

Recognizing and Playing Turn Taking Strategies*

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Abstract

Intertemporal cooperation typically involves players taking turns as the active participant undertaking a particular task. A laboratory experiment is used to determine if subjects can cooperate on a turn taking outcome using a multiperiod signaling device. The primary finding is that the signals sent are for a particular type of turn taking equilibrium but that groups of four still have a difficult time coordinating actions. Some groups of two and three are able to use the signaling device to achieve intertemporal cooperation.

1 Introduction

In many games, such as the Prisoner's Dilemma or stag hunt, individuals can raise payoffs by choosing to cooperate on a non-stage game equilibrium outcome or the Pareto efficient equilibrium of multiple equilibria. This cooperation, however, occurs within-period in that all players are better off in the current period by cooperating than they would be by choosing not to cooperate. Unlike within-period cooperation, intertemporal cooperation requires individuals to view the repeated game as a whole in order to increase payoffs and typically requires that some individuals forgo earnings in the current period so that they may receive a higher payoff in future periods as well as a higher total payoff.

A turn-taking strategy (TTS) is a strategy in which players take turns as the active participant undertaking a particular task. Turn-taking is a pattern that is present in many aspects of life. An early study of turn-taking in conversation is provided by Sacks, Schegloff, and Jefferson (1974).¹ Mitchell and Silver (1990) show how turn-taking is more apt to arise under cooperative goal settings rather than individual goal settings. Colman and Browning (2009) show how turn-taking may have evolved without the use of language as an aid. Kaplan and Ruffle (2005) also provide examples of personal exchange in which players take turns, including drivers merging from two lanes into one and siblings alternating who sits in the front seat of a car. In an impersonal exchange or market setting, this alternating may mean that firms take turns being the active participant in the market. Consider the following story:

Jeffrey Katzenberg, a Dream-Works co-founder, who is also a friend of Mr. (Harvey) Weinstein, said in an interview today that he had breakfast with Mr. Weinstein last week in New York to discuss their respective movies' release dates and joked that they settled their differences after the two ate waffles, and later 'stayed up late telling manly stories.'

All kidding aside, he agreed that the decision was based more on economics than breakfast food and bonding. 'He and I had many conversations about why releasing the movies on the same day was in none of our interests,' Mr. Katzenberg said. 'It was an uncomfortable situation as both companies have a big investment in Leo DiCaprio.'

Laura Holson, *New York Times*, pg. C1, October 11, 2002

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¹A review of techniques for studying the organization of conversation, including turn-taking, can be found in Roulston (2006).

The quotation above is in relation to two Leonardo DiCaprio films, *Gangs of New York* and *Catch Me if You Can*. Both were scheduled to open on Christmas Day 2002. In the end, Mr. Weinstein altered his release date and Miramax chose to release *Gangs of New York* just five days earlier, on December 20th. Perhaps the most famous example of a TTS in the industrial organization literature is the “phases of the moon” bid rotation scheme employed in the electrical switchgear industry in the middle of the 20th century. According to Scherer (1970), this scheme involved:

...dividing the United States into four quadrants, assigning four sellers to each quadrant, and letting the sellers in a quadrant rotate their bids. A ‘phases of the moon’ system was used to allocate low-bidding privileges in the high voltage switchgear field, with a new seller assuming low-bidder priority every two weeks pgs. 159-161

While both examples show overt discussion, it is possible that business practices, such as announcing product release dates, could serve as a means of facilitating coordination of this type.² Note that there is a distinct difference between a verbal discussion and a signaling device such as announcing product release dates. With a verbal discussion one can convey both the strategy *and* the rationale for that strategy; with a non-verbal signal, one can only convey the strategy and hope that the rationale is inferred by others. The focus in the current study will be to use an economic experiment to determine if participants can use a multiperiod signaling device, similar to nonbinding announcements of product releases, to facilitate the use of a TTS. The experiment is formulated as a choice between two options, entering and remaining out, with per period payoffs determined by the entry decision and how many other participants entered that period. Note that the only method to increase profit is through intertemporal cooperation, which gives the TTS its best chance at occurring as within-period methods of cooperation are removed.

In addition to providing an experimental test of the conditions necessary for the use of a turn-taking outcome (TTO) to arise, this paper also extends the literature on how signaling devices affect the possibility of cooperative (or collusive) outcomes. Prior experiments, discussed in more detail in section 2, show that one period ahead pre-play signaling can lead to more cooperative outcomes when the actions taken lead to cooperation within the current period. Other experiments allow face-to-face or interface-to-interface communication, which is typically required to achieve intertemporal cooperation. Whether this is due to the ability to signal the intertemporal strategy or to the ability to convey the rationale of the strategy is an open question. The introduction of a multiperiod signaling mechanism in the current study allows subjects to communicate intertemporal strategies during each period of play. The focus of the study is only on the signaling aspect of communication, not the conveyance of rationale aspect.

Group size, payoffs to entering the market, and the ability to signal are varied in the experiment. Consistent with prior experimental research, the results show that two player groups are able to coordinate fairly well from the beginning of the experiment as long as the opportunity cost to miscoordination is low, mixed results for three player groups, and little coordination among four player groups. Also, holding group size constant, more coordination occurs in the treatments with lower opportunity costs of coordination attempts. When the signaling device is not available, there is less coordination in the groups. When groups are able to coordinate, they coordinate in a specific manner by alternating entry in a set sequence. The use of the multiperiod signaling device varies in a similar manner, with more usage the lower the number of players in a group as well as the lower the opportunity cost of coordination attempts. There are some instances among two and three subject groups where groups were not able to coordinate at the beginning of the session but were able to use the signaling device to overcome their miscoordination.

Section 2 discusses prior results from single-shot and repeated game coordination experiments as well as repeated game market experiments. A brief overview of theoretical support for the TTO is presented in section 3 and the experimental design is presented in section 4. Section 5 presents aggregate results of the experiment as well as econometric results at the individual and group level. Section 6 concludes.

2 Prior Experimental Research

There is a wealth of literature on the effects of communication and pre-play signaling in games which require within-period cooperation, such as in stag hunt games or the Prisoner’s Dilemma, as well as the effects of

²See Grether and Plott (1984) for early experimental work on the ability of advance notice of price changes to foster collusion.

communication in market experiments. Cooper, et al. (1992) use one-way and two-way communication in an attempt to alleviate coordination problems in simple and cooperative coordination games. They find that while one-way communication alleviates the coordination problem in the simple coordination game, two-way communication removes nearly all coordination failures. However, in the cooperative coordination game, which includes a dominated strategy, they find that one-way communication shifts the bulk of play from a low payoff equilibrium to a higher payoff equilibrium, but that two-way communication causes a mixture of play among the equilibria.

In a minimum effort game with no communication, Van Huyck, Battalio, and Beil (1990) observe that subjects do not coordinate on the high effort strategy despite the fact that their incentives are aligned to do so. Furthermore, play converges towards the minimum effort level within four periods. Van Huyck, Battalio, and Beil (1991) run experiments using a median effort game, and find that subjects are also unable to fully coordinate on equilibrium strategies. Blume and Ortmann (2007) add pre-play communication to the minimum and median effort games in Van Huyck, et al. (1990) and Van Huyck, et al. (1991) by allowing subjects to send a non-binding signal of their intended play next period. They find that allowing the signals greatly facilitates coordination, even for groups greater than size 2. Duffy and Feltovich (2002) examine the impact of history of play and pre-play communication in the prisoner's dilemma, stag hunt, and chicken games. They find that adding either a history of play or pre-play signaling increases the amount of coordination, although the history of play performs better than pre-play communication in games such as the prisoner's dilemma, where players have conflicting interests. These papers show that cheap talk signaling can induce more coordination by subjects. However, the type of cooperation in most of these experiments is fundamentally different than when subjects can only increase total payoff by forgoing a higher payoff in the current period.

A number of studies have examined behavior in environments in which a TTO may be a viable equilibrium in the repeated game. Cooper, et al. (1989) study one-way and two-way communication in single shot Battle of the Sexes games. The pre-play communication allows subjects to send a signal of which action they will take, but is not free-form. They find that one-way communication is the most efficient means of coordination but that two-way coordination still increases coordination, more so when multiple rounds of two-way coordination are allowed. Duffy and Hopkins (2005) study the market entry game of Selten and Guth (1982) in which there are N subjects who must decide to enter a market or not each period, and there is a capacity $c < N$ such that if the number of entrants is greater than c the entrants earn less than those who do not enter. Setting $N = 6$ and holding c constant throughout 100 periods of their experiment, they find that the number of entrants is close to c each period, though the identity of the entrants changes throughout the session. In a full information treatment in which subjects can see the decisions of all subjects in their group they find some subjects always entering and some always staying out. They note that no groups were able to coordinate on the joint profit-maximizing level of profits, which is a turn-taking outcome.

Studies closer to the current one include Dickhaut, et al. (2002) and Kaplan and Ruffle (2005). In Dickhaut, et al. (2002), a pair of subjects play a Shapley game, which has only a mixed strategy Nash equilibrium to the stage game. However, the payoffs to the mixed strategy Nash equilibrium are much lower than those that can be obtained if the subjects coordinate intertemporally. The authors find that allowing interface-to-interface communication via chat room greatly increases intertemporal coordination for subjects. Kaplan and Ruffle (2005) focus on an entry game where subjects receive a private value draw each round and propose that subjects may use either a cutoff strategy or an alternating strategy. The cutoff strategy occurs when subjects enter only when the private value is greater than some threshold while the alternating strategy is akin to the TTS. Using 2-subject groups they find that when the percentage difference between the upper and lower bound of the value distribution is large subjects use the cutoff strategy but that when the percentage difference is small subjects use an alternating strategy.

Sibly, Tisdell, and Evans (2015), and Bjedov, Madies, and Villeval (2016) focus specifically on how communication affects turn-taking behavior. Sibly, Tisdell, and Evans (2015) focus on behavior in three finitely repeated games that use cheap talk communication. They find that turn-taking arises in both an allocation game (in which turn-taking is one of multiple equilibria) and in a dominant strategy equilibrium game (in which it is not). Free-form cheap talk communication reduces behavior consistent with competitive preferences in the dominant strategy equilibrium game and fosters turn-taking. Bjedov, Madies, and Villeval (2016) investigate behavior in a two-stage coordination game with asymmetric payoffs. In their setting, turn-taking may resolve the conflict that arises from the asymmetric payoff structure and allow players to earn

maximum payoffs. Treatments with one-way and two-way free-form communication are conducted. At the beginning of the communication sessions, about 80%-85% of the groups are taking turns and by the end of those sessions between 90%-98% of groups are taking turns. In contrast, only about 50% of the groups in the treatment without communication begin by turn-taking, and only 70% are taking turns at the end of the treatment. Thus, communication enables turn-taking to develop more quickly, and helps sustain turn-taking throughout the session.

In market experiments, instances of group behavior consistent with the TTO occur at least as early as Fouraker and Siegel (1963). In one of their quantity choice experiments, two subjects settle on a TTO where they alternate producing 25 units and 8 units each round. This occurs without any discussion on the part of the subjects. Instances such as these are scattered throughout market experiments, particularly when subjects are allowed free-form communication. In the Davis and Holt (1998) posted-offer environment with secret discounts, a group of subjects discusses possible collusive strategies and settle on a TTO despite the fact that increasing marginal costs of production cause the TTO to provide lower payoffs than other collusive strategies. In the posted-offer environment of Isaac, Ramey, and Williams (1984), one group settles on a rotation scheme where one of the four sellers will remain inactive each period, allowing each of the other three sellers to sell one unit of the good.

There are also TTO results in the auction literature. Using sealed bid auctions, Isaac and Walker (1985) and Davis and Wilson (2002) provide evidence that some groups will attempt to form a TTO when allowed to communicate, even if such TTO formation is inefficient. Kwasnica and Sherstyuk (2007) study collusion in multiple unit auctions with complementarities and find a result similar to the TTO. When complementarities were large, bidders would take turns submitting the minimum bid in each round to avoid competing away the complementarity.

These prior experiments show the prevalence of intertemporal cooperation in both stylized normal form games and market experiments. In addition, anecdotal evidence, such as that about the two Leonardo DiCaprio films mentioned in the introduction, suggests that this type of cooperation is not confined to the laboratory. Given the abundance of situations in which turn-taking outcomes may occur, further study is needed to determine which outcomes are chosen and what devices are needed to coordinate upon a particular outcome.

3 Defining the Turn Taking Outcome

Simply stated, the TTO occurs when players take turns as the active party undertaking a particular task.³ However, there are many different manners in which players could choose to take turns. The most basic among these is that players take turns in a set order and then once all players have taken a turn the first player takes another turn. A 3-player example would be 1, 2, 3, 1, 2, 3, etc. Call this the alternating sequential entry (ASE) outcome. Another possible TTO would have participants take turns in a set order and after all participants have entered once they then enter in reverse order. A 3-player example would be 1, 2, 3, 3, 2, 1, 1, 2, 3, etc. There are more elaborate outcomes where one participant might enter for a few consecutive periods and then others follow suit by entering in the next set of periods. A 3-player example would be 1, 1, 2, 2, 3, 3, 1, 1, etc.

In an infinitely repeated game, all of these TTOs can be supported as subgame perfect Nash equilibria provided that the discount rate is high enough. Suppose there are k players. Let $\Pi_{i,t}^m$ be the payoff to a single player i being the active participant at time t and $\Pi_{i,t}^k$ be the payoff to each player i if all k players are active at time t . Let $\Pi_{i,t}^d$ be the payoff if a player deviates from the TTO, which occurs if a player is active during a time period in which it is another player's turn to be active. Assume $\Pi_{i,t}^m > \Pi_{i,t}^k$, $\Pi_{i,t}^d > \Pi_{i,t}^k$, and leave the relationship between $\Pi_{i,t}^d$ and $\Pi_{i,t}^m$ unspecified. Should a deviation be observed, all players choose to be active each period (Nash reversion) for the remaining time periods. Let $\delta \in [0, 1)$ be the discount rate. For all TTS outcomes where participants have an equal (or potentially infinite) number of turns, it can be established that a discount rate $\delta^* \in [0, 1)$ exists for each TTO such that the particular TTO can be

³Lau and Mui (2008) derive conditions under which turn taking increases welfare in Battle of the Sexes games. Leo (2017) takes a mechanism design approach to analyze turn-taking behavior, with possible swaps of turns.

supported as a subgame perfect Nash equilibrium as long as:

$$\Pi_{i,t}^m \geq k\Pi_{i,t}^k \quad \forall i \in (1, 2, \dots, k) \quad (1)$$

Proposition 1 *If equation (1) is satisfied for all players, then a discount rate $\delta^* \in [0, 1)$ exists for each turn taking outcome such that the particular set of strategies leading to each turn taking outcome is a subgame perfect Nash equilibrium.*

Proof. For specific payoffs and turn-taking sequences, as in the experiment, one can appeal to a Folk Theorem argument. More generally, the Limit of Means criterion (see Aumann and Shapley, 1994 and Osborne and Rubinstein, 1994) is not sensitive to a change in payoff in a single period nor the position of when $\Pi_{i,t}^m$ is received and can be used to establish the existence of a $\delta^* \in [0, 1)$. ■

While it is an open question as to which TTO individuals would choose to coordinate their actions, prior experimental research discussed in section 2 shows that the ASE rotation strategy is the most commonly used in laboratory experiments. This choice is in spite of the fact that a rotation system which reverses the order every round (call this a “reversal rotation”) leads to a more equitable distribution of payoffs when payoffs are discounted.⁴ Note that there is no particular TTO which is preferred by all players because all players prefer the particular TTO in which they receive payoffs first relative to other TTOs. For instance, player 1 in a 2-subject TTO will always prefer a TTO which follows the 1,2,1,2 pattern to the one which follows 1,2,2,1 while player 2 prefers the opposite. The parameters used in the experiment permit many types of turn taking outcomes; a further discussion of the viability of each type is discussed after the experimental payoffs are presented in section 4.

The focus thus far has been on a group of k individuals forming a full group TTO. Depending on the number of participants and the payoff structure it may be possible that $n < k$ individuals form an n -person TTO. Suppose one individual, for whatever reason, chooses to be active every round. The remaining $k - 1$ individuals could then form a $k - 1$ person TTO, as long as equation 1 is satisfied for the group of $k - 1$ individuals. While this will lead to a less equitable division of payoffs as the person who is not part of the rotation will receive a higher payoff, it is still possible that these reduced participation TTOs form as the members of the rotation will be better off than if they had not formed the TTO.

There are many possible equilibria in the repeated game described, leading to a question of which equilibrium will arise. Further, the game requires sophistication beyond that of typical cooperation in games in that cooperation must occur intertemporally and by individuals choosing different actions. Thus, consider how a cheap talk signaling game may aid the individuals in coordinating on a particular equilibrium. Because cooperation can only occur intertemporally, allowing a single period signal will be less likely to help than allowing a multiple-period signal that can convey the specific form of turn-taking a participant is considering.

Without signaling individuals can only condition their coordination attempts on how play has unfolded up to a point in time and hope the other group members will do the same. Also, there is no ability to communicate desired future play to other group members. Unless the individuals randomly coordinate on a particular equilibrium at the beginning of time, it will take longer for a stable TTO to develop without signaling than with signaling. Also, the signals sent can confirm that the actions taken by other participants are purposeful; without the signals a participant might believe that those individuals choosing to be inactive are irrational or are making decisions randomly.⁵

4 Experimental Design

The experiment is designed to determine if multiperiod signaling, without free-form communication, can enable turn taking outcomes. The experiment is a choice experiment where subjects choose either “A” (meaning enter the market) or “B” (meaning to stay out of the market) during a period. Payoffs are

⁴In many fantasy sports drafts this type of rotation system, called a snake draft, is used to equalize the distribution of talent across teams. Brams and Taylor (1999) discuss balanced alternation, which is similar to this type of rotation system, though slightly more complex.

⁵Even with the signals participants may believe others are not acting purposefully but the signals, along with the actual play, would provide other players with both a plan of action as well as the follow up on that plan.

	1 entrant	2 entrants	3 entrants	4 entrants	Stay Out
4N, 3N, 2N	3600	1600	900	576	100
4E	3150	1150	450	126	100
3E	2900	900	200	–	100
2E	2200	200	–	–	100

Table 1: Payoffs to entrants, in ECUs, under various treatments.

structured such that the Nash equilibrium of the stage game is for all subjects to enter the market. Subjects participated in fixed groups for the duration of the session.

In some treatments each subject is able to send nonbinding signals to all subjects in the group. These nonbinding signals are binary, with a 1 corresponding to choosing option A and a 0 corresponding to choosing option B. Signaling decisions are made simultaneously and prior to any subject making a choice of A or B for the period. Once all subjects have submitted their signals they are displayed to all group members while they make their entry decision for that period.

These signals could be sent for the upcoming 10 periods. Thus, in period 1 subjects can send signals for periods 1-10; in period 2, subjects can send signals for periods 2-11; etc. Note that the default is that all signals are set to 0, so that a subject must deliberately change the signal if he wishes to convey a message of choosing A for a particular period. As an aid to subjects who might desire to be consistent in their signal sending, the signal they sent in the prior period for each of the following periods is recorded on the screen for them. Thus, in period 2, the signals sent in period 1 for periods 2-10 are presented on the screen for the subjects.

In addition, subjects always had a history of entry decisions for their group members displayed on the screen, regardless of whether it was the signal sending stage or the entry decision stage. The history of entry decisions is included to provide a further aid to subjects in achieving the joint profit maximizing outcome. Given that cooperation must occur intertemporally, a history of which players entered and when they entered is a useful aid to help minimize errors.

There are two principal treatment variables, creating six possible treatment cells. The first variable is the number of subjects in a group, with either 2, 3, or 4 subjects in each group. The second variable is the payoff to the subjects. In the no entry cost treatments, payoffs are based upon the profit from a k -player Cournot model with linear demand, where k is the number of players who enter each period. Note that payoffs are denominated in Experimental Currency Units (ECUs). In the entry cost treatments, a fixed amount is subtracted each period a player chooses to enter. The entry costs are set at 450, 700, and 1400 ECUs. The entry costs are set so that when all players in a group enter the opportunity cost of staying out is very low (either 100 or 26 ECUs). If a subject chose NOT to enter the market in a particular period then he receives 100 ECUs regardless of the decisions of the other subjects.⁶

Table 1 shows the payoffs in ECUs to those subjects who enter the market under the various treatments. The treatments are referred to as 4N, 3N, 2N, 4E, 3E and 2E where the number stands for the number of subjects in a group while the letter N corresponds to the treatment with no entry costs and E corresponds to the treatment with entry costs. In addition, control sessions without the signals are conducted using the payoffs from the entry cost treatments. These sessions are labeled 2E-NoSignal, 3E-NoSignal, and 4E-NoSignal.

In total, 5 groups completed the 2E, 2N, 3N, and 4E-NoSignal sessions; 4 groups completed the 3E, 4E, 3E-NoSignal, and 4E-NoSignal sessions; and 6 groups completed the 4N session. A fifth session of subjects in the 4E treatment terminated after 14 periods due to hardware problems; this group is not included in the data analysis that follows. The exchange rate was 5000 ECUs for US\$1 for the no entry cost treatments and 4000 ECUs for US\$1 for the entry cost treatments.

4.1 Experimental Procedures

The experiment was programmed and conducted with the software *z-Tree*, described in Fischbacher (2007). Subjects were seated at visually isolated computer terminals and were randomly and anonymously placed

⁶The choice of 100 ECUs instead of 0 ECUs reflects a general opportunity cost for participating in the experiment.

	3-subj	2-subj	Full entry
4N	600	500	576
4E	450	275	126
3N	—	850	900
3E	—	500	200

Table 2: ECU payoffs per period for reduced participation TTOs

into groups of 2, 3 or 4 depending on the treatment. Subjects knew the total number of members in their group and were told that while the other members of their group would remain anonymous, they would remain the same throughout the duration of the experiment. They were also told that the experiment would last at least 80 periods, and that after 80 periods there was an 85% continuation probability after each additional period. This randomly determined endpoint provides the stimulus to ensure that subjects do not view the game as one with a fixed endpoint. Initial sessions were run using undergraduates at Florida State University, and subsequent sessions used undergraduates from George Mason University and UNC Charlotte. Average cash payouts were \$22 for a 30-120 minute experiment.

4.2 Predictions and hypotheses

Payoffs are structured such that full group turn taking is an equilibrium for all treatments. Yet there are multiple TTOs that could arise in this setting and theory provides little guidance as to which will arise. However, prior experimental results suggest that if a TTO occurs it will be the one using the ASE rotation. Comparing a reversal rotation with that of ASE rotation, given the experimental payoffs, the highest discount rates for any player in a particular group size and for a particular payoff structure occur when using the reversal rotation. While there is some difference, note that there is not much difference between the discount rates holding group size and payoff structure constant. Another factor as to why ASE rotation may be more prevalent is that it involves the smallest repeated sequence of numbers. In a 3-person group ASE rotation would require repetition of a sequence of three numbers (123,123,123), while other types of TTOs would require more than three. Reversal rotation requires repetition of a sequence of six numbers in a 3-person group (123321,123321).⁷ The first hypothesis is:

Hypothesis 1: *If players settle on a TTO, it will be the one using the ASE rotation.*

The tendencies of individual participants may make full group turn taking difficult. Thus, subsets of the groups may form reduced participation TTOs. However, it is not always profitable for reduced participation TTOs to form in equilibrium, particularly in the no entry cost treatments. Table 2 shows the average payoffs per period in ECUs if subjects play the stated reduced participation TTO, assuming the subjects not playing the TTO are always entering. In the no entry costs sessions, reduced participation TTOs are unlikely as the only reduced participation TTO more profitable than the minimum guaranteed amount from entering is a 3-subject TTO in the 4N session. Even in that treatment, average per period profit is only 24 ECUs greater from participating in the 3-subject TTO than the minimum per period profit from always entering. In the entry cost treatments, reduced participation TTOs are more likely to form as they all yield at least double the minimum profit one could receive from always entering. The second hypothesis is:

Hypothesis 2: *Cooperation will be higher in the entry cost treatments as it is possible to form reduced participation TTOs if full group TTO formation fails. Additionally, the opportunity cost of choosing to not enter is reduced in the entry cost treatments.*

While theoretical models assume perfectly rational players can coordinate on an equilibrium from the beginning of the game, prior experimental research suggests that achieving a TTO will become more difficult as the number of players in the game increases. The third hypothesis is:

Hypothesis 3: *Cooperation and TTOs will be more prevalent in treatments with smaller numbers of participants, all else equal.*

Additionally, achieving any TTO can be a difficult task. Face-to-face or interface-to-interface communication would certainly help players reach this outcome, but the goal is to determine which players recognize

⁷Note that this is true of all other patterns, not just reversal rotation. The goal is to state reasons why ASE rotation might be used more frequently and reversal rotation is simply used as an example for other TTOs that could form.

Session	1-entrant	2-entrants	3-entrants	4-entrants	0-entrants	CEI
4N	0.4	7.4	28.1	<i>64.1</i>	0.0	14.3
4E	0.9	14.8	<i>57.1</i>	27.2	0.0	29.3
4E-NoSignal	0.7	6.0	36.6	<i>56.7</i>	0.0	16.6
3N	15.2	30.7	<i>53.4</i>	—	0.7	29.7
3E	11.2	<i>60.4</i>	28.1	—	0.3	47.3
3E-NoSignal	8.7	33.9	<i>56.0</i>	—	1.5	15.3
2N	15.6	<i>83.0</i>	—	—	1.4	7.2
2E	<i>57.7</i>	41.1	—	—	1.2	67.4
2E-NoSignal	<i>51.6</i>	46.7	—	—	1.7	51.4

Table 3: Percentage of times each session achieved a particular number of entrants

how to achieve higher payoffs through intertemporal coordination and whether or not they can communicate their goals through the use of communication that is not free-form. In an industry setting, one might view this as firms pre-announcing non-binding release dates for products, as in the story in the introduction concerning the two movies. Thus, the incorporation of multiperiod signaling yields a fourth hypothesis:

Hypothesis 4: *Cooperation and TTOs will be more prevalent in treatments with signaling. Further, ASE signaling will increase as the barriers to coordination decrease, and this increase in ASE signaling will lead to more ASE outcomes.*

Taken together, these hypotheses suggest that the groups which should be best at coordinating on a TTO are the two subject groups that are allowed to signal and have the entry cost payoff structure. The groups which should be worst would be the four subject groups without entry costs and without the ability to signal.

5 Results

The results of the experiment focus on entry decisions and signaling behavior. First, aggregate and group level data on entry decisions and signaling decisions are presented. Following this discussion is an analysis of how signals impact entry decisions. The initial empirical investigation details how individual entry decisions are affected by signaling decisions and control variables of the experiment. A second analysis of the data details how group entry is affected by the behavior of the group members. Overall, turn taking strategies are more likely to be used in the entry cost treatments, as the number of subjects decreases, and when signaling is present in 3 and 4 subject groups.

5.1 Aggregate Entry Results

Table 3 shows the percentage of outcomes for each number of entrants that is achieved in each session. The last column of table 3 provides the Cooperative Effectiveness Index (CEI). Because the payoffs differ between sessions, a straightforward comparison of the total payoffs received by each group throughout the session would inherently favor those sessions without the entry costs. Let Π^M , Π^K , and Π^A denote the total profit each group would have received in the experiment if there had been only one entrant, the total profit each group would have received in the experiment if all the subjects in a group entered each period, and the total profit actually received by each group throughout the entire experiment, respectively. The CEI is then $\frac{(\Pi^A - \Pi^K)}{(\Pi^M - \Pi^K)} * 100$. This standardization allows more accurate comparisons as to how well the subjects performed in capturing the cooperative (or monopoly) profits throughout the experiment.

Table 3 shows that a substantial number of periods resulted in less than full entry in all treatments. The italicized number in each row shows the modal market structure. In all sessions without the entry cost, the modal number of entrants is the stage game Nash Equilibrium outcome where all players enter each period, while in all sessions with the entry cost the modal number of entrants involves one less entrant than full entry. The 3E-NoSignal and 4E-NoSignal sessions are similar to the 3N and 4N sessions, while the

2E-NoSignal are similar to the 2E sessions. These results suggest that the signaling mechanism does foster additional cooperative efforts in group sizes of three and four.

In general, the data in table 3 show that as the barriers to forming a TTO decrease more subjects choose to exit the market. Holding the number of participants in a group constant, less entry occurred in the entry costs treatments than in the treatments without entry costs. Also, the CEI shows that subjects in the entry costs treatments were able to obtain a larger portion of the monopoly profits than those in the no entry cost treatments. Using group level CEI measures for the entire session, Mann-Whitney U-tests show that the 2E and 4E treatments had statistically significantly higher CEIs than their respective 2N and 4N counterparts, while the 3E and 3N treatments did not.⁸ Comparing group level CEIs for the entire session for the treatments with signals and entry costs to those without signals, the 4E and 3E treatments have statistically higher CEIs than their counterparts without signals, while there is no difference between the 2E and 2E-NoSignal treatments.⁹

Within the entry costs treatments, the lower the number of participants in a group the more the monopoly outcome was achieved, and the less the full entry outcome was achieved. Results for the no entry cost treatments are not as monotonic, as the participants in the 2N session did not play the TTS because the opportunity cost to playing the TTS was high (3700 ECUs every two periods for playing the TTS, 3200 for playing the stage game NE). Except for the 2N treatments, the aggregate data support Hypotheses 2, 3, and 4, that more cooperation occurs as the number of subjects decreases, the opportunity cost to entering decreases, and when signaling is allowed.

5.2 Signal Usage

The signals that the subjects sent can be used to determine the degree to which they attempt to communicate a TTS with other members of the group. There are 1024 distinct signaling strings that can be sent and at most 89 periods in a session, so most of the signal combinations will not be sent by each subject. However, several signaling strings can be identified as consistent with suggesting TTS behavior. In particular, the focus is on those which suggest the ASE outcome.

The ASE signaling combinations are complex. For instance, a subject participating in a 4N or 4E session may send any of the following sequences of binary signals in an attempt to communicate desire to participate in a 4-subject ASE outcome: 1000100010, 0001000100, 0010001000, and 0100010001. The number of times that the subject sent any one of those signals is counted as an attempt to signal a 4-subject ASE outcome. For a 3-subject ASE outcome the strings 1001001001, 0100100100, and 0010010010 are counted while for a 2-subject ASE outcome the strings 1010101010 and 0101010101 are counted. While these signaling strings do not capture all of the attempts at coordination, they do capture attempts to signal the ASE strategy as it is defined in Section 4.

Figure 1 shows the percentage of ASE signaling strings sent under the various treatment conditions. In all treatments the modal ASE signaling string corresponds to a full participation ASE outcome for that treatment. Also, more ASE signals are sent in the 4E and 2E treatments than in the corresponding 4N and 2N treatments (18.1% to 8.9% for the 4E and 4N treatments, 50.6% to 2.2% for the 2E and 2N treatments). For the group size of 3, slightly more ASE signals were sent in the 3N treatments than in the 3E treatments (35.1% to 30.5%), primarily because of the one 3N group that achieved full ASE coordination by the middle of the treatment. Also, as the number of subjects in a group decreases, the number of ASE signals increases. These results provide partial support for Hypothesis 4, as more ASE signals are sent in the entry cost treatments as the number of participants in the group are held constant. They also provide support for Hypothesis 1, as the signals sent correspond with the ASE outcome, suggesting that it is the particular TTO on which subjects focused.

If subjects are not submitting ASE signals, which other signals are they submitting? Perhaps there is a lack of coordination on a particular TTO due to the fact that subjects are attempting to coordinate on different equilibria. In addition to the ASE signals, there are three other signaling strings that are commonly sent. One is the default signaling string of all zeros, one is a signaling string of one in the first period and zeros in the remaining periods, and the other is a signaling string of all ones. Figure 2 shows the percentage of each of these strings by session. Looking at these strings shows how subjects who are not engaged in

⁸The p-values for one-tailed Mann Whitney U tests for the 2, 3, and 4 subject groups are 0.014, 0.206, and 0.086 respectively.

⁹The p-values for one-tailed Mann Whitney U-tests are 0.208, 0.038, and 0.036 for the group sizes of 2, 3, and 4 respectively.

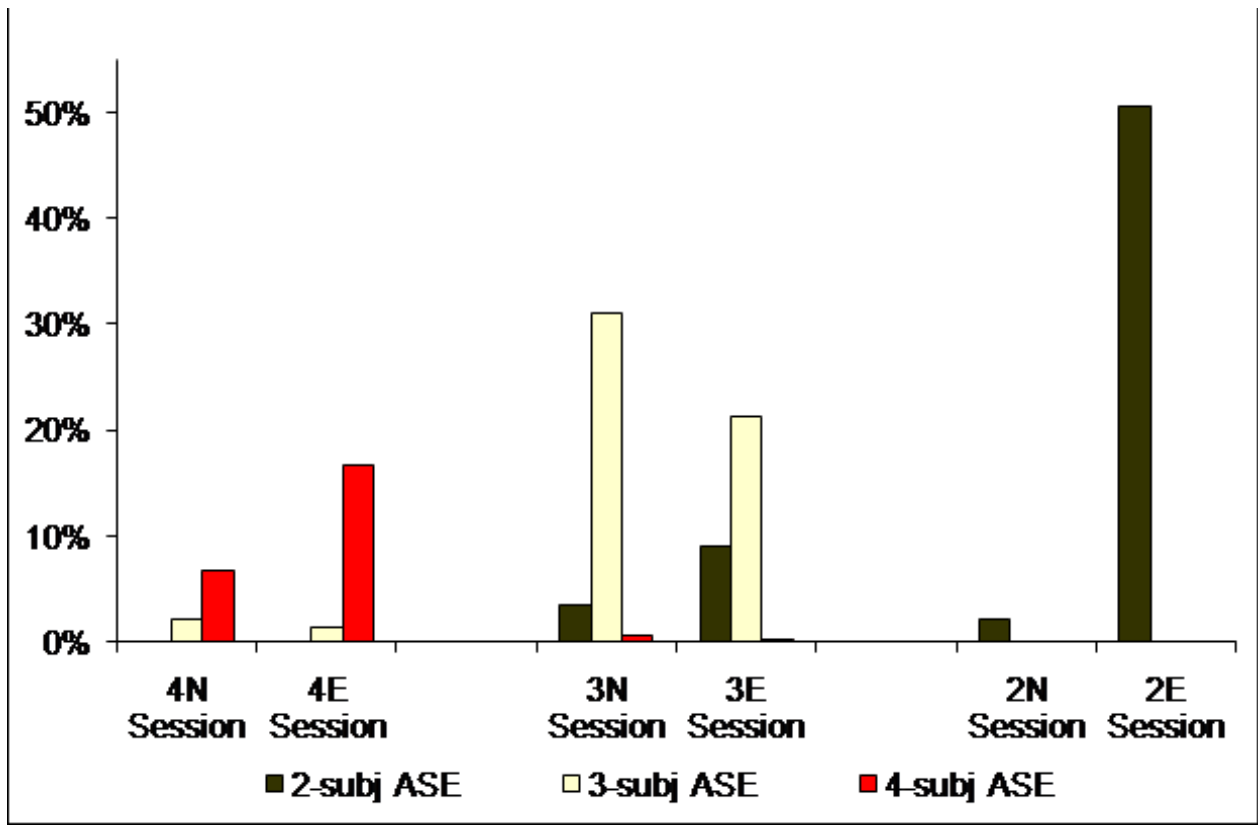


Figure 1: Percentage of ASE signals sent by treatment.

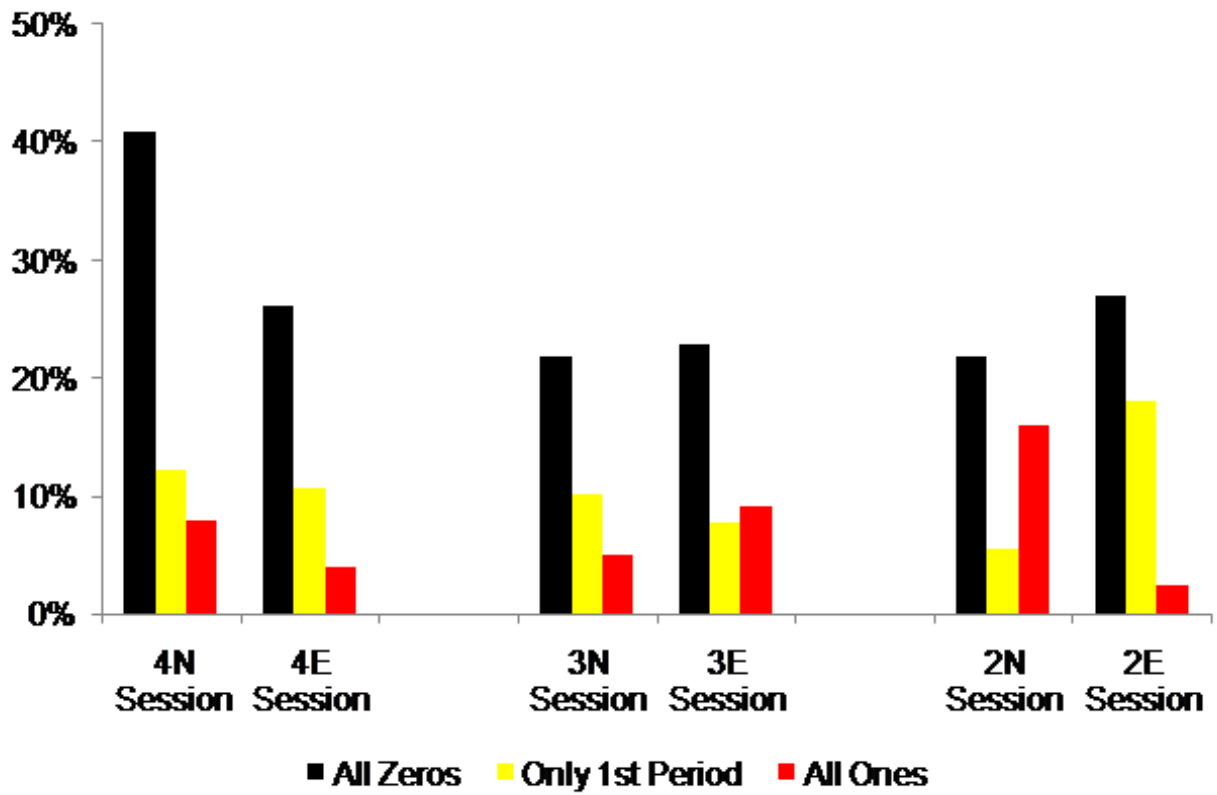


Figure 2: Percentage of commonly sent non-ASE signals by session.

Treatment	Group	%Entry		CEI		Std. Dev.		%ASE		%Truth	
		1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
2N	1	71	79	-3	43	7425	12374	0	0	96	93
	2	95	100	-10	0	4950	0	3	1	58	51
	3	71	96	18	8	42073	2475	15	0	51	13
	4	95	99	10	3	4950	2475	0	0	54	31
	5	98	100	5	0	0	0	3	3	93	89
2E	1	90	99	15	3	5940	1485	19	5	66	45
	2	50	50	100	100	0	0	99	100	100	100
	3	50	50	100	100	0	0	100	100	100	99
	4	84	91	22	18	7425	1485	1	4	70	69
	5	80	56	35	82	2970	1485	36	46	51	68
2E-NoSignal	1	75	81	39	27	2970	7425	-	-	-	-
	2	50	49	100	97	0	1485	-	-	-	-
	3	59	50	77	100	1485	0	-	-	-	-
	4	83	88	30	20	0	0	-	-	-	-
	5	93	98	15	5	2969	2969	-	-	-	-
	6	60	50	80	100	47518	59397	-	-	-	-
	7	84	95	27	10	16334	5940	-	-	-	-
	8	89	86	12	28	1485	16334	-	-	-	-
	9	55	49	90	97	2970	1485	-	-	-	-
	10	74	81	42	38	10394	22274	-	-	-	-

Table 4: Selected results for the 2-subject groups by half session

ASE signaling are using the signaling device. Note that there is a higher percentage of each of these types of signals in the 4N treatment than in the 4E treatment. For the 3N and 3E treatments the percentages are similar, while the 2E session has more of all types except the string of all ones. Figure 2 is inversely related with Figure 1 in that these commonly sent non-ASE signals tend to be sent more often as group size increases and in the no-entry cost treatments.

Figures 1 and 2 show that the bulk of the signals sent are either the ASE signals or one of the three aforementioned signaling strings. Taken together, the nine ASE signaling strings and the three additional signaling strings account for about 45% of the strings sent in the 2N session, 60% of the strings in the 4E session, 70% of the strings in the 4N, 3N, and 3E sessions, and 98% of the strings in the 2E session. The most common signaling strings not present in Figures 1 and 2 tend to be either abbreviated strings of the all ones string or abbreviated two-subject ASE strings. Based upon this information, the subjects appear to be using the signaling device to either signal an ASE outcome, to provide only a signal of behavior for the upcoming period, or to send no signal at all. There is no evidence that subjects are sending signals for turn taking outcomes other than the ASE outcome. Thus, it is unlikely that it was confusion upon which TTO to coordinate, but either lack of recognition of how intertemporal cooperation could increase payoffs or aversion to losing some current period payoff if the ASE was not followed.

5.3 Results by group

Thus far the results have focused on results at the treatment level. Tables 4-6 provide information on individual groups for periods 1-40 (1st half) and periods 41-80 (2nd half). The columns for %Entry show the percentage of periods in which subjects in the group entered, so that 100% indicates that all subjects entered in every period during that half of the session. The columns for CEI show the CEI achieved over that half of the session, while those for Std. Dev. show the intra-group standard deviation of payoffs for each half of the session. Finally, the columns for %ASE and %Truth refer to signals sent – %ASE to the percentage of ASE signals sent and %Truth to the percentage of truthful signals. To measure truthfulness, the last signal sent for a period is used as the indicator of intent and if the subject’s entry decision for that

Treatment	Group	%Entry		CEI		Std. Dev.		%ASE		%Truth	
		1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
3N	1	52	43	56	87	2021	5635	70	97	79	89
	2	77	98	37	4	9751	1500	53	38	58	30
	3	97	98	5	3	3464	1732	11	12	53	32
	4	69	82	40	29	14309	4770	28	9	65	63
	5	86	79	23	33	11057	12662	6	26	53	60
3E	1	66	76	48	37	14929	7893	32	23	63	65
	2	83	81	26	30	7114	9384	9	1	51	38
	3	72	68	44	51	13001	11491	47	62	65	73
	4	64	66	55	52	1514	1890	46	28	82	88
3E-NoSignal	1	71	75	41	34	9625	6252	—	—	—	—
	2	73	81	34	29	6897	6548	—	—	—	—
	3	71	66	37	44	5769	10096	—	—	—	—
	4	88	98	18	3	4670	924	—	—	—	—
	5	58	55	61	52	5200	3495	—	—	—	—
	6	97	98	5	3	2227	924	—	—	—	—
	7	90	91	15	14	2838	4406	—	—	—	—
	8	83	84	26	25	8240	6990	—	—	—	—
	9	79	67	32	52	7031	9238	—	—	—	—
	10	98	100	3	0	924	0	—	—	—	—

Table 5: Selected results for the 3-subject groups by half session

Treatment	Group	%Entry		CEI		Std. Dev.		%ASE		%Truth	
		1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
4N	1	94	95	7	6	3090	3200	23	38	55	54
	2	96	100	5	0	800	0	4	4	56	43
	3	99	100	2	0	462	0	1	1	29	25
	4	85	73	19	35	5237	8395	2	9	53	76
	5	73	74	35	34	8267	9867	31	48	61	73
	6	89	88	14	16	3484	5282	21	9	44	23
4E	1	79	83	28	23	5860	4131	46	34	49	37
	2	81	82	25	23	4025	5075	22	27	60	71
	3	72	86	37	19	7947	3029	25	12	70	67
	4	65	72	47	37	10097	5738	41	12	33	30
4E-NoSignal	1	86	98	18	3	3252	808	—	—	—	—
	2	88	97	15	4	1838	875	—	—	—	—
	3	91	99	12	1	1468	175	—	—	—	—
	4	91	91	11	11	1050	2223	—	—	—	—
	5	87	81	17	24	2530	3435	—	—	—	—
	6	84	74	20	33	3675	7433	—	—	—	—
	7	70	75	40	33	4481	4249	—	—	—	—
	8	91	93	11	10	1471	2494	—	—	—	—

Table 6: Selected results for the 4-subject groups by half session

period matches the signal it is considered truthful.¹⁰

As the data from tables 4-6 show, the most successful groups at playing the TTS were in the 2E sessions – 2 of the 5 groups played the TTS from the first period, while a third group settled on the TTS about halfway through their session. We can determine this result, in part, by looking at the CEI and the intra-group standard deviation of payoffs. Groups 2 and 3 in the 2E session had CEIs of 100 for both halves of the session and the standard deviation of payoffs was 0. The only possible method for achieving these two results is if a single subject entered each period *and* the subjects entered an equal amount of times. There is a dramatic increase in CEI from the first half of the session to the second for group 5 of the 2E session, and the standard deviation of payoffs dropped, again suggesting the subjects are settling on a TTO. As table 4 shows, the signaling device may or may not have played much of a role in two subject groups forming a TTO as groups 2 and 3 in the 2E-NoSignal sessions also formed successful TTOs. It seems clear that the entry costs facilitated TTO formation in the two subject groups as entry rates for the 2N sessions were above 95% for all but group 1.

Results for the three subject groups are not as clear as those in the two subject groups. Group 1 is the only group in treatment 3N to ever achieve a CEI above 40% for either half of the session. The TTO for that group is fairly stable for the latter part of the first half of the session and the beginning of the second half of the session but begins to break down near the 70th period. Also, group 3 in the 3E session reached a fairly stable reduced TTO. One participant entered every single period, and around period 20 the other two participants coordinated their entry decisions to alternate entry. At first, one subject enters every third period while the other enters in the other two out of three periods, while around period 60 those two subjects adjust behavior and simply alternate entry every period as in a two subject session.

Those groups which saw their CEI increase from the first half of the session to the second typically saw an increase in the percentage of ASE signals from the first half of the session to the second. The opposite is also generally true – groups which saw a decrease in CEI across halves tended to also see a decrease in the number of ASE signals sent. The 3E-NoSignal sessions typically show a decline in CEI across halves of the session, and one of the groups is almost at full entry for all periods in the second half. By looking at half sessions it appears that groups which begin with a high percentage of entry (85%-90%) will be unable to coordinate on a TTO while those which begin the session with a lower rate of entry have a chance at cooperation. Thus, part of the determinant of whether or not a TTO forms is likely due to the characteristics of the individuals in the group. Group 1 in the 3N session is evidence of this behavior as they were able to achieve a fairly stable TTO despite being in the no entry cost treatments. It is unlikely that the group would have formed the TTO without the signals as a large percentage of signals sent by the group are ASE signals and they also have a high percentage of truthful signaling.

In the 4-subject groups there is little coordination, though there is more in the 4E groups than in the 4E-NoSignal and 4N groups. In the 4E-NoSignal and 4N groups there are groups in which subjects are choosing to always (or nearly always) enter in the second half of the session. Group 4 of the 4N treatment is the only group in the treatment which saw an increase in CEI in the second half of the session, but this result is due to a single subject who stopped entering for a long period of time and not due to increased alternation. In the 4E-NoSignal treatments there were few attempts by subjects to play any TTO as all but one half of one group had the percentage of entry greater than or equal to 85%. As in groups of size two and three, ASE signaling tends to be negatively correlated with entry. Those groups which sent few ASE signals had a large percentage of entry, while those that sent more had less entry.

5.4 Analyzing Individual Entry Decisions

The prior sections provide information on aggregate entry behavior and aggregate signal sending behavior. What follows links the impact of signals, both a player’s own signal as well as those of the group, to individual entry decisions. A random effects logit model is estimated with entry at time t as the dependent variable. Independent variables include a player’s signal at time t for the current period (equal to 1 if the subject intends to enter, 0 otherwise), the period number, the sum of a group j ’s signals at time t , the sum of a group j ’s entry decisions at time $t - 1$, and a treatment dummy (labeled EntryTreatment) equal to 1 if the treatment is an entry cost treatment and 0 otherwise. In addition, the treatment dummy is interacted with

¹⁰For many periods there are multiple signals sent. For instance, there will be ten signals sent for the decision in period 10, one in each period from 1-10. Only the last one sent is used to determine truthfulness.

	2-subject groups		3-subject groups		4-subject groups	
	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.
Signal	4.19***	0.218***	3.942***	0.377***	3.182***	0.099***
Period	0.042***	0.001**	0.012***	0.001**	0.002	0.000
Total signals (t)	-0.375	-0.012	-0.685***	-0.061***	-0.213*	-0.006
Total entry (t-1)	0.0074	0.000	0.878***	0.078***	0.887***	0.026***
EntryTreatment	-2.97**	-0.122	1.553*	0.135	1.174	0.032
EntryTreatment*signal	3.53***	0.067**	-0.522	-0.053	0.332	0.009
EntryTreatment*period	-0.041***	-0.001**	-0.011*	-0.001*	0.017***	0.0005**
EntryTreatment*signals (t)	-1.20**	-0.037*	-0.026	-0.002	-0.027	-0.001
EntryTreatment*entry (t-1)	1.98***	0.061**	-0.708***	-0.063**	-0.915***	-0.027**

Table 7: Random effects logit estimation for individual entry decisions by group.

the other independent variables. The unit of observation for the random effect is the individual in this analysis. Formally, the model estimated is:

$$\Pr(\text{enter}_{it} = 1) = f \left(\begin{array}{l} \text{signal}_{it} + \text{period}_{it} + \sum_j \text{signal}_{j,t} + \sum_j \text{entry}_{j,t-1} + \text{EntryTreatment}_i + \\ \text{signal}_{it} * \text{EntryTreatment}_i + \text{period}_{it} * \text{EntryTreatment}_i + \\ \sum_j \text{signal}_{j,t} * \text{EntryTreatment}_i + \sum_j \text{entry}_{j,t-1} * \text{EntryTreatment}_i + \varepsilon_{it} \end{array} \right) \quad (2)$$

Table 7 shows the estimates of equation (2) as well as the marginal effects for each variable. Separate models were estimated for each group size. Comparing the $2N$ groups to the $2E$ groups, there is a large difference in the impact of the individual’s signal for that time period as there is a 6.7 percentage point increase in the probability of entry when an individual signals that he will intend to enter. Thus a signal of enter in the $2E$ session is more likely to lead to the individual entering than in the $2N$ session. Also, there is a positive increase in entry over time in the $2N$ treatment that is offset in the $2E$ treatment, suggesting that there may have been early attempts at coordination in the $2N$ sessions that were abandoned as time passed. The number of entry signals sent by the group members for period t had an insignificant effect in the $2N$ treatment but a negative effect in the $2E$ treatment, meaning that the more entry signals sent as a group led to lower individual entry in the $2E$ session. Total entry at time $t - 1$ was also insignificant in the $2N$ treatment, but had a positive effect in the $2E$ treatment. Thus, it appears that participants in the $2E$ treatment responded to entry in the prior period by increasing entry in the subsequent period. Finally, even controlling for these other factors, there is a 12.2 percentage point decrease in entry simply from participating in the $2E$ treatment.

There is little difference between the $3N$ and $3E$ treatments. A signal of enter is still the biggest determinant of entry, with a signal equal to 1 leading to a 37.7 percentage point increase in entry. Note that the interaction term of signal sent and treatment is insignificant so there is no significant difference between the $3N$ and $3E$ treatments regarding the signal sent. There is a very small positive time effect on entry in the $3N$ treatment, suggesting some additional entry as time passes, but that small effect is offset in the $3E$ treatment. As in the 2 subject treatments, a larger total number of group signals lead to less entry at the individual level, regardless of treatment. The more entry there is at time $t - 1$ leads to an increase in the probability of entry at time t in the $3N$ treatment, but again that effect is almost entirely offset in the $3E$ treatment. Controlling for these factors there is no statistically significant effect of the treatment itself on the probability of entry.

Comparing the $4N$ and $4E$ treatments, the largest difference between the two treatments stems from how entry at time $t - 1$ affects entry at time t . In the $4E$ treatment, entry at time $t - 1$ has little impact on entry at time t , so that the subjects in the $4E$ treatment are not influenced by prior period entry,¹¹ while in the $4N$ treatment there is a 2.6 percentage point increase in entry at time t . The effect of the period is different in the 4 subject group treatments than from treatments with less subjects – as more time passes participants in the $4E$ treatment are more likely to increase entry than decrease it. This result may occur because there

¹¹This is likely due to the persistent play of the 4-subject ASE strategy by some subjects despite little recognition or reciprocity by others.

are few individuals in the 4 subject treatments who are actively playing a TTS, leading to other participants who might have been willing to play a TTS to abandon their attempts and choose the stage game Nash strategy. An individual's current period signal of enter leads to a 10% increase in entry, but there is no significant difference between the treatments. Once again there is a statistically significant negative effect of the number of total entry signals sent at time t , though this effect is economically insignificant. Finally, controlling for these factors there is little difference remaining between the treatments.

Overall Table 7 documents important differences in individual entry behavior between treatments holding group size constant. While there are some similarities across the 2 and 3 subject groups and the 3 and 4 subject groups, there are few variables that have similar significant directional impacts across group sizes. Only the current period signal has the same effect across group sizes, though the impact diminishes as the number of subjects increases. This result suggests that more subjects in the 2 subject group were truthfully revealing their upcoming entry decision, which is consistent with the data in tables 4-6. This behavior is also consistent with Table 3 and Figure 2 as about 40% of the subjects in treatment 4N sent a signaling string of all zeros while 64% of the periods in treatment 4N had full entry. Thus, truth telling in signal sending may also impact the formation of a TTO.

5.5 Linking entry to ASE signals

A final question to address is whether or not the sending of ASE signals affected entry behavior at the aggregate level and at the individual group level. To address the question about aggregate behavior, the impact of each type of ASE signal on aggregate entry at the group level is estimated. Given that aggregate entry per period is an integer between 0 and 4, random effects Poisson regression is used.¹² To determine the impact of ASE signals on aggregate entry the number of 2, 3, and 4-subject ASE signals are counted for each period for each group. This count of ASE signals is then used as an explanatory variable in determining aggregate entry for the group in the period. Because more ASE signals suggest a greater recognition of the ASE strategy by the group, there should be a negative relationship between the amount of ASE signals and aggregate entry. Given that total entry at time $t - 1$ is significant in the individual entry results it is included in addition to the number of ASE signals.

The model estimated is:

$$Entry_{j,t} = ASE2_{j,t} + ASE3_{j,t} + ASE4_{j,t} + Entry_{j,t-1} + Period_{j,t} + \varepsilon_{j,t} \quad (3)$$

where $Entry_{j,t}$ is a count of the number of entrants in period t for group j , $ASE2_{j,t}$, $ASE3_{j,t}$, and $ASE4_{j,t}$ are counts of two, three, and four-subject ASE signals sent at time t by group j , $Entry_{j,t-1}$ is the number of entrants in group j at time $t - 1$, $Period$ is the period of the session in which group j submitted their decisions, and $\varepsilon_{j,t}$ is the random effects error term at the group level. Only ASE signals for the ASE outcomes that involve a number of players less than or equal to the number of players in a group are included in the estimation, as very few signals were sent for ASE outcomes larger than the group size. Note that treatment differences are individually and jointly insignificant and as such those variables are dropped from the analysis. The cumulative number of each type of ASE signal sent within each group was initially included as an explanatory variable, in case there was a cumulative effect from repeated observation of ASE signals, but was dropped either because it caused instability in the convergence process or because it was insignificant.

Table 8 shows that an increase in ASE signaling leads to a decrease in total group entry regardless of group size. In all group sizes, there is a statistically significant negative effect of full group ASE signals sent on entry. In 2 subject groups, each additional 2 subject ASE signal sent decreases the amount of entry by 0.36 individuals. In 3 subject groups each 3 subject ASE signal sent decreases entry by .30 and in 4 subject groups each additional 4 subject ASE signal sent decreases the number of entrants by 0.25. The largest effect is in groups of size 2, suggesting that it is in this environment that the ASE signals have the most impact. The number of 3-subject ASE signals also had a negative and significant effect in 4-subject groups, and this impact is larger than that of 4-subject ASE signals. It may be that the ASE pattern becomes clearer with 3-subject ASE signals as three full rotations can always be seen with 3-subject ASE signals.

¹²The Poisson model is chosen instead of the negative binomial because the negative binomial requires overdispersion in the data, which is not present.

	2-subject groups		3-subject groups		4-subject groups	
	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.	Coeff.	Marg. Eff.
2-subject ASE	-0.231***	-0.363***	-0.077	-0.173	-0.037	-0.125
3-subject ASE			-0.132***	-0.295***	-0.146*	-0.491*
4-subject ASE					-0.074***	-0.250***
total entry (t-1)	0.168*	0.264*	0.116	0.259	0.077*	0.260*
period	0.001	0.001	0.001	0.002	0.001	0.002

Table 8: Results from a random effects Poisson regression with number of entrants for a group in a period as the dependent variable.

Whether these effects are due to learning on the part of other individuals after seeing ASE signals or the fact that certain individuals sent ASE signals as well as played an ASE strategy is difficult to determine. However, the econometric results are consistent with the results across half sessions from tables 4-6. What is clear is that less entry occurs as more ASE signals are sent.

6 Conclusion

The primary goal of the study is to determine how a multiperiod signaling device can serve as an aid in intertemporal cooperation. For groups larger than a size of two, the signaling device provides some benefit in that entry decreases and payoffs increase. For groups of size two, for which coordination should be quite easy even without the device, there may still be some benefit in that subjects can coordinate quicker. Previous studies have shown that intertemporal cooperation tends to arise when subjects are allowed free-form verbal or written communication, but is less frequent when one-period ahead signaling is used. This is particularly the case when more than two subjects are involved. The experiments in this study provide evidence that free-form communication may still be necessary to educate those subjects who fail to grasp the underlying dynamics of intertemporal cooperation from the signals sent, but that some groups of subjects are capable of using a simple multiperiod signaling device to coordinate their actions.

A secondary result is the pattern of alternation upon which the subjects coordinate. The signals sent show recognition of a particular type of intertemporal cooperation in which the subjects enter sequentially and retain that order throughout the session. Few signals are sent for other types of coordination, so the fact that the TTO does not arise in some sessions is not due to miscoordination on which equilibrium to play. While this result may not be surprising, it is important as it documents how subjects think about cooperating intertemporally.

The broader implication of the study is that coordination may occur when a simple multiperiod signaling mechanism such as pre-announcement of product release dates exists. Given that anonymously paired, unexperienced subjects can recognize the possibility of beneficial coordination, and at times coordinate their actions, it is likely that experienced individuals familiar with one another could use a similar device to coordinate actions. Whether or not this coordination of actions is detrimental to social welfare is unclear, but such possibilities should be examined closely.

There are various extensions that could be pursued to supplement the results. One is to incorporate costly signaling in the experiment. Given that signal sending is costless in the current experiment, it may be that the mixture of signals from those who understand how to cooperate intertemporally with those who do not hinders cooperative efforts. Costly signaling can be done by either requiring that subjects who wish to send signals pay some fixed amount per signal, such as taking out an advertisement to announce a product release, or by making it costly to deviate from signals sent, particularly when the time period for which the signals are sent is close to the current time period. Also, if the entry cost increased with amount of times entry occurred, reflecting either oversaturation of the current product or increased difficulty in coming up with a new product.

References

- [1] Aumann, Robert J. and Lloyd S. Shapley (1994). Long-term Competition – A Game Theoretic Analysis in *Essays in Game Theory*. ed. N. Megiddo, New York: Springer-Verlag, 1-15.
- [2] Bjedov, Tjasa, Thierry Madies, and Marie Claire Villeval (2016). Communication and Coordination in a Two-Stage Game. *Economic Inquiry* 54:3, 1519-1540.
- [3] Blume, Andreas and Andreas Ortmann (2007). The Effects of Costless Pre-play Communication: Experimental Evidence from Games with Pareto-ranked Equilibria. *Journal of Economic Theory* 132, 274-290.
- [4] Brams, Steven J. and Alan D. Taylor (1999). The Win-Win Solution Guaranteeing Fair Shares to Everybody. New York: W. W. Norton & Company, Inc.
- [5] Colman, Andrew M. and Lindsay Browning (2009). Evolution of Cooperative Turn Taking. *Evolutionary Ecology Research*, 11, 949-963.
- [6] Cooper, Russell, Douglas V. DeJong, Robert Forsythe, and Thomas W. Ross (1989). Communication in the Battle of the Sexes Game: Some Experimental Results. *RAND Journal of Economics* 20:4, 568-587.
- [7] Cooper, Russell, Douglas V. DeJong, Robert Forsythe, and Thomas W. Ross (1992). Communication in Coordination Games. *Quarterly Journal of Economics* 107:2, 739-771.
- [8] Davis, Douglas and Charles Holt (1998). Conspiracies and Secret Discounts: Initial Laboratory Results. *Economic Journal* 108, 1-21.
- [9] Davis, Douglas and Bart Wilson (2002). Collusion in Procurement Auctions: An Experimental Examination. *Economic Inquiry* 40:2, 213-230.
- [10] Dickhaut, John, Margaret Ledyard, Kevin McCabe, and Arijit Mukherji (2002). Pareto Optimal Allocations from Multi-period Coordination: The Catalytic Role of Communication. Working Paper.
- [11] Duffy, John and Nick Feltovich (2002). Do Actions Speak Louder Than Words? An Experimental Comparison of Observation and Cheap Talk. *Games and Economic Behavior* 39, 1-27.
- [12] Duffy, John and Ed Hopkins (2005). Learning, Information, and Sorting in Market Entry Games: Theory and Evidence. *Games and Economic Behavior* 51, 31-62.
- [13] Fischbacher, Urs (2007). z-Tree Zurich Toolbox for Readymade Economic Experiments. *Experimental Economics* 10:2, 171-178.
- [14] Fouraker, Lawrence and Sidney Siegel (1963). *Bargaining Behavior*. USA: McGraw-Hill.
- [15] Grether, Dave and Charles Plott (1984). The Effects of Market Practices in Oligopolistic Markets: An Experimental Examination of the Ethyl Case. *Economic Inquiry* 22:4, 479-507.
- [16] Holson, Laura (2002). Miramax Blinks, and a Double DiCaprio Vanishes. *New York Times*, October 11, pg. C1.
- [17] Isaac, R. Mark, Valerie Ramey, and Arlington W. Williams (1984). The Effects of Market Organization on Conspiracies in Restraint of Trade. *Journal of Economic Behavior and Organization* 5, 191-222.
- [18] Isaac, R. Mark, and James Walker (1985). Information and Conspiracy in Sealed Bid Auctions. *Journal of Economic Behavior and Organization* 6:2, 139-159.
- [19] Kaplan, Todd and Bradley J. Ruffle (2005). Which Way to Cooperate. Ben-Gurion University Working Paper.
- [20] Kwasnica, Anthony M. and Katerina Sherstyuk (2007). Collusion and Equilibrium Selection in Auctions. *Economic Journal* 117, 120-145.

- [21] Lau, Sau-Him Paul and Vai-Lam Mui (2008). Using Turn Taking to Mitigate Coordination and Conflict Problems in the Repeated Battle of the Sexes Game. *Theory and Decision* 65, 153-183.
- [22] Leo, Greg (2017). Taking Turns. *Games and Economic Behavior* 102, 525-547.
- [23] Mitchell, Terence R. and William S. Silver (1990). Individual and Group Goals When Workers Are Interdependent: Effects on Task Strategies and Performance. *Journal of Applied Psychology*, 75:2, 185-193.
- [24] Osborne, Martin J. and Ariel Rubinstein (1994). *A Course in Game Theory*. Cambridge, Massachusetts: MIT Press.
- [25] Roulston, Kathryn (2006). Close Encounters of the CA Kind: A Review of Literature Analysing Talk in Research Interviews. *Qualitative Research*, 6, 515-534.
- [26] Sacks, Harvey, Emanuel A. Schegloff, and Gail Jefferson (1974). A Simplest Systematics for the Organization of Turn-Taking for Conversation. *Language*, 50:4, 696-735.
- [27] Scherer, Frederic M. (1970). *Industrial Market Structure and Economic Performance*. Chicago: Rand McNally.
- [28] Sibly, Hugh, John Tisdell, and Shaun Evans (2015). Turn-Taking in Finitely Repeated Symmetric Games: Experimental Evidence. Discussion Paper Series, Tasmanian School of Business and Economics, University of Tasmania.
- [29] Van Huyck, John B., Raymond C. Battalio, Richard O. Beil (1990). Tacit Coordination Games, Strategic Uncertainty, and Coordination Failure. *American Economic Review* 80:1, 234-248.
- [30] Van Huyck, John B., Raymond C. Battalio, Richard O. Beil (1991). Strategic Uncertainty, Equilibrium Selection, and Coordination Failure in Average Opinion Games, *Quarterly Journal of Economics* 106:3, 885-910.

Appendix A. Instructions for the Experiment

This appendix includes a sample of the instruction script that subjects were read in the experiment. This particular script is the one used on May 26th, 2004.

Script for AZ 5/26/04 Experiment

Thank you for participating in today's experiment. I will read aloud from this script to ensure that all sessions of this experiment receive the same information. However, if you have any questions please do not hesitate to ask myself or one of the other experimenters. At this time I ask that you refrain from talking to any of the other subjects. If you violate this rule then the experimenter reserves the right to remove you from the experiment and you will receive only your \$7 show-up fee.

How are groups determined?

In today's experiment the computer has randomly placed subjects into 3 groups of 4. Your decisions and those of the members of your group will determine your payoff. The exact method in which your payoff will be determined will be described momentarily. It is important to note that although the members of the groups will remain anonymous, the other subjects in your group will remain the same THROUGHOUT THE EXPERIMENT.

How are payoffs determined?

At this point in time it should be noted that all currency amounts will be denoted in a fictitious currency, called Experimental Currency Units (or ECUs). ECUs will be exchanged at the rate of 50 ECUs = \$0.01, or 50 ECUs = 1 penny. Thus, 5000 ECUs = \$1. The only number that is not transformed is your \$7 show-up fee, which remains fixed at \$7 US dollars.

Stages

There are 3 stages in this experiment. The three stages are called:

1. Message sending
2. Choice
3. Payoff display

Although the “Choice” stage is the 2nd stage in the actual experiment I will discuss it first as the choice stage determines your payoff for a period.

Please turn your attention to your computer screen now, but do not hit any buttons at this time. In the center of the “choice” stage it has your subject ID number for your group. You will retain this identification (P1, P2, or P3) throughout the experiment. Also, your overall subject number is noted, but you can disregard this number – it is essentially there for my benefit as I walk around. Also note that the current period and the remaining time for the particular stage are indicated in a header along the top of the screen.

Upper-left

The upper-left corner of the “Choice” stage contains two buttons, A and B (although in the demo only B is a button – in the actual experiment both A and B are buttons). In today’s experiment you will be asked to decide between choosing option A and choosing option B in the “Choice” stage of each period. You make this choice by pressing the button in the upper left corner of your screen that corresponds to the choice you wish to make for the current period. You will have 30 seconds to make this decision. Once you have made your choice you will be asked to wait patiently until all other subjects have made their choices. This ensures that all groups proceed at the same pace so that one group does not end up finishing the experiment prior to another group. Your choice, as well as the choices made by the other members of your group, will determine your payoff for that period.

Lower-left

Your payoff is a function of how many members of the group choose option A and how many choose option B. The table in the lower left corner of your computer screen shows your payoff schedule based on your choice and the choices of the other members of your group. You should note that ALL members of your group (as well as all members of the experiment) see the SAME payoff schedule. The payoffs will NOT change throughout the course of the experiment. Please recall that all payoffs are denoted in ECUs and that 5000 ECUs = \$1. Note that any time you choose option B you receive 100 ECUs, regardless of what your fellow group members chose. Your payoff table shows that if only 1 subject in your 4-subject group chooses option A within a particular period then ONLY that subject will receive 3600 ECUs for that period. If exactly 2 subjects in your group choose option A within a particular period then EACH subject who chose option A will receive 1600 ECUs for that period. If exactly 3 subjects in your group chose option A then EACH subject who chose option A will receive 900 ECUs for that period. This is how your decisions and your group member’s decisions determine your payoff.

Note that when you make a choice of A or B it is ONLY for the CURRENT period, and you may change from choice A to choice B as frequently or infrequently as you like from period to period.

Upper-right

The box in the upper right-hand corner of the “choice” screen is the “history of play” box. As of right now, the box contains a header row with Period, P1, MesP1, P2, MesP2, P3, and MesP3. Period corresponds to the period in which the decision was made and the columns beneath P1, P2, and P3 correspond to the decisions actually made by that specific subject in your group for that period. As an example, if P1 chooses A in period 1, when you see the choice screen in period 2 you will see the number one, “1”, appear in the cell of the history box that corresponds to column P1 and Period 1. If P1 chose B in period 1, then the number zero, “0”, will appear in the cell of the history box that corresponds to column P1 and Period 1. It is important to remember that A = 1 and B = 0 throughout the experiment. In the demo it is period 1 and it is as if all the players chose B in period 0. You will be able to observe the decisions made by every member of your group for every completed period of the experiment. Again, note that you will only be able to see their decisions in the periods following the current period (you will only be able to see period 1 decisions once we have moved to period 2, you will see period 1 and period 2 decisions when we have moved to period 3, etc.). Eventually a scroll bar will appear that will allow you to scroll up and down the history box – when this occurs you will initially see the most recent periods of play at the bottom of the box, and then you may scroll up to view the prior periods of play.

The MesP1, MesP2, and MesP3 columns will be explained after I explain the “messages sent” box in the lower right corner of the screen.

Lower-right

Finally, the lower right-hand corner of your screen is the “Messages Sent” box. In this experiment you will be able to send binary (0 or 1) messages to your fellow group members. These messages are able to be sent 10 periods in advance for each message – I will explain how the messages are sent momentarily. Note that the messages sent box contains the labels period, P1, P2, and P3. Each cell in the messages sent box corresponds to the most recent message sent by that player for that period. For example, if a 0 appears in the messages sent box corresponding to period 4 and subject P3, this means that subject P3 has sent a message that he or she INTENDS to choose B in period 4. If a 1 appears in the messages sent box corresponding to period 4 and subject P2, this means that subject P2 has sent a message that he or she INTENDS to choose A in period 4. It is important to note that these messages are non-binding, which is why I stressed the word INTENDS – thus neither you nor the other subjects in your group have to follow the messages sent.

Again, you will see messages for the next 10 periods, including the current period (the message sending screen, to be described shortly, actually comes first in the experiment). Also, your payoff does NOT depend on the messages that you have sent, nor does it depend on the messages the other members of the group have sent. Your payoff ONLY depends on the actual choices of A and B made by the group members during each period.

Finally, return to the history box. When you see MesP1 this shows the message that was sent IMMEDIATELY prior to the actual choice made by that player. As an example, consider period 10. There will be 10 period 10 messages (one for each period from 1-10) that will be sent by each subject prior to the actual choice of A or B for period 10. The message that appears in the history box corresponds to the period 10 message for period 10. That is, if player 1 chooses to send a message of A (or 1) for period 10 prior to making his actual choice for period 10, then when the choice screen appears for period 11 that message of 1 will be recorded under MesP1 for period 10, regardless of the messages sent by player P1 for period 10 in periods 1-9.

Note that you will have 25 seconds to reach a decision in the choice stage – if you do not reach a decision within 25 seconds a red “please reach a decision” will flash in the upper-right corner of your screen (it should be flashing now). Although you will never be forced off of the screen, it is asked that you make your decisions in a timely manner so that we can finish all of the intended periods. Throughout the first few periods of the experiment I will allow some excess time as you familiarize yourself with the interface, but after 5-10 periods I will ask that you try to adhere to the 25 second clock.

To exit the choice stage, simply click on the button that corresponds to the actual decision that you wish to make for the current period, A or B. In the demo only B is a button – in the real experiment both A and B are buttons. If you have no questions about the choice stage please click on B now to move to the next screen. Note that you will not receive any payment for the choice made in this demo.

Message sending stage

PRIOR to entering the choice stage you will see the “Message Sending Screen”. In this stage you have the ability to send messages about the option you plan on choosing in each of the next 10 periods of the experiment. Again, the top of the screen contains a header with the current period as well as a countdown clock.

The first column contains the labels for each row: Period, Choose A, Choose B, Current Choice, and Last Round. The row for “period” corresponds to the period for which you are sending a message. The rows for “Choose A” and “Choose B” will contain buttons in the actual experiment (although they are only boxes now), that will allow you to send a message of A or B for the upcoming periods. Pressing the button that corresponds to Period 1 and Choose A will change the number in the “current choice” row under period 1 to a 1, and pressing B will change the number back to a 0. Remember, a 1 corresponds to a message that you INTEND to choose option A in a particular period, while a 0 corresponds to a message that you INTEND to choose option B in a particular period. It is important to note that when a new period begins the “Current Choice” will always reset to all zeroes.

Is everyone clear on how to send messages for the upcoming 10 periods?

The row corresponding to “last round” shows the message that you sent last round for that period. Suppose that it is period 1 and you sent a message of 1 for periods 2 and 9. When the period 2 message

sending screen appears, the period labels at the top will shift one spot to the left (so that period 1 is now where period 0 is), as period 0 drops off and period 10 appears. The “Last round” row will also shift, so that if you wish to send the same messages that you sent the previous period you merely need to look below the column to see which message you sent for the last period – you do NOT need to keep track of which periods you sent which messages in, as the software does that for you. Thus, if you sent a message of 1 for periods 1 and 9 you would see a 1 in the first and next to last “last round” columns in period 2, rather than the second and last columns. You WILL need to change your messages from zeroes to ones IF you wish to send the same message for each period. Also note that the cell for “last round” under Mes10 will always be a zero, as you will never have sent a message for that period before.

When you have finished making your message selections you can submit your messages by pressing the “Submit” button in the lower right-hand corner of your screen. You will NOT be allowed to change your messages once you have pressed the submit button, but you are allowed to change messages prior to pressing the submit button. When you submit your messages you will see the “Waiting Screen”, which asks you to wait patiently until all subjects in the experiment have finished submitting their messages. Again, note that these messages are non-binding and that they do NOT affect your payoffs in any way.

There is a 45 second countdown clock in the upper right-hand corner of your screen. Once 45 seconds have passed, a message will flash in red asking you to please reach a decision. Although the program will not force you to the next stage, it is asked that you make your message sending decisions in a timely manner so that we can finish all of the intended periods for this session. Again, due to the complexity of the interface I will allow a little excess time during the first few periods.

The last piece of information is the history of play box. It is identical to the history of play box in the choice stage except that it only contains the actual decisions by the subjects in your group.

If you have no questions about the message sending screen, please hit the submit button to exit the stage now.

Payoff display screen

The payoff display screen simply shows your payoff for the just completed period as well as your total payoff from all the previous periods, including the one just completed. Both the current payoff and the total payoff are denominated in ECUs. You can leave this screen by pressing the OK button in the lower right-hand corner. The timer is set for 7 seconds for this screen – you will exit the screen if 7 seconds elapses.

Length of the experiment

The experiment is intended to run for at least 80 periods. After the 80th period there is an 85% chance that the experiment will continue for an additional period. This endpoint has been previously determined by a random number generator and has been embedded into the software.

Questionnaire

Once the experiment finishes you will be asked to fill in your first and last name for record keeping. This facilitates the payment process for me. Once you have input your name press the “OK” button and please wait patiently until your name is called.

Are there any questions?

Appendix B. Experiment Screen Shots

Message Sending Screen

Period <div style="text-align: center; font-size: 24px; margin-top: 5px;">2</div>	Remaining time [sec]: 33									
Period	2	3	4	5	6	7	8	9	10	11
Choose A	A	A	A	A	A	A	A	A	A	A
Choose B	B	B	B	B	B	B	B	B	B	B
Current Choice	0	0	0	0	0	0	0	0	0	0
Last Round	Mes1 1	Mes2 1	Mes3 1	Mes4 1	Mes5 1	Mes6 1	Mes7 1	Mes8 1	Mes9 1	Mes10 0
History of Play	Period 1	P1 0	P2 1	P3 0	P4 1					
Message Sending Screen	You are subject number: 1		You are identified in the experiment as: P4				<input type="button" value="Submit"/>			

Message Sending Screen.

Choice Screen

Period
2

Remaining time [sec]: 20

A

B

You are subject #: 4

You are identified in the experiment as: P1

History

Period	P1	MesP1	P2	MesP2	P3	MesP3	P4	MesP4
1	0	0	1	1	0	0	1	1

Messages Sent

Period	P1	P2	P3	P4
2	0	1	0	1
3	0	1	1	0
4	0	1	0	1
5	0	1	1	0
6	0	1	0	1
7	0	1	1	0
8	0	1	0	1
9	0	1	1	0
10	0	1	0	1
11	0	1	1	0

Number of others choose A	Payoff if you choose A	Payoff if you choose B
0	3600	100
1	1600	100
2	900	100
3	576	100

Choice screen.