliefs about intentions affect behavior to develop a psychologically-based theory of fairness.

This paper similarly focuses on a subtle change in the way a game is played that may also affect behavior. This change deals with the timing of moves. To see what we are interested in, imagine a game in which somebody moved before you, but you don't know what they did. Does it matter that they moved already? The standard answer in game theory is "No." Perhaps surprisingly, the empirical answer discovered in previous experiments is "Yes, it can matter." This paper adds to the evidence that timing of unobserved moves can matter, and reports experiments designed to more closely test a theory of how timing affects behavior.

The potential problem with standard game theory comes from the fact that it relies on identical representations of two very different situations. The first situation is where one player moves before another but the player's move is unobservable; the second is where both players move simultaneously. In traditional game theory, there is no distinction between how these two situations are respresented.

Specifically, in noncooperative games of imperfect information, a player's ignorance about the move of a player who moved before her is represented in an extensive form game tree by linking all the nodes that could result from the other player's earlier moves, in an "information set." The information set represents all the possible nodes in the game that are indistinguishable to the player making a decision at those nodes – since she does not know what the earlier-mover did, she only knows that she is at one of the nodes in the information set.

The same information set representation is also used when moves are simultaneous. That is, for games where all moves are taken at the same time, the extensive form representation of a game is the same as it is for games where one player moves first but subsequent players do not observe what choices were made. Even though moves are simultaneous, in the "game tree" diagram some players are depicted as "moving" earlier in the tree. This graphical convention effectively implies that the time at which unobservable moves were made does not matter, only information about what these moves were does.

However, timing-irrelevance is not merely the result of a graphical convention used to draw trees. It is an "invisible assumption" in game theory that follows from the more basic principle that if the outcome of an event is unknown, it does not matter when the event happened (or is happening). That is, unobservability trumps timing.[1]

Rapoport (1997) points out that in the earliest development of game theory, von Neumann and Morgenstern (1947, p. 51) recognized the distinction between "anteriority" (priority in time) and "preliminarity" (priority in information). Preliminarity implies anteriority, but not vice versa, and thus may seem more fundamental.[2] Having recognized the distinction between timing and observability, they opted to make priority in information the basic way of characterizing strategies, defined strategies with no reference to chronological order of moves, and effectively banished timing, per se, from game theory.

However, several previous experimental studies indicate that even when moves are unobservable, timing <u>can</u> matter.

Previous results demonstrating the effects of varying timing without varying information come from games with multiple equilibria, in which one equilibrium is preferred by one player and another by a different player. An example from Cooper, et al. (1993), is shown in Table 1. The game is a "battle-of-the-sexes" (BOS) in which the

[1] Bagwell (1995) makes this point in a different way: In a class of games in which there is an advantage to moving first (e.g., in Coumot duopoly), he shows that the commitment value of moving first is severely undermined if observability of the earlier move is even slightly in doubt. However, in experimental results consistent with the research in this paper, Huck and Muller (2000) find results contradicting Bagwell's result: players do not ignore prior moves, even when observability is noisy.

[2] Having information about a previous move implies the move happened earlier, but an early move need not be known.

Row player prefers the Nash equilibrium (B, A) and Column prefers the equilibrium (A, B). There is also a mixed-strategy equilibrium in which both players mix with probabilities (0.25, 0.75).

It is important to note in this game that if players move sequentially (with the Row player moving first), and previous moves are observable, then Row should choose B and, observing that, Column should choose A. This is the unique subgame-perfect equilibrium of the observable sequential-move game. The player who moves first earns the high payoff (600) and the second-mover earns the lower non-zero payoff (200).

Table 1: Battle-of-the-sexes game and results from Cooper et al (1993)

		Column A	Column B	frequency of choices: simultaneous	frequency of choices: sequential
ROW	A	0, 0	200, 600	38%	12%
	B	600, 200	0, 0	62%	88%
simultaneous:		35%	65%		
sequential:		70%	30%		

Table 1 also presents the frequency of choices in an experiment by Cooper, et al. (1993). The choice frequencies show that when moves were simultaneous both players approached the mixed-strategy equilibrium, choosing strategy B either 62% (Row) or 65% (Column) of the time.

In the sequential condition, Row moved first and the order of moves was commonly known, but Row's move was not known to Column. According to traditional game theory, these two conditions are equivalent: Even though the timing of moves differs between the two games, there is no difference in the information held by Column when making her choice. However, in the experiment, Row players chose strategy B 88% of the time and, more strikingly, Column players chose strategy A 70% of the time. Thus, merely knowing that Row moved first caused players to move toward the equilibrium (B, A), which is the subgame perfect equilibrium in the game where Row moves first and his action is observable. This is surpiring given that Column did not know Row's previous move when she chose.[3]

In another experiment, Rapoport (1997) studied a three-player BOS. As in the two-player experiment mentioned above, players chose in a predetermined order, but did not know the moves of the previous players. Behavior again indicated that subjects behave differently under this timing condition, than they do when all players move simultaneously. Similarly to the experiments by Cooper, et al., most subjects (about 60%) chose the strategy that gave the first-mover her preferred outcome. The percentages of players choosing the first-mover's preferred equilibrium did not vary much across the move order (66.3%, 62.9%, and 59.2% for first- through third-movers).

Rapoport (1997) and colleagues also reported substantial timing effects in "resource dilemma" games. In these games, players draw from a "common resource pool" of either certain or uncertain size. If the resource pool is overdrawn nobody gets anything. When players move in order and previous moves are observable, first-movers take more of the pool, leaving less for later movers (a similar outcome to the sequential, observable BOS). However, when the order of moves is commonly known but the first mover's actual draws are unknown, Budescu, Au, and Chen (1997) report that first movers take more and later-moving players take less. In a five-player game, first movers draw 28%, third movers draw 23%, and last-movers draw 20% of the pool's expected size. These figures are close to the corresponding fractions in games where earlier moves are observable, which are 34%, 25%, and 20% (Rapoport, Budescu, and Suleiman, 1993). In two- and three-player resource-dilemmas the results are weaker but still significant (the corresponding first- and last-mover fractions are 52% vs. 48%, and 34% vs. 31%, respectively). Perhaps more importantly, players generally expect that those moving before them will have taken more than those moving after them will take. This result is much like the BOS result: Simply by introducing differences in the timing of moves – even when first-movers' moves are unknown – behavior changes in the direction of the subgame perfect equilibrium if moves were observable.

[3] Similar results were conjectured by Kreps (1990, pp. 100-101) and reported in informal experiments by Amershi et al (1989), Muller and Sadanand (1998), and other investigators (see Cooper, et al., 1993, footnote 6).

Rapport (1997) also studied a "step-level" or threshold public goods game, in which a public good is provided if 4 (or more) out of 7 players contribute. The payoffs were chosen so that if exactly three others contribute, a player prefers to contribute, but otherwise she prefers not to contribute. These games have many pure-strategy equilibria in which a subset of four players contribute. In Rapoport's study, as above, players know the order in which they choose to contribute but not the contributions of those who moved previously. Also similarly to the above studies, if moves were observable, the subgame-perfect equilibrium would be for only the later-moving players to contribute, resulting in an equilibrium favoring the earlier movers. The effect of varying only timing is striking: When the timing of moves was varied (without varying information), only 18% of the first three players contributed, but 38% of the last three players contributed.

Finally, Güth, Huck, and Rapoport (1998) studied symmetric and asymmetric 2-player BOS games and a class of 2-player games in which a pure-timing effect (based on a theory in which the first-mover obtains her preferred outcome) would entail disequilibrium play. Interestingly, they find no timing effect when the prediction entails disequilibrium play. This is not too surprising, but it does provide an important boundary to the effect of timing. They also find that the timing effect is much weaker in the presence of a fair (equal-payoff) outcome, from which they conclude that the "first-come-first-served" rule implied by the timing effect is weaker than norms of fairness.

The above experiments all leave open the possibility that models in traditional game theory are missing an important element distinguishing between two dissimilar situations. While traditional theory predicts that differences in timing without differences in information should not change behavior, the above experiments all raise the possibility that people play games differently when only the timing of moves is varied. Even more surprisingly, the above results point to the possibility that subjects may play what would be the subgame-perfect equilibria in games where prior actions are observable, even when these actions are not observable. If firmly established, such a result would be inconsistent with traditional game theory, but would be consistent with a theory where players "break" information sets – treating unobservable actions as observable – to apply subgame perfection.

Such a theory would allow players to act like earlier players' moves are "virtually observable," meaning that players expect first movers to choose strategies as if subsequent players observe them perfectly and respond optimally. Introducing timing, even without observability, would mean that players play as if they could observe prior moves. This idea was first carefully articulated by Amershi, Sadanand, & Sadanand (1989) in a refinement of Nash equilibrium they call MAPNASH, for "manipulated Nash equilibrium."[4] Heuristically, this theory of virtual observability means players erase information sets and act like moves will be observable, and then they apply subgame perfection. If this process selects a unique equilibrium *that is also a Nash equilibrium in the actual game* (i.e., once the original information sets are restored), then this equilibrium is selected as the equilibrium to the game. Put more precisely:

> To see how virtual observability refines the set of Nash equilibria once timing differences are introduced:
>
> i) Fix a game of imperfect information in which previous moves are unobservable.
> ii) Maintaining the temporal order of moves, assume that all previous moves are observable.
> iii) Find any subgame-perfect equilibria of the game with observable moves.
> iv) If any such equilbrium is also a Nash equilibrium of the original game, then select this equilibrium of the original game.
> v) Otherwise, timing will not affect play.

Note that virtual observability essentially states that players will play as if they could observe previous moves, as long as there is a subgame perfect equilibrium to the game with observable moves and as long as this outcome is also an equilibrium for the game with unobservable moves.

The results of the experiments above demonstrating a pure-timing effect are consistent with virtual observability. In the BOS, resource dilemma, and threshold public

[4] The idea is that the first mover can "force" her most-preferred choice on the second-mover, hence the term "manipulated equilibrium" chosen by Amershi et al.

goods games, there are many Nash equilibria, but one (or only a few) of those are also subgame-perfect equilibria in the sequential game with observable moves. Virtual observability correctly predicts that these should be more frequently played when only the timing of moves is varied. Moreover, in the game studied by Güth, Huck, and Rapoport (1998), the subgame perfect equilibrium of the observable sequential game is not an equilibrium of the original game with unobservable moves, and is therefore not selected by virtual observability. Virtual observability, therefore, correctly predicts that this outcome should not obtain.

However, while virtual observability is consistent with the previous timing results, there is another explanation – that has nothing to do with timing, per se – that could also account for the results. This explanation is simply based on the fact that in coordination games any asymmetry may help select an equilibrium.[5] More specifically, in the BOS, resource dilemma, and threshold public goods games, there are multiple equilibria, meaning that players face a coordination problem in selecting one of these. Moreover, the equilibria differ in how attractive they are for different players. For instance, in the threshhold public goods game, there are several pure strategy equilibria in which different combinations of four players contribute, and all players prefer equilibria in which they do not contribute to ones in which they do. As Schelling (1960) points out, coordination games are sensitive to any asymmetry that distinguishes some combination of players' actions as unique. Therefore, one possible explanation of the previous results is that timing simply introduces an asymmetry between the players that makes certain equilibria – the ones preferred by players who move first – more salient and results in these equilibria being selected. For instance, in the BOS game, the change in behavior

[5] Two further possible explanations can be found in psychological principles. First, "causal illusions" occur when people think that actions they take at time t might affect actions of others at time t+l, even though there is no apparent causal mechanism for such an affect. For example, Morris, Sim & Girotto (1998) report that subjects playing a prisoners' dilemma are more likely to cooperate if they know the player they are paired with moves after them than if the other player moves before them. Players act as if their cooperative choice can magically induce reciprocal cooperation by a player who moves later.

A second psychological difference arising from timing is that players who move later know there is information they could have-- what earlier players chose-- but do not. They may feel more regret if they make a mistake in this situation (since there is something they "could have known"), then if they make an equivalent mistake moving first. Heightened regret can then cause them to act as if they are more averse to uncertainty or ambiguity (see Camerer & Karjalainen, 1994) when they move second.

may be due simply to one player being labeled the "first mover," even if this is independent of any change in the actual order of moves. In this sense, the effect is not due to timing, but to the labelling of one or more players as different, or more prominent, than the others.[6] This alternative explanation is also consistent with the results of Güth, Huck, and Rapoport (1998), who find no timing effect in a game where there is a unique Nash equilibrium.

To directly test virtual observability, we need a game where changing the order of moves is predicted to have an effect by the theory, but where greater salience of one player relative to others will not simply induce coordination on that player's preferred outcome. Specifically, we need a game where subgame-perfection in the observable-move game refines a set of Nash equilibria, but where this refinement is not also consistent with coordination on the earlier mover's preferred equilibrium. Table 2 shows an example of such a game, known as "stag hunt." In stag hunt both players can move L or H. The equilibrium (H,H) Pareto-dominates (L,L), but choosing L is less risky and (L,L) is an equilibrium too.

Table 2: Stag Hunt Game

		Column L	Column H
Row	L	200, 200	200, 0
	H	0, 200	600, 600

If the players move sequentially with observability, (H,H) is the unique subgame-perfect equilibrium in stag hunt. Since this is also an equilibrium in the simultaneous-move game, it is selected by virtual observability. However, since both players' payoffs are identical in the two pure-strategy equilibria, designating one player as the "first mover" does not make one equilibrium focal simply by making that player salient and highlighting that player's preferred equilibrium. Hence, while virtual observability predicts a timing effect in the stag hunt game (more (H,H) choices), as in most of the

[6] For instance, we conjecture that behavior in the BOS game might similarly move towards the equilibrium preferred by a subject who was labelled the "star participant."

previous games used, the alternative explanation discussed above predicts no timing effect.

In the rest of this paper, we report two experiments designed to test whether the timing effects predicted by virtual observability obtain once we control for the alternative explanation above. We first report an experiment exploring timing effects in ultimatum bargaining games. Ultimatum bargaining games have multiple Nash equilibria, but only one subgame perfect equilibrium when played sequentially. Since the Nash equilibria are differentially preferred by players, the game has the same properties of the games in previous studies that mean we can not use it to rule out the alternative explanation of equilibrium selection by labelling – the unique equilibrium predicted by virtual observability is also preferred by the first mover. However, we include this game to ensure that we replicate the timing effect demonstrated in the previous studies.

In a second experiment, we use an n-player version of stag hunt, the "weak-link" coordination game, to directly test the prediction of virtual observability, while eliminating the alternative explanation. Our evidence suggests that the alternative explanation that timing effects are due solely to the salience of certain equilibria being associated with the first-mover is not the whole story and virtual observability may be a good general explanation for previous results.

II. Ultimatum bargaining and multiple equilibria

To show what virtual observability predicts in the ultimatum bargaining game, we need to show that this game has multiple equilibria, but that only one is selected by subgame perfection when the game is played sequentially with observable actions. In this section, we draw this connection, and also note that there is an important relation between coordination and bargaining that partly motivates our interest in timing and bargaining. We also show that players' preferences over the equilibria are opposed, indicating that the alternative explanation based on salience and equilibrium selection also applies to this game.

Theorists have long recognized the inherent coordination problem present in most bargaining. For example, Schelling (1960, p. 69) points out that "the fundamental problem in tacit bargaining is that of coordination." In any game with a range of mutually acceptable outcomes, players seek to coordinate on one of those outcomes – since failing to agree results in an outcome that is worse for both – while striving to get the most for themselves.

One widely studied bargaining game in which the issue of coordination has not been given much attention is ultimatum bargaining. In the ultimatum game two players must divide a sum of money X. The first player (labeled the *proposer)* offers some portion x of a pie X to the second player (labeled the *responder).* If the responder accepts the offer then the responder receives x and the proposer receives X - x. If the responder rejects the offer then both players receive zero. A typical result from many experiments using this game is that proposers offer around 40% of the amount being divided, and responders reject offers with high frequency if they are less than 20% or so. This basic result has been replicated dozens of times, in several countries and with large variations in stakes.[7]

In most experiments the ultimatum game is played sequentially. A proposer makes a specific offer, which is transmitted to the responder, who accepts or rejects it. If responders are rational and self-interested, and proposers know that, then the unique subgame perfect equilibrium is for proposers to offer some small amount $e > 0$ and for responders to accept it.[8] Note that in this analysis, there is no coordination problem because the subgame perfect equilibrium is unique.

An alternative experimental method, which is more informative about responders' preferences, is for the responder to precommit to a threshold "minimum acceptable offer" (MAO) that she will accept (and any lower offer will be rejected). This modification is significant: when the game is played using the MAO method it is closely related to BOS. Table 3 shows how.[9]

[7] See Camerer and Thaler (1995) for a review.
[8] We assume for simplicity that the smallest offer must be positive.
[9] The simplified ultimatum game in Table 3 is also closely related to the "Nash demand game," in which two players propose shares for themselves of x_1 and x_2, and they earn their shares if and only if $x_l+x_2<10$ (otherwise they earn nothing). The difference between the demand game and the ultimatum game is that if the proposed shares (x, and MAO) add to less than \$10 in the ultimatum game the shortfall goes to the proposer, while it is discarded in the Nash demand game. In pure-strategy equilibrium there is no shortfall, so the pure-strategy equilibria of the two games are exactly the same.

The table shows a simplified ultimatum game in which players can choose to offer, and state as MAOs, only elements of (2.50, 5.00, 7.50). If the MAO is less than or equal to the offer x, the payoffs are (10-x, x); otherwise they are (0, 0).

The kinship to BOS is apparent along the diagonal – the set of pure-strategy Nash equilibria – the payoffs represent every feasible division of $10. Lower offers clearly favor proposers and higher offers favor responders. Hence, within these set of Nash equilibria players face a coordination game identical to the BOS. Both players prefer some agreement to none, but different agreements benefit them differently. The key difference between the games occurs in the cells below the diagonal – these indicate the the colum player has a weakly dominant strategy to select a MAO of $2.50, even though all of the outcomes along the diagonal are pure strategy Nash equilibria.

Table 3: Simplified Ultimatum Game

		Responder MAO		
		2.50	5.00	7.50
	2.50	7.50, 2.50	0, 0	0, 0
Proposer offer	5.00	5.00, 5.00	5.00, 5.00	0, 0
	7.50	2.50, 7.50	2.50, 7.50	2.50, 7.50

The close relation with the BOS emphasizes that a coordination problem exists in the ultimatum game too. And since we know that timing seems to affect equilibrium selection in BOS and in related games with multiple equilibria (resource dilemmas and step-level public goods provision), the ultimatum game appears as a natural game with which to attempt to replicate the previous timing results.

III. Ultimatum bargaining experiments

In our ultimatum game experiments, large groups of University of Chicago MBA students were recruited (often at the beginning or end of a class; n = 284 in total). Subjects were randomly paired with one another and told they were paired with someone else in the same room, but they would not know who that person was.[10] Proposers offered a division of $10 to a responder, in increments of $0.50. Responders indicated which offers they would accept by checking "accept" or "reject" from a list of all

[10] Instructions are in the appendix.

possible offers. From their acceptances we computed a minimum acceptable offer (MAO). Offers and MAOs were matched by the experimenters and subjects were paid what they earned (typically in an envelope distributed at the end of class, or at the beginning of the subsequent class).

Ultimatum games were played in three conditions. In the simultaneous (SIM) condition, proposers and responders filled out their offer and MAO forms at the same time. In the proposer-responder (PR) condition, proposers first handed in their offer forms, then responders filled out MAO forms and handed them in. Thus, in the PR condition both players knew the proposer moved first, but responders did not know the proposer's offer. Finally, the responder-proposer (RP) condition is the opposite: Responders handed in MAO forms first, then proposers made offers.

As we mention above, this game is similar to the BOS game. Virtual observability predicts that the equilibrium selected in conditions PR and RP will be the unique subgame perfect equilibrium in the sequential game with observable moves. For condition PR, this is where the proposer makes the lowest possible offer and this offer is accepted. For condition RP, this is where the responder selects the highest possible MAO and the proposer best responds with an offer equal to this. Thus, the hypothesized effects of timing, predicted by virtual observability, are as follows:

Offers H1:	Offer(RP)	>	Offer (SIM)	>	Offer (PR)
MAOs H1:	MAO (RP)	>	MAO (SIM)	>	MAO (PR)

However, the alternative of equilibrium selection based on the highlighting of one player as the "first-mover" and this player's preferred equilibrium being selected is also consistent with this predicted behavior. Therefore, these experiments are not intended as a clean test of virtual observability – as the next experiments are – as much as a replication of previous results.

Figure 1 shows the cumulative distribution function (cdf) of MAOs in the PR, SIM, and RP conditions. Table 4 reports descriptive statistics and an Epps-Singleton characteristic function statistic testing whether the three distributions appear to be drawn from the same population. There is a clear ordering in the three means, but the standard deviations are large and only MAOs from the more extreme conditions, PR and RP, are significantly different with a p-value less than 0.05.

Looking at Figure 1, the difference in conditions is a little more evident: For low offers, around $1-$3, the rejection rates vary from about 60% to 65% to 80% when responders move after, at the same time, or before proposers. The test statistic reported in Table 4 confirms that the PR-RP difference is highly significant, the RP-SIM difference is only marginally significant (p = 0.07) and PR and SIM are hard to distinguish. Hence, we cannot reject the hypothesis of equality of MAOs in favor of the strict ordering predicted by H1, but we can reject equality in favor of the extreme prediction MAO(RP) > MAO(PR).

Table 4: Statistics testing equality of MAO distributions

		Descriptive Statistic		
condition	N	mean	median	Std dev
PR	75	2.82	4.25	2.33
SIM	33	3.39	4.50	2.30
RP	45	3.69	4.50	1.85
		Epps-Singleton CF statistic (p)		
condition	N	RP	SIM	
SIM	33	9.05 (.07)		
PR	75	19.14 (.001)	1.28 (.85)	

Note: Test statistics are distributed chi-squared with 4 degrees of freedom under the null hypothesis of distributional equality. All p-values are one-tailed.

Figure 2 shows the cumulative frequency of offers in all three conditions. The offer distributions are very similar since, as in most studies, offers are tightly clustered around $5. There is a slight tendency for lower offers in the PR condition (and a few more super-generous offers above $5 in the RP condition), but no differences in the three conditions are significant. While there is a modest timing effect in the offers, we cannot reject the hypothesis of equality of offers in favor of the timing-based alternative H1.

Overall, the ultimatum data show a modest effect of timing.[11] In particular, MAOs are indeed lower when responders know they move second, and are higher when they move first. However, this difference is not great and only the PR-RP difference is significant. Moreover, offers do not change much at all. Still, the fact that we find any timing effect is surprising, and consistent with previous experiments. These experiments, however, do not allow a direct test of virtual observability. The next experiment – using a version of the stag-hunt game – does this.

IV. Weak-link coordination game experiments

The main purpose of this paper is to test virtual observablity in experiments using coordination games. More precisely, we hope to use a version of the stag hunt game to explore whether the result predicted by virtual observability obtains when it does not coincide with an equilibrium that is also uniquely preferred by the player designated as the "first mover." Table 5 shows payoffs in the "weak-link" coordination game, first studied by Van Huyck, Battalio & Beil (1991).

In the weak-link game, groups of three subjects choose numbers from 1 to 7. The row player's payoff depends on the number she chose (shown in the rows) and on the smallest number chosen by any player in the group (hence, the term "weak link" game). The payoffs are an increasing function of the smallest number chosen, and a decreasing function of how far the row player is from the smallest number. Since everyone wants to

[11] Two other studies report evidence of timing effects in ultimatum games. Bagai (1992) collected MAOs when subjects were told a division was proposed "earlier this semester" or "will [be] propose[d]." The "earlier" group, corresponding to our PR, had mean MAOs of $2.34 and the "will propose" group, corresponding to RP, had mean of MAOs of $1.69. The difference is in the opposite in direction of ours, and is insignificant.

Blount (1995) also changed timing (though the change in timing was deliberately confounded with a change in subjects' knowledge of the distribution of offers from which an offer would be drawn). Her data suggest a timing effect which is in the same direction as our SIM-PR difference, but larger: Sixty percent of the responders in the PR condition, who received an offer in an envelope stapled to their response sheet, accepted $1 or less. The corresponding figure is only 28% in a separate simultaneous-move study. While this difference in MAOs is dramatic (the two cdf s are much further apart than ours in Figure 2d), the low sample size in the SIM condition limits test power (large sample KS statistic=4.74, p=.09 by a one-tailed test).

Taken together, Blount's study and ours show that a weak first-mover advantage appears to drive MAOs down if responders know an offer has already been made and, more significantly in our data, to raise MAOs if responders know they move first. (Bagai's result is opposite, and puzzling.) The effect is modest in size, however, is only significant in the most extreme comparison between responder-last RP and responder-first PR conditions.

be no higher than the minimum, and wants the minimum to be as large as possible, the game requires coordination. Every number is a Nash equilibrium and the equilibria are Pareto-ranked: coordinating on X provides higher payoffs for everyone than coordinating on X-1, and coordinating on 7 yields the highest payoff of all.

Table 5: Weak-Link Coordination Game

		MINIMUM VALUE OF X CHOSEN						
		7	6	5	4	3	2	1
	7	1.30	1.10	.90	.70	.50	.30	.10
YOUR	6		1.20	1.00	.80	.60	.40	.20
CHOICE	5			1.10	.90	.70	.50	.30
OF X	4				.100	.80	.60	.40
	3					.90	.70	.50
	2						.80	.60
	1							.70

The weak link game models situations in which group production is determined by the level of the lowest-level input. Examples include: keeping a secret, meeting a group at a restaurant that will not seat anyone until everyone in the group has arrived, output in "high reliability" organizations in which a single failure or low-quality component causes disaster, or submitting chapters to a book which cannot be printed until all the chapters arrive (e.g., Camerer & Knez, 1997).

In the weak-link game, virtual observability implies that if players move in a specified order, the first player will act as if others see his move and best-respond to it (and similarly for the second player). Recall that if an outcome is a subgame perfect equilibrium of the sequential move game where choices are observable, then it is selected by virtual observability if it is also an equilibrium of the original game with unobservable moves. To see what this predicts for the weak link game, denote the first and second player's choices by X_1 and X_2. Assuming that prior moves are observable, then the third player will choose $\min(X_1,X_2)$, so the second player will choose $X_2 = X_1$ (choosing less would mean creating a lower minimum), and the first player will choose $X_1 = 7$. Since the third player “follows” the second, and the second follows the first, the first player can “ensure” a minimum of 7 simply by choosing 7 to begin with. Virtual observability therefore implies an efficient outcome in the weak-link game.

Notice, however, that the alternative explanation that players simply use the asymmetry created by timing to coordinate on the first-mover’s preferred equilibrium does not make a similar prediction in this game. In fact, because there is no asymmetry in the equilibirum payoffs, this explanation predicts no difference when timing is introduced without observable moves. Thus, we can use weak-link games to test virtual observability separately from the alternative explanation of equilibrium selection by salience and labelling of one player as focal.

In our experiments, groups participated in one of three conditions. In the SIMultaneous condition, all three subjects made their choices at the same time. After each round, forms recording the choices were collected, the experimenters recorded choices by others in the group on the same forms, and the forms were returned to the subjects. To ensure comparability with the other conditions, subjects learned the choices of each of the other two subjects in their group.

In the SEQuential condition subjects moved in a specified order – A first, then B, then C – but later-moving subjects did not know what the earlier choices were.[12] As in the SIM condition, after all subjects made choices their forms were collected, filled out to show the choices of others in each group, and returned to subjects.

In the OBServable condition, subjects knew the moves of all players in their group who moved before them. After A’s made choices the forms were collected, and A’s choices were told to the corresponding B and C subjects. Then, after B subjects made choices their choices were told to the corresponding C subjects.

The OBS condition provides an empirical benchmark against which the SEQ condition can be judged. The test is simple: Virtual observability predicts SEQ will be like OBS, and not like SIM. Unlike previous experiments, however, the alternative

[12] To help ensure that subjects could not tell when others in the room made their choices (so that subjects could not easily identify who might be in their group), as the A subjects recorded their choices the B and C subjects marked an “X” in a box on their forms. This way, all subjects made a mark on their sheets at the same time. After the A subjects had all marked choices, the B subjects made their choices (and A and C subjects marked Xs), then C subjects made choices.

explanation based on salience and first-mover preference does not make a prediction other than that of traditional game theory: SEQ will be like SIM, and not like OBS.

Virtual observability predicts that coordination will improve, to choices near seven, when we move from simultaneous moves to sequential moves that are unobservable. We can write this formally, denoting the distribution of number choices by D(.), and representing stochastic dominance relation among distributions by $A >_{Sd} B$ (the distribution A stochastically dominates B). Since cumulative distributions with more choices of high numbers will stochastically dominate distributions with more low-number choices, we have the following prediction of virtual observability:

$$\text{H2:} \quad D(SIM) \quad <_{sd} \quad D(SEQ) \quad = \quad D(OBS)$$

We conducted experiments with groups of Caltech undergraduates (n = 60) recruited from a list of subjects who had participated in previous experiments, and UCLA undergraduates (n = 72) recruited from an accounting class.

In each session 6-18 subjects sat in a room together. Subjects were randomly assigned numbers and letters (A, B, or C) and were formed into three-person groups. They did not know which other subjects were in their group. After reading the instructions (see Appendix) out loud to all subjects, the subjects answered two questions about how different choices led to different payoffs. When all subjects had answered correctly, the experiment began. In the Caltech sessions (which were conducted first), subjects played 8 periods of the weak-link game in the same condition. The UCLA sessions proceeded in the same way, except that we conducted 5 periods because of greater time constraints and because the last few periods in the Caltech sessions did not reveal significant changes in behavior.

To convey the data compactly, we averaged the choices of all subjects in each round, in each condition, for each subject pool. Figure 3 shows the data from Caltech subjects. In the SIM condition, choices initially averaged just above 6, and drifted slightly upward over eight rounds. The SEQ condition results are initially close to those of SIM, but they converge much more quickly to 7 and are much closer to the choices in OBS in later periods. SEQ choices in the first four periods are slow to converge upward (as in SIM) but in the last four periods 93 of 96 SEQ choices were 7s (as in OBS). Overall, the data suggest some predictive accuracy to virtual observability, since choices in SEQ more closely resemble those in OBS with experience.

Figure 4 shows similar data from UCLA undergraduates. Choices are lower and more dispersed than the Caltech choices.[13] The UCLA data also provides support for hypothesis H2, since the choices in SEQ are much closer to those in OBS, particularly in later periods. Overall the pattern is the same in both figures: SEQ choices are initially close to those in SIM, but are much closer to choices in OBS in later periods.

Table 6: Minima from UCLA weak-link groups by rounds
(medians in parentheses)

		Condition	
Period	SIM	SEQ	OBS
1	13333444 (3)	11134447 (4)	34555667 (5)
2	13445345 (4)	14741557 (4.5)	36667767 (6)
3	13466346 (4)	25764577 (5.5)	43637777 (6.5)
4	13466147 (4)	16773777 (7)	55547777 (6)
5	13477147 (4)	17773677 (7)	77317177 (7)
All	(4)	(5)	(6)

Since the minima in each group are sensitive to outliers in the left tail of the choice distributions, the minima may be a good place to look for distributional differences that are not strikingly apparent by looking at the averaged data in Figures 3 and 4. Table 6 shows the minima from all groups in all rounds, for the UCLA data (medians of the minima are shown in parentheses). The period 1 row lists minima of each group in each condition, from low to high. Subsequent rows (representing later rounds) list a group's minima in the same column as in the first row. If you want to track a particular group, read straight down vertically. For example, the rightmost group in the

[13] We excluded one group from the OBS condition because two of three subjects reported that they were deliberately choosing low numbers to harm fraternity brothers they guessed (correctly) were in their group. Their choices resulted in minima of 3,3,3,1, and 6; including those data would only bolster our conclusion that SEQ data are similar to OBS, by lowering the average OBS choices.

SIM condition that chose 4 in round 1, then chose minima of 5, 6, 7, and 7 in later periods.

In the UCLA data, the SEQ and OBS conditions reach minima of 7 a total of 40% and 42.5% of the time, respectively, compared to only 10% in the SIM condition. The median minimum in each round is always larger in SEQ than in SIM. Across all rounds, the median of the minima in the SEQ condition, 5, is halfway between the SIM and OBS medians of 4 and 6. With respect to minima, SEQ is squarely between SIM and OBS.

Table 7: Tests for differences among minima in weak-link treatments

Period	First			Second from last (CIT: 7, UCLA: 4)		
Summary of minima	Mean	St. Dev.	N (groups)	Mean	St. Dev.	N (groups)
SIM	3.94	1.57	16	5.13	2.16	16
SEQ	3.88	1.96	16	6.31	1.74	16
OBS	5.67	1.30	12	6.25	1.14	12

Comparison	SIM-SEQ	SIM-OBS	SEQ-OBS	SIM-SEQ	SIM-OBS	SEQ-OBS
t-statistic (d.f)	0.10 (30)	3.17 (26)	2.85 (26)	1.71 (30)	1.73 (26)	0.11 (26)
p<(1-sided)	N.S.	0.01	0.01	0.05	0.05	N.S.

To do more formal hypothesis tests using all the data, we looked at the distributions of minima in the first period and in the second-to-last period, pooling across treatments and subject pools.[14] [15] A comparison using only the minima is conservative since it controls for the lack of independence between observations within a group and

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[14] We use the second to last period – instead of the final period – because the final period of play in weak-link games often exhibits "end game" behavior in which subjects in previously efficiently coordinated groups lower their choices (perhaps because of a desire to have a higher relative payoff than others, or because of the fear others will do so). We use different periods in both sessions (4th and 7th) because we are interested in behavior near the end of the experiment. If we use a test using the 5th period in both locations, as one referee suggested, the difference between SIM (5.19) and SEQ (6.19) is similar, but the statistical significance is slightly weaker (p < 0.08).

treats an entire group as a single observation. The results are reported in Table 7. This table presents the average of all the minima in each treatment in the first round and in the second-to-last round, pooling across populations. The bottom of the table presents the results of tests of pairwise comparisons of the mean minimum between conditions, for both earlier and later rounds. As the tests at the bottom of the table indicate the pattern of differences presented in Figures 3 and 4 is significant. SEQ is closer to SIM at the beginning of the experiment, but much closer to OBS in later rounds. Therefore, it seems that virtual observability does not "work" right away, but begins to work as subjects learn.

V. Conclusions

This paper explored the effects of changing the timing of moves – without changing the information available to any players – in noncooperative games. We find that the timing of moves alone affects behavior in experiments using two games. Moreover, the results of both experiments are consistent with the predictions of a theory, virtual observability, that predicts that players act as if they can tell what those who moved earlier did, and that earlier-movers expect this anticipation. (It is as if the players erase information sets, compute subgame perfect equilibria, then restore the information sets and check that the selected equilibrium is also a Nash equilibrium of the original game.) While previous studies have demonstrated similar results that are also consistent with this theory, they do not rule out an important alternative explanation that we carefully rule out in our second experiment. Specifically, we use the weak-link coordination game in which virtual observability predicts timing should matter, but the alternative explanation of equilibrium selection by first-mover salience does not.

Our results have several implications.

<u>Sequential coordination.</u> The results on weak-link coordination show that simultaneity of choices may be an important source of coordination failure. Spreading choices out in time, even when previous choices are not observed, can improve coordination (as conjectured by Bryant, 1983). When previous choices <u>are</u> observed,

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[15] We pool data from the two populations since, as Figures 3 and 4 indicate, the general patterns of results between the two conditions is similar for both UCLA and Caltech groups.

then subgame perfection selects the efficient outcome uniquely, but several levels of iterated rationality are needed (in the three-person game) to achieve the efficient outcome. For the first player A to choose 7 she must be rational, believe that players B and C are, and believe that B believes C is rational. For B to reciprocate and choose 7 as well requires her to be rational and believe C is. For C to reciprocate requires only that she be rational. The frequency of coordination failure in the observable condition casts doubt on the willingness of players to bet on these levels of iterated rationality, as has been observed in many other dominance-solvable games (e.g., Ho, Camerer & Weigelt, 1998; Weber, 2001).

Fairness and timing. Previous experimental findings on ultimatum bargaining are often characterized as showing that responders are willing to give up money to punish proposers they think have treated them unfairly. The timing results we report suggest this interpretation is incomplete. If only distaste for unfairness drives responders to state positive MAOs, why do their MAOs fall substantially when they know proposers move first? Within the fairness framework, the obvious answer is that a low offer is more fair when proposers move first than when proposers move second. But this answer suggests that fairness means "fair exercise of advantage," and thus cannot be completely decoupled from variables that alter advantage.

On the other hand, the effect of timing in our ultimatum-bargaining experiments is also much smaller than in the previous BOS studies. The BOS results are probably much larger because timing does not compete with fairness as a selection principle in those games, since an equal split outcome is not possible. Ultimatums are more like resource dilemmas in which equal resource-use is an obvious fair point.[16] In those dilemmas the effect of timing should therefore be muted by the strength of equal-use as a focal principle. Indeed, the effects of timing reported by Rapoport, et al., in resource dilemmas, described above, are more like our ultimatum results in magnitude, and substantially weaker than in BOS. This does not mean timing effects can be ignored. Instead, the overall picture from BOS, resource dilemmas, and ultimatum games shows that many structural features of games act as selection principles. Equal-payoff is a strong principle, and has a bigger effect than the subtle effect of timing.

Elicitation methods and timing cues. Our results have some implications for how game theory experiments are conducted and their results interpreted. The first important point is that previous studies have confounded timing and "response mode" by either confronting responders with specific offers or eliciting an MAO. The MAO method has generally been used in simultaneous move games whereas the specific-offer method makes clear that proposers move first. There is a sense from this literature that MAOs are higher than corresponding rejections of specific offers, which suggests a dynamic inconsistency in which subjects may state an MAO of $5, say (a mode in many samples), but actually accept less than $5 when faced with a specific offer.[17] We think, instead, that MAOs are inflated partly because the order of timing is ambiguous. When we made it clear that responders move second, in our PR treatment, MAOs fell substantially and almost half accepted $0.50 or zero.

Once simultaneous-move ultimatum games are seen as coordination games, the possibilities that wording, methods by which roles are assigned, and other variables might affect outcomes become natural since all these features could create different focal points or act as selection principles. For example, Blount and Bazerman (1996) elicit MAOs two different ways: One method asks responders to directly record an MAO, implicitly evaluating their outcomes independently, and the second method asks them to circle which offers they would accept from a list of possible offers, implicitly evaluating outcomes comparatively. They find substantially higher MAOs in the direct method (median $5) than in the list method (median $2.50). A timing-based interpretation of their finding is that the list method contains a proposer-first timing cue which the direct method does not clearly have. Similarly, Boles & Messick (1990) found that when offers were physically presented to subjects-- dollar bills were laid in front of responders-- then offers were accepted more frequently. One explanation is that physical presentation acts as a timing cue.

Timing and the psychology of belief formation in games. Our findings should pique the curiosity of game theorists (and psychologists too) about how players actually

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[16] The equal split outcome is not possible in the BOS.
[17] Bagai (1992) tested for such reversals explicitly, and did not find any from 34 subjects.

form beliefs in games. As pointed out at the start, the standard game-theoretic model draws no special distinctions among a player's beliefs about what another player did, is doing, or will do. But the psychology of reasoning suggests several ways in which these thinking processes might differ. Players may be better at reasoning backward, about events known to have already happened, than reasoning forward. Evidence from psychology experiments (e.g., Mitchell, Russo.& Pennington, 1989) shows that description of possible outcomes of previously-occurring events is often richer and more complex than description of later-occurring events: The past is easier to "imagine" than the future.[18] In the same way, B and C subjects in the weak-link games, moving second and third, might be able to imagine that earlier-moving A subjects will chose high numbers more easily than if those A subjects move at the same time as B and C do.

Abele, Bless and Ehrhart (in press) suggest a related interpretation: When games are played sequentially (even if later-movers do not know what earlier players did), players are more likely to think of the game as a social interaction and reason about what others would do, than when games are played simultaneously. They report several experiments which corroborate this hypothesis by moderating the degree of the timing effect according to whether games are construed as social or random.

A similar point can be made about other features of games that could affect belief formation, but are conventionally assumed not to. The psychological distinction between chance moves by nature and moves by another person is an example. The convention for modelling imperfect information games is to treat these two sources of uncertainty as equivalent. But players may reason about them differently (e.g., Blount, 1995; Camerer and Karjalainen, 1994). Recognizing the distinction, and exploring it both experimentally and formally, can only improve the descriptive accuracy of game theory.

[18] Credit and blame are also assigned differently depending on when agents acted (e.g., Miller and Gunasegram, 1990). In American law, for example, there is a doctrine that the agent with the "last clear chance" to avoid an accident is responsible.

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Figure 1. Cumulative MAO Frequencies Across Conditions

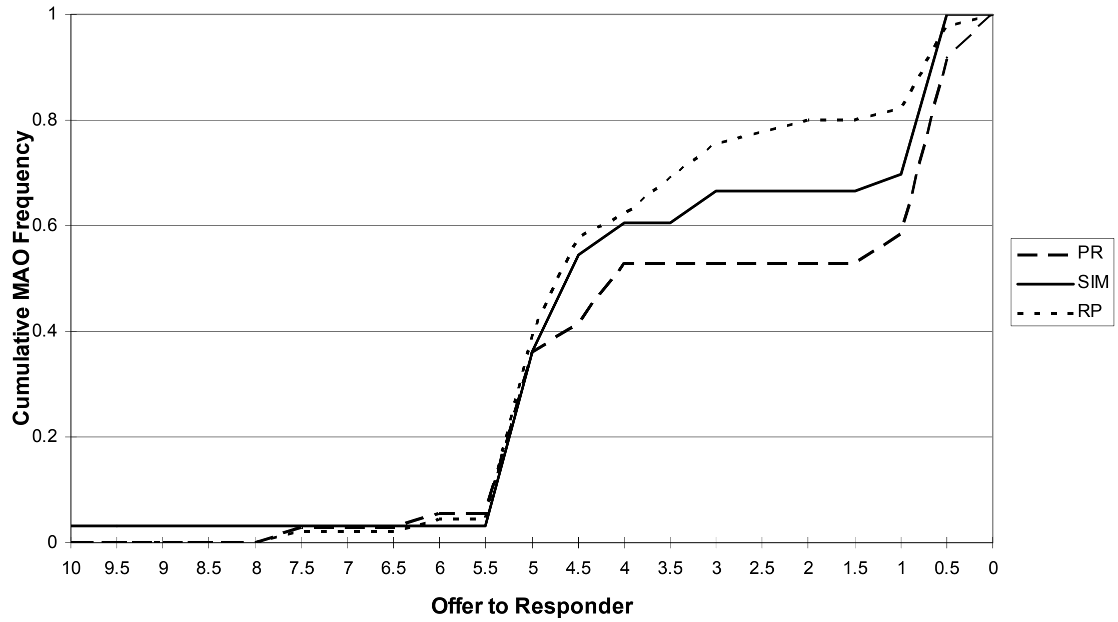


Figure 2. Cumulative Offer Frequencies Across Conditions

Figure 3. Average weak-link choices by condition (Caltech)

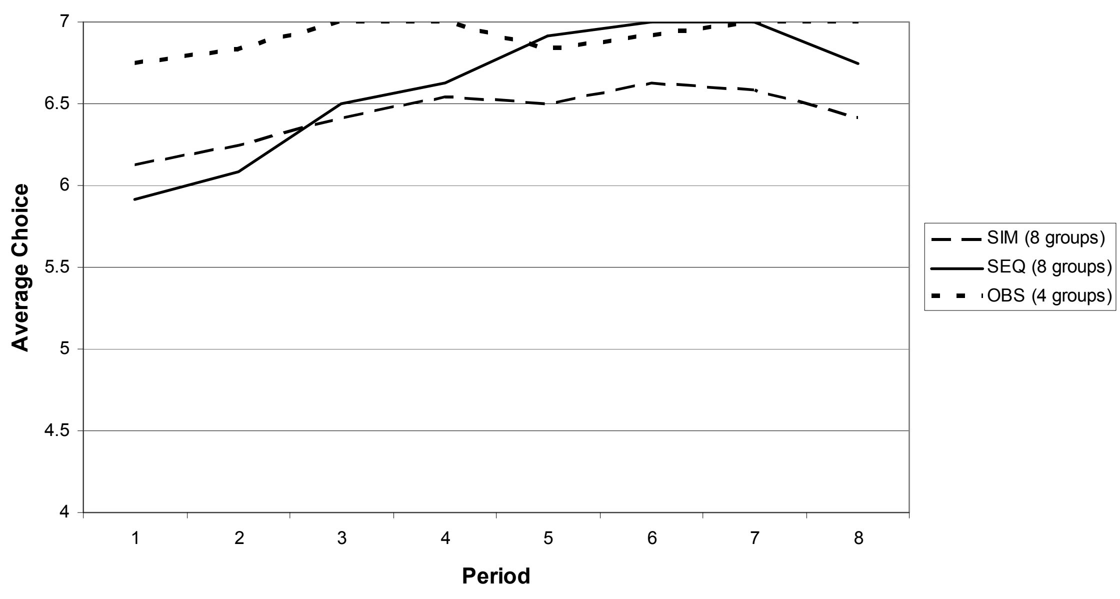
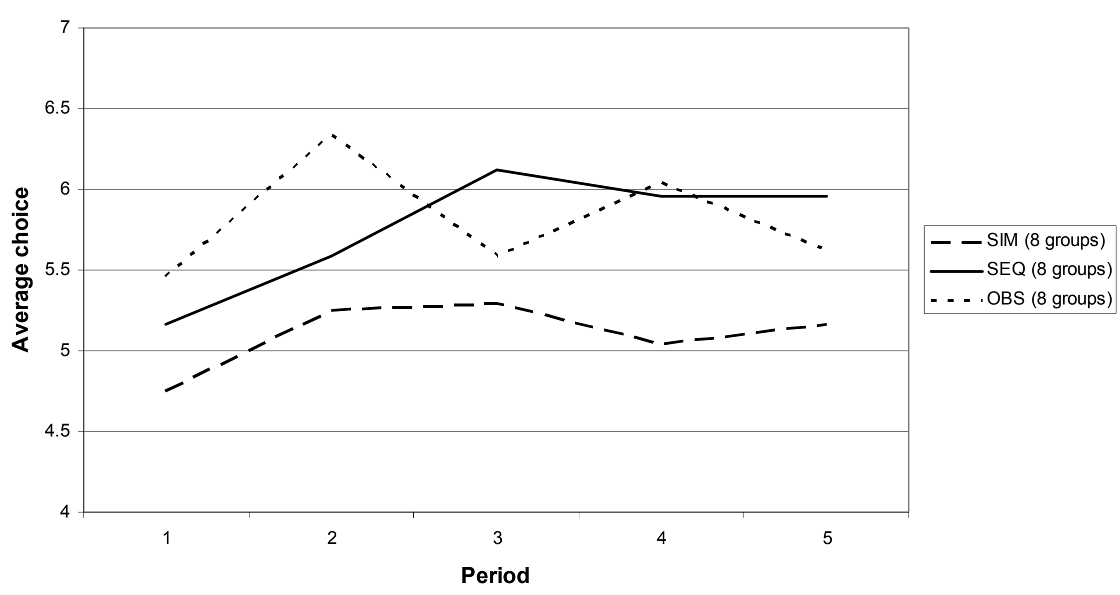


Figure 4. Average weak-link choices by condition (UCLA)



Appendix A: Ultimatum Instructions

In this experiment you will either be a proposer or a responder. The proposer has to decide how to divide up a ten dollar bill between him or herself and the responder The proposer makes an offer of X dollars, where X is divisible by fifty cents. If the responder accepts then the responder receives $X and the proposer receives $10 - $X. If the responder rejects the offer then both the responder and the proposer receive zero.

You have been randomly assigned the role of proposer or responder. If you are a proposer you have an OFFER sheet, if you are a responder you have an ACCEPTANCE sheet. At the top of your sheet you are given an ID number. For example, if your ID number is P12 then you are proposer number 12, while if your ID number is R12 then you are responder number 12. Finally, proposer P12 will be making an offer to responder R12. Your ID number is strictly confidential. Moreover, at no time during or after the experiment will you know the identity of the person you are paired with.

Treatment RP: *There will be two steps in the experiment. First, each responder will record the minimum offer that he or she is willing to accept from the proposer. The number the responder writes down is binding. That is, if the offer the responder receives is greater than or equal to this number, then the offer is accepted. However, if the offer is less than this number then the offer is rejected. Also, the number the responders record should be in increments of fifty cents. Once all the acceptance sheets have been collected, each proposer will then record their offer to the responder on their OFFER sheet, where the offer should be in increments of fifty cents.*

Treatment SIM: *Each responder will record the minimum offer that he or she is willing to accept from the proposer. The number the responder writes down is binding. That is, if the offer the responder receives is greater than or equal to this number, then the offer is accepted. However, if the offer is less than this number then the offer is rejected. Also, the number the responders record should be in increments of fifty cents. While the responders are making their decisions, each proposer will record their offer to the responder on their OFFER sheet, where the offer should be in increments of fifty cents.*

Treatment PR: *There will be two steps in the experiment. First, each proposer will record their offer on their OFFER sheet, where the offer should be in increments of fifty cents. Once all the offers have been collected, each responder should record the minimum offer that he or she is willing to accept from the proposer. The number the responder writes down is binding. That is, if the offer the responder receives is greater than or equal to this number, then the offer is accepted. However, if the offer is less than this number then the offer is rejected. Again, the number the responders record should be in increments of fifty cents.*

Once all of the record sheets have been collected, your record sheet will then be paired with your partner's as indicated by your identification number. The experimenter will then determine whether or not offers are accepted or rejected and how much each participant receives. Your cash payoff will then be placed in an envelope and at the end of the session you should pick up the envelope corresponding to your identification number.

Appendix B: Weak-link instructions

This is an experiment in the economics of market decision making. The instructions are simple and if you follow them closely and make wise decisions, you may make an appreciable amount of money. These earnings will be paid to you in cash at the end of the experiment.

In the experiment you will participate in a game with two other people. You will not know the identity of the people you are playing with and any communication between yourself and them will be **only** through the experimenters. Members of a group will be identified as **A**, **B**, or **C**.

The experiment will consist of five periods of play. In each period, you will select a number denoted by **X**. The values of X you may choose are 1, 2, 3, 4, 5, 6, 7. The value you pick for X and the minimum value of X chosen by all members in your group (including yourself) will determine your payoff in any one period of play.

Table 1 tells you how you earn money. Please look at the table now. The entries in the table give each player's earnings from selecting alternative values of X. The earnings in each period may be found by looking across from the value you choose on the left-hand side of the table, and down from the minimum value chosen from the top of the table. For example, if you chose a 4 and the minimum value chosen was a 3, you earn 80 cents that period. Alternatively, if you chose 4 and the minimum value of X chosen was 4, then you earn one dollar. Note that all three players (A, B, and C) have the same payoff table.

The experiment will consist of five periods, where in each period you will play with the same two participants. In your folder you are given a Record Sheet. Please look at it now. The order of play goes as follows:

Treatment SIM:

1. At the beginning of the period, you are asked to write down your choice of X for that period. Your choice of X is private and should not be discussed with anyone during the experiment.

2. After collecting all the Record Sheets, the experimenters will record the minimum value of X chosen in your group in the appropriate shaded box on your Record Sheet and return it to you. The actions selected by the other two members of your group will also be recorded.

3. Determine your earnings from Table 1 for that period and record it in the "Earnings from Choice" column on the Record Sheet.

*Note that you **do not** know your partners' choices of X before making your selection.*

Treatment OBS:

*1. At the beginning of each period, Player A will be asked to write down their choice of X for that period in the appropriate space on the Record Sheet. Player B and Player C will be asked to place an '**x**' in the first column of their Record Sheet for that period. Player A's choice of X is private, except for what the experimenter reveals to other subjects, and should not be discussed with anyone during the experiment.*

2. After everyone has completed writing what they are supposed to, the experimenters will collect all of the Record Sheets and return them after filling in the appropriate cells. Note that Players B and C will now be aware of what value of X Player A has selected.
*3. Player B will then be asked to write down their choice of X for that period. Player B's choice of X is also private, except for what the experimenter reveals to other subjects, and should not be discussed with anyone during the experiment. Player A and Player C will be asked to place an '**x**' in the second and third columns of their Record Sheets, respectively.*
4. After everyone has completed writing what they are supposed to, the experimenters will collect all of the Record Sheets and return them after filling in the appropriate cells. Note that Player C will now be aware of what values of X both Player A and Player B have selected.
*5. Player C will then be asked to write down their choice of X for that period. Player C's choice of X is also private and should not be discussed with anyone during the experiment. Player A and Player B will be asked to place an '**x**' in the third and fourth columns of their Record Sheet, respectively.*
6. After collecting all the Record Sheets, the experimenters will record the minimum value of X chosen in your group in the appropriate shaded box on your Record Sheet and return it to you. The actions selected by the other two members of your group will also be recorded.
7. Determine your earnings from Table 1 for that period and record it in the "Earnings from Choice" column on the Record Sheet.

Treatment SEQ:
*1. At the beginning of each period, Player A will be asked to write down their choice of X for that period in the appropriate space on the Record Sheet. Player B and Player C will be asked to place an '**x**' in the first column of their Record Sheet for that period. Player A's choice of X is private and should not be discussed with anyone during the experiment.*
2. After everyone has completed writing what they are supposed to, the experimenters will come by to make sure that everyone has correctly written in the appropriate cells.
*3. Player B will then be asked to write down their choice of X for that period. Player B's choice of X is also private and should not be discussed with anyone during the experiment. Player A and Player C will be asked to place an '**x**' in the second column of their Record Sheets.*
4. After everyone has completed writing what they are supposed to, the experimenters will again come by to make sure that everyone has correctly written in the appropriate cells.
*5. Player C will then be asked to write down their choice of X for that period. Player C's choice of X is also private and should not be discussed with anyone during the experiment. Player A and Player B will be asked to place an '**x**' in the third column of their Record Sheets.*
6. After collecting all the Record Sheets, the experimenters will record the minimum value of X chosen in your group in the appropriate shaded box on your Record Sheet and return it to you. The actions selected by the other two members of your group will also be recorded.

7. Determine your earnings from Table 1 for that period and record it in the "Earnings from Choice" column on the Record Sheet.

Note that you ***do not*** *know your partners' choices of X before making your selection.*

Please write in your Record Sheet only when you are instructed to do so.

At the beginning of the experiment you will be given a player letter. You should not share your player letter with any other participants in the experiment. At the end of the fifth period you should add up your earnings from the experiment and record it in the total earnings box at the bottom of your experiment Record Sheet.

Questions

1. Suppose you select 3, and suppose the minimum choice is 2, how much do you earn?

2. Suppose you select 5, and suppose the minimum choice is 4, how much do you earn?