

Cartwright, Edward; Gillet, Joris; Van Vugt, Mark

Working Paper

Endogenous leadership in a coordination game with conflict of interest and asymmetric information

School of Economics Discussion Papers, No. 09,13

Provided in Cooperation with:

University of Kent, School of Economics

Suggested Citation: Cartwright, Edward; Gillet, Joris; Van Vugt, Mark (2009) : Endogenous leadership in a coordination game with conflict of interest and asymmetric information, School of Economics Discussion Papers, No. 09,13, University of Kent, School of Economics, Canterbury

This Version is available at:

<https://hdl.handle.net/10419/50571>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

University of Kent

School of Economics Discussion Papers

**Endogenous Leadership in a Coordination Game
with Conflict of Interest and Asymmetric
Information**

Edward Cartwright, Joris Gillet, Mark Van Vugt

September 2009

KDPE 0913



Endogenous leadership in a coordination game with conflict of interest and asymmetric information

Edward Cartwright

Department of Economics, University of Kent, Canterbury, Kent,
CT2 7NP, UK. E.J.Cartwright@kent.ac.uk

Joris Gillet

Universität Osnabrück, Department of Economics
Rolandstr. 8, D-49069 Osnabrück

Mark Van Vugt

Department of Work and Organizational psychology, VU University Amsterdam,
1081 BT Amsterdam, The Netherlands, m.van.vugt@psy.vu.nl

17th September 2009

Keywords: Coordination game, Conflict of interest, leadership

JEL Codes: C72, D11, D80

Abstract

We analyze a coordination game characterised by varying degrees of conflict of interest, incentive to coordinate and information asymmetry. The primary objective is to question whether endogenous leadership better enables coordination. A secondary objective is to question whether preference and information asymmetries cue who should lead. Both experimental and theoretical results are provided. We find that in theory leadership should allow coordination, whether or not preferences are common knowledge. In practice we found that leadership did enable coordination but information about others preferences also helped. This was explained as due to some participants being too eager to lead. Which may be surprising given that we find, both in theory and in practice, leaders get relatively low payoffs, particularly when preferences are private information.

Financial support from the Economic and Social Research Council through Grant number RES-000-22-1999, ‘Why some people choose to be leaders: The emergence of leadership in groups and organizations’ is gratefully acknowledged.

1. Introduction

Coordination games are ubiquitous in human and economic interaction, whether it be friends deciding how to spend their free time or firms investing in technology (Schelling 1960; Cooper 1999). Of interest, therefore, to question whether players can realize the gains to coordination in such games and, if not, what factors can better facilitate coordination. In this paper, we analyze a coordination game that we feel captures some of the more important issues that arise in coordination problems, and provide both theoretical and experimental results addressing these questions. Of principle interest for us will be whether *leadership* facilitates, or not, better coordination in games where there is *conflict of interest* and *preference and information asymmetries*.

To explain the coordination game that we shall consider, imagine a group of friends, each of whom is deciding whether to buy computer programme X or Y. We would expect that each friend has *different intrinsic preferences* over X and Y. For example, one friend may prefer the graphics of X, and another the ease of use of Y. We will capture this by assigning to each friend two numbers, *value for X* and *value for Y*, detailing the intrinsic utility the friend gets from each programme. A friend may also benefit, because of *network effects* and the like, from having the same programme as others. For example, friends might want to share information about the programme or files written with the programme. We will capture this by assigning to each friend a third number, *coordination value*, detailing how much additional payoff a friend gets for every other friend who uses the same programme. Total payoff is value for the programme chosen plus coordination payoff. Key to our approach will be that friends can differ in their values for X, Y, and coordinating. We capture this by assuming that *nature randomly determines all values* at the start of the game.

In motivating why this game is interesting we begin by noting how it gives rise to three possible features: *conflict of interest*, *differing incentives to coordinate* and *asymmetric information*. There will be a *conflict of interest* if one friend prefers X (that is has a higher value for X) and another prefers Y. In this case both friends may want to coordinate their choice, but would each prefer to coordinate on a different programme, hence a conflict. There will be different *incentives to coordinate* if one friend cares little about network effects (that has a relatively low coordination value) and so has little incentive to coordinate, while another cares a lot. The randomness of the values for X, Y and coordinating, naturally give rise to varying degrees of conflict of interest and incentives to coordinate. It also suggests *imperfect and asymmetric information about others preferences*. Friends may not, for example, know the payoff values of others, and so be unaware whether there is a conflict of interest or not. Or, maybe one friend is informed, because of experience or communication, while others are not.

To further motivate the game considered we note that conflict of interest, differing incentives to coordinate and asymmetric information, are important features

of many applied coordination games. For example, they can appear in settings with network externalities (Katz and Shapiro 1994), volunteering (Bliss and Nalebuff 1984), search (Couzin et. al. 2005), and entry to a naturally monopolistic market (Farrell 1987). Furthermore they are features which could prove crucial in determining the ease or not of resolving a coordination problem. In particular, as we shall now explain, conflict of interest suggests difficulties in coordinating while different incentives to coordinate and asymmetric information may make coordinating easier.

That conflict of interest makes coordinating difficult is amply illustrated in the Battle of the Sexes Game. Cooper, DeJong, Forsythe, and Ross (1989, 1993), for example, look, experimentally, at coordination in the Battle of the Sexes with various institutions such as pre-play communication or outside options. In short, they find that coordination failure is very common (over 50% of the time) and that institutions are generally speaking not as successful as one might hope at stopping this. Similar conclusions are drawn by Brandts and Holt (1995), on the advantages of an outside option, and Rapoport (1997), on the perception of sequential moves.¹ Crawford, Gneezy and Rottenstreich (2008) provide possibly the most compelling illustration of how conflict of interest can lead to coordination failure, by showing how the slightest asymmetry in preferences can significantly reduce the power of focal points. In short, conflict of interest makes coordinating difficult.

Interestingly, the only institutions, of those considered, that really seem to resolve the Battle of the Sexes coordination problem are those in which one, *and only one*, player moves first, either by communicating what he intends to do (Cooper et. al. 1989) or deciding on an outside option (Cooper et. al. 1993). This is suggestive of an institution with an exogenously determined leader.² Intuitively, leadership and sequential decision making should help to resolve coordination problems because followers can coordinate on the action of the leader. Things, however, are not so simple. First, there is the question of *who should lead or follow?* If leadership confers an advantage then there may be conflict of interest in who should lead. Second, the advantages of leadership are not so clear in the presence of *incomplete information*. This is because a leader may, unknowingly, choose an action that no one else likes causing potential coordination failure and low payoffs for the leader.

One means by which a leader may endogenously emerge, and resolve a coordination problem is preference and/or information asymmetries. This is because the asymmetries may serve as a signal or means to coordinate who should lead. Preference asymmetry may, for example, be a means to resolve who should provide a public good (Bliss and Nalebuff 1984). Similarly, cost asymmetry may be a means to

¹ See also Abele, Bliss and Ehrhart 2004 and Weber, Camerer, Knez 2004.

² Communication proves unsuccessful at enabling coordination if two or more people can communicate (Farrell 1987; Cooper et. al. 1989). Also, outside options prove less successful at coordinating play if a player decides on the outside option simultaneous with the other player (Cooper et. al. 1993).

coordinate on who leads in oligopoly competition (Van Damme and Hurkens 1999, 2004; Amir and Stepanova 2006). Potters, et. al. (2005) lend some experimental support to the importance of asymmetry by showing that the more informed emerge as leader in a public good setting, and this enables coordination. More generally, however, the experimental support for the relevance of asymmetry is mixed. For example, the evidence on timing in duopoly games shows that subjects have problems coordinating actions and problems coordinating on who should be leader (Huck et. al. 2002; Fonseca et. al. 2005; Fonseca et. al. 2006; Data and Dechenaux 2007).³ Nosenzo and Sefton (2009) obtain similar results for a public good game.⁴ It remains, therefore, questionable how much player asymmetry does cue leadership, particularly, in coordination games.

To summarise: if conflict of interest is a barrier to coordination, then leadership, conditioned on preference and information asymmetries, may overcome the barrier. This seems a fundamentally important conjecture to test and refine in order to better understand behaviour in coordination settings. That is the main motivation behind this paper. In practice this means we shall study the game described above, where preference asymmetries arise naturally, and question the value of information, both about others actions and others preferences, in enabling coordination. More specifically, we shall contrast settings where *preferences* are commonly known, private, or known by only some players, and settings where *actions* are chosen sequentially, implying leadership, or simultaneously.⁵ Of primary interest, will be to see how well players coordinate conditional on the information available to them. Of secondary interest will be whether preference and information asymmetries do provide a cue for leadership. This will help inform whether leadership can overcome the coordination problems created by conflict of interest.

We begin the analysis by characterizing a particular type of Nash equilibrium and formulating two hypotheses about how people may behave. This involves introducing what we refer to as persuasive strategies. A player has a persuasive strategy if his choosing an action will persuade sufficiently many others to choose the same action, that it would be worthwhile for him to choose the action. Hypothesis 1 predicts that players with an iterated dominant or persuasive strategy should commit before those without. This hypothesis, therefore, helps to characterize who should lead and who follow. Hypothesis 2 predicts that players should choose iterated dominant and persuasive strategies. This hypothesis, therefore, characterizes what

³ This could stem from inequality aversion or simply a preference to wait and observe (Santos-Pinto 2008; Tykocinski and Ruffle 2003).

⁴ Papers, that do not have sequential decision making but still cast doubt on the relevance of asymmetries include Rapoport, Seale and Winter (2002) looking at market entry games and Brandts, Cooper and Fatas (2007) looking at minimum effort games.

⁵ To use game theoretic terminology we may have incomplete information (about preferences) and/or imperfect information (about actions).

actions players should choose. We find experimental support for both Hypothesis 1 and 2 with one caveat, namely, that some participants were too eager to move early.⁶

That we find support for Hypothesis 1 and 2 does not mean that subjects necessarily did solve for the optimal strategy, but it does suggest we can make predictions on aggregate outcomes based on the behaviour predicted by Hypothesis 1 and 2. We do this to predict the consequences of information on both aggregate payoffs and relative payoffs. In terms of aggregate payoffs, we find (Hypothesis 3) that leadership and information about *actions* is predicted to significantly increase payoffs, while information about *preferences* is predicted to have a weaker, possibly even negative, effect. Thus, there is a coordination problem, because of the conflict of interest, and leadership can largely overcome this problem while more information about preferences does not. In terms of relative payoffs we find (Hypothesis 4) that leaders, or first movers, are predicted to get relatively high payoffs if preferences are common knowledge and low payoffs if preferences are privately known. This is due to the greater uncertainty and risk of leading when the preferences of others, and their likelihood of following, are not known.

The experimental results provide an interesting mix of evidence relative to the theoretical predictions. We do find support for Hypothesis 4, and the relative payoffs of leaders and followers. We find, however, mixed support for Hypothesis 3. Specifically, average payoffs were significantly higher when choices were made sequentially, but were also significantly increasing in information about preferences. Leadership did, therefore, help players to coordinate but it was only when preferences were common knowledge that the full, predicted gains were realized. We argue that this latter effect is due in large extent to some participants moving earlier than was predicted (or they should have done to maximise their payoff). In particular, some participants, given their lack of information and large incentive to coordinate, should have waited to see what others did, but they did not. Instead they chose first or second and ultimately coordinated with fewer other players than they should have.

To put these results in context, our main finding is that both in theory and our experiments, leadership, and sequential choice, do help players coordinate and overcome a problem that arises from conflict of interest. This is an important result in understanding how coordination problems can be, and are, resolved, particularly, as leadership is typical in human society (Van Vugt 2006). Our secondary finding is that preference and information asymmetries do provide a cue for leadership but our experiment participants did not respond to these cues quite as strongly as predicted. This is consistent with the prior literature discussed above with one twist. We argue that our results are consistent with some participants being too eager to lead, while the prior literature has highlighted some being too eager to follow (Nosenzo and

⁶ That we find support for Hypotheses 1 and 2 is encouraging because solving for iterated dominant and persuasive strategies is not easy in this game, and the general evidence on backward induction and iterative deletion of dominated strategies is mixed at best (Camerer 2003).

Sefton 2009). The consequences of this are that leadership is not as effective as it could be when preferences are not commonly known.

We shall conclude this introduction by briefly highlighting that to the best of our knowledge neither the experimental or theoretical literature has really tackled the issues of leadership and/or preference uncertainty in coordination games with conflict of interest. Instead, much of the experimental and theoretical literature on coordination games has focussed on settings with no conflict of interest, but Pareto ranked equilibria or focal points, and on repeated interaction (e.g. Crawford 2001, Van Huyck et. al. 2007, Lau and Mui 2008, Manzini et. al. 2009).⁷ Closer to our approach is the literature looking at repeated market entry games (e.g. Rapoport et. al. 2002, Duffy and Hopkins 2005). Even, here, however, there is still little conflict of interest because equilibrium profits from staying out of a market approximately equal those of entering. We believe, therefore, that there is a real need for more research that addresses issues of leadership and preference uncertainty in coordination games with conflict of interest. We hope that this paper will make an important contribution to doing that.

We proceed as follows: Section 2 introduces the coordination game that we wish to study. Section 3 presents some theoretical results and hypothesis. Section 4 presents some experimental results, and Section 5 concludes. Additional materials are left to an appendix.

2. A coordination game with network externalities

There is a set $N = \{1, \dots, n\}$ of *players* and two *actions* X and Y. For example, consider friends choosing between computer programme X or Y. The game lasts for at most T seconds and during the game each player must *choose* action X or Y. A player can only choose once but can choose at any point during the game. We explicitly rule out the possibility that two players can choose at the same time.⁸ The game finishes when all n players have chosen. At the end of the game an action profile $a = \{a_1, \dots, a_n\}$ details the action a_i that player i has chosen.

The game begins with each player $i \in N$ being independently assigned a coordination value, c_i , value for X, x_i , and value for Y, y_i , each drawn randomly from some subset of the non-negative real line. Given action profile a and player $i \in N$, let $m_{x,i}$ and $m_{y,i}$ denote the number of players, excluding i , who have chosen action X and Y. The payoff of player i is

$$u_i(a) = \begin{cases} x_i + m_{x,-i}c_i & \text{if } a_i = X \\ y_i + m_{y,-i}c_i & \text{if } a_i = Y \end{cases}$$

⁷ One issue that has received attention is how imperfect information can lead to strategic delay (e.g. Gale 1995, Chamley 2003).

⁸ If two or more players do *plan* to choose at the same time then we assume that chance randomly decides which one will be allowed to choose.

The payoff of a player thus depends on his value for the action he chooses and the number of others who choose the same action.⁹ For example, x_i and y_i may measure friend i 's preference for programmes X and Y while c_i measures the positive network externality from having the same programme as other friends. We shall denote by t the time elapsed in the game and by $mx_{-i}(t)$ and $my_{-i}(t)$ the number of players who *are known by player i to have chosen action X and Y* by time t .

2.1 Information

To complete the description of the game we need to say what information players have when making their choices. We shall contrast games with differing *information about others actions* and *information about others preferences*:

In a *sequential* game every player sees the *action* of agent i as soon as agent i chooses. A player can, therefore, condition his own choice on previous choices. Note that the ordering of moves is endogenous and determined by who chooses quickest. In a *simultaneous* game the actions chosen by other players are only known at the end of the game. Thus, a player must choose his action without knowing the actions of others. If friends go to a computer shop together then we can think of choices as observed and so sequential, while if they go independently choices are not observed and so simultaneous.

In a *full information* game every player knows the values, and thus preferences, of all other players. In other words, payoff values are common knowledge. In a *no information* game each player only knows his own values, and so values are private. In a *half information* game there is an asymmetry where some of the players know the values of all other players while other players only know their own values. Friends, because of prior experience, communication and the like, may have differing knowledge about what others preferences would be over the two programmes and how much they would want to coordinate. This is captured by the possibilities of full, half and no information.

2.2 Strategy

A strategy for player $i \in N$ should detail when, and to what, he will commit as a function of information available at the time. A strategy (and equilibrium strategy) can take very complicated and un-intuitive forms and so we impose two restrictions, that they be well behaved and symmetric. To explain what this entails we need some

⁹ Note that none of the results we shall present (as is clear from the proofs) use the fact that i 's payoff is linear in the number who commit to the same action or that the coordination value is the same when committing to X as Y. More specifically we could obtain our results if

$$u_i(a) = \begin{cases} x_i + f_i^x(mx_{-i}) & \text{if } a_i = X \\ y_i + f_i^y(my_{-i}) & \text{if } a_i = Y \end{cases}$$

where f_i^x and f_i^y are non-decreasing functions of their argument. The present formulation has the advantage of simplicity and also matches the experimental set up used.

notation. We shall denote by θ_{ij} the information that player i has about player j . This can take three forms: a vector $\{x_j, y_j, c_j\}$ of values, a pair $\{a_j, t_j\}$ of action chosen and time chosen, or the empty set \emptyset .¹⁰

We introduce the concept of a *well behaved strategy* to capture the intuition that a player should only change what he wants to do if he gets some new information. Specifically, player i 's strategy is well behaved if it can be written as a function $s_i(\theta_{i1}, \dots, \theta_{in})$ mapping from information to pair $\{p_i, t_i\}$ consisting of a probability p_i of choosing action X and time $t_i < T$. In interpretation s_i details the time t_i that player i will choose and p_i the probability that he will choose (at time t_i) action X (choosing Y otherwise). Note that this is *provided no new information* is observed before t_i . If new information is observed then a new pair $\{p_i, t_i\}$ will be determined as given by function s_i .¹¹ Note also, that player i 's decision is conditional, as we would expect, on his information about himself θ_{ii} .

We introduce the concept of *symmetry* to capture the intuition that the arbitrary labels X and Y should not matter. More specifically, given information θ_{ij} let θ_{ij}^c denote information in which labels X and Y are swapped. For example, if $\theta_{ij} = \{x_j, y_j, c_j\}$ then $\theta_{ij}^c = \{y_j, x_j, c_j\}$, or if $\theta_{ij} = \{X, t_j\}$ then $\theta_{ij}^c = \{Y, t_j\}$. We say that player i 's strategy is symmetric if $s_i(\theta_{i1}^c, \dots, \theta_{in}^c) = \{1 - p_i, t_i\}$ whenever $s_i(\theta_{i1}, \dots, \theta_{in}) = \{p_i, t_i\}$. Note that if player i has a strategy that says choose X for some set of information then symmetry implies that he would choose Y for the complementary set of information. Symmetry is useful in ruling out Nash equilibria where all players, say, choose Y irrespective of information.

We shall assume throughout that players use well behaved and symmetric strategies. With a slight abuse of notation we denote by $u_i(s_i, s_{-i})$ the expected utility of player i given the *strategy profile* (s_1, \dots, s_n) , where s_i is the strategy of player j . We say that strategy profile (s_1, \dots, s_n) is a Sub-Game Perfect Nash Equilibrium with Symmetric Strategies (SPNESS) if $u_i(s_i, s_{-i}) \geq u_i(s', s_{-i})$ for any strategy s' and any possible subgame.

2.3 Timing of choices

In order to characterize a strategy s_i we need to say *what action* player i should choose, and to say *when* he should choose it (where the latter issue proves redundant in a simultaneous game). We shall, therefore, with a slight abuse of notation, talk of 'strategy at time t ' to mean 'planned action and time of choice, given available information at time t '. Saying what action a player should choose is relatively

¹⁰ For example, in a simultaneous, no information game it must be that $\theta_{ij} = \emptyset$ for all $j \neq i$. In a simultaneous, full information game it must be that $\theta_{ij} = \{x_j, y_j, c_j\}$. In a sequential simultaneous game $\theta_{ij} = \{a_j, t_j\}$ if player j has chosen, and $\theta_{ij} = \{x_j, y_j, c_j\}$ otherwise. And so on.

¹¹ Why might a strategy not be well behaved? One example is that player i chooses X on even numbered seconds and Y on odd numbered seconds. This might sound a little strange but could actually be a Nash equilibrium if everybody else is doing the same.

straightforward but saying when he should choose requires some important terminology.

In characterizing the planned timing of commitment we will be primarily interested in *who should choose first*.¹² In order to do this we introduce two important pieces of notation. We say that *player i plans to choose strictly before player j* if $t_i < t_j$. We say that *player i plans to choose weakly before player j* if $t_i \leq t_j$. The distinction between weakly and strictly will prove important. In particular, that player *i* plans to choose *strictly* before player *j* implies both that *i* wants to choose before *j* and that *j* wants to choose after *i*. There is, therefore, no conflict in what they want. For example, one friend may want to lead while another is happy to wait and see what he buys. By contrast, if player *i* plans to choose *weakly* before player *j* and player *j* plans to choose *weakly* before player *i* then they clearly plan to choose at the same time. This is suggestive of a conflict where both *i* and *j* want to be first and so there is a *race* to choose. For example, two friends may know that their choice may influence others and so race to make the first choice.

The ‘strictly before’ and ‘weakly before’ notation puts the focus firmly on the *order* of choices. We could, but will not, push the model to its limit and assume that each second of the game is a chance to choose. Doing this would allow us to say more on *when* players should commit rather than just in what *order* they should commit. We do not do this on the basis that we would not learn much of interest from doing so, and would depart from what the model can realistically predict. In particular, it will take players time to mentally compute what action they wish to choose and so the choice of time unit would be arbitrary. Further, some may compute quicker than others (and know this) further complicating matters.

3. Some Theoretical Insights

The coordination game introduced is relatively complex to analyse and there will typically be many SPNESS, let alone Nash equilibria. This, however, is symptomatic of coordination games in general and an inevitable consequence of the gains to coordination. What we can do, however, is introduce the concept of dominant and persuasive strategies. This will allow us to go somewhat to characterise SPNESS and make comparisons between games with different types of information. In order to do this we work through different games in turn before making comparisons.

3.1. No information about actions or preferences, a benchmark case

If there is no information about others preferences or actions then there exists a unique and simple SPNESS.

¹² Once one player has chosen first, information is updated, and we are interested in who, of those remaining, will next choose first, and so on.

Proposition 1: In a simultaneous game, SPNESS requires that each player $i \in N$ who does not have information about others preferences choose X if $x_i > y_i$ and choose Y if $y_i > x_i$.

This result makes clear that the simultaneous, no information case provides a benchmark case because each player should simply choose the action that gives him highest value. This leaves coordination entirely down to chance and will result in minimal coordination. In particular, there is no hope of resolving any conflict of interest. A player who values X most will choose X and a player who values Y most will choose Y, so they cannot coordinate, even if it would be in their interests to do so. In a half information game things will be marginally better because those with information can predict what other players, who do not have information, may do. Coordination failure remains, however, likely. Having set this benchmark for low coordination we now turn to questioning how information about preferences or actions can improve matters.

3.2. Simultaneous choice but full information about preferences

We first question whether information about preferences can help improve coordination. In doing this we introduce the standard notion of dominant and iterative dominant strategy. We say that player i has a *dominant strategy* at time t to choose X if¹³

$$x_i + 2mx_{-i}(t)c_i > y_i + (n - 1)c_i.$$

An analogous definition details when i has a dominant strategy to choose Y.

If a player has a dominant strategy at time t to play X (and he has not already made a choice) then he should choose X at some point in the game if he is to maximize his payoff. Others, therefore, may want to take this into account. We say that player i has a *1-step dominant strategy at time t to choose X* if

$$x_i + 2[mx_{-i}(t) + dx_{-i}(t)]c_i > y_i + (n - 1)c_i.$$

where $dx_{-i}(t)$ denotes the number of players, other than i , who *are known* by i to have a dominant strategy at time t to choose X or Y and *have not yet chosen*. Note that the ‘are known’ requirement is crucial here. For example, in a no information game a player cannot, by definition, have a 1-step dominant strategy. Continuing, for any integer $k > 1$ we say that player i has a *k -step dominant strategy at time t to choose X* if

$$x_i + 2[mx_{-i}(t) + dx_{-i}^{k-1}(t)]c_i > y_i + (n - 1)c_i.$$

¹³ It may be easier to see that player i has a dominant strategy at time t to choose X if

$$x_i + mx_{-i}(t)c_i > y_i + (n - 1 - mx_{-i}(t))c_i.$$

where $dx_{-i}^{k-1}(t)$ is the number of players, other than i , who are *known by i* to have a $k-1$ -step dominant strategy at time t to choose X and *have not yet chosen*.

We say that player i has an *iterated dominant strategy at time t to choose X* if he has a k -step dominant strategy at time t to choose X for some k . The interpretation of iterated dominant strategy is standard and any Nash equilibrium requires players to play an iterated dominant strategy. We reiterate that a player can only have a k -step dominant strategy (but not dominant strategy) if he has full information, and can thus see that others have a dominant, or $k-1$, dominant strategy.

We might conjecture that information about others preferences would help players coordinate. The following result casts doubt on that.

Proposition 2: In a simultaneous, full information game, if there exists a player i without an iterated dominant strategy then there exists an SPNESS where player i chooses X and one where he chooses Y.

Outcomes, therefore, become ambiguous with preference information (even restricting to SPNESS). In interpretation we can say that preference information lets players know there is a conflict of interest without offering a solution to it. Thus, while more information should allow better coordination because players can see who has dominant and iterated dominant strategies, full coordination may still be hard to achieve. We shall see this more clearly in Section 3.5

3.3. Sequential choice but no information about preferences

We now turn to the consequences of sequential choice. We can immediately state a result dealing with the no information case.

Proposition 3: In a sequential, no information game, at any time t , SPNESS requires that any player *with* a dominant strategy to choose X (or Y) (and positive coordination value) must plan to choose strictly before any player *without* a dominant strategy plans to choose Y (or X).

Thus, *any player with a dominant strategy should commit quickly, while those without a dominant strategy should wait*. Intuitively, this should permit better coordination because those without a dominant strategy (who could be influenced by others) wait and see what those with a dominant strategy (who would not be influenced by others) will do. Note that those with a dominant strategy have an incentive to move early, even though their choice of action could not be influenced by others, because they may influence others. Also note that, Proposition 3 suggests not only who should lead or move first but also who should move second, third, and so on. The following example may help to illustrate.

Example 1: Consider the payoff values as given below

Player	x_i	y_i	c_i
1	10	0	3
2	10	0	4
3	0	5	6
4	0	5	3

In a simultaneous, no information game SPNESS would say that players 1 and 2 choose X and players 3 and 4 choose Y giving payoffs 13, 14, 11 and 8 respectively. In looking at the sequential game, we note that player 1 has a dominant strategy to choose X. So, SPNESS requires that player 1 lead and choose X. Once player 1 chooses X, player 2 has a dominant strategy to choose X. So, SPNESS requires that player 2 choose X. Carrying on, we see that player 3, followed by 4 should choose X. Thus, all players choose X giving payoffs 19, 22, 18 and 9 respectively.

The possibility, in Example 1, to wait and observe what others do allows all players to achieve a higher payoff. In particular, players 3 and 4 get to learn that players 1 and 2 have a strong preference for X and so can realise gains from coordination. It need not be that all players *do* gain from waiting (change c_4 to 2, for instance in Example 1) but all players should *expect* to gain. This is why players do have an incentive to lead when they have a strong preference for one action and an incentive to wait and see, when they do not have a strong preference.¹⁴

3.4. Sequential choice with information about preferences

Finally, we turn to the consequences of both sequential choice and information about payoff values. In doing this introduce what we call *persuasive strategies*. A persuasive strategy results from a standard application of backward induction and applies when a player who prefers, say X, can, by choosing X, make it in the interests of sufficiently many others (persuade others) to also choose X. We shall introduce two types of persuasive strategy. First, we formalise that *player i prefers X at time t* if

$$x_i + [mx_{-i}(t) + dx_{-i}^n(t)]c_i > y_i + [my_{-i}(t) + dy_{-i}^n(t)]c_i.$$

In other words a player prefers X if, given his knowledge of the iterated dominant strategies of others, X stands to give a higher payoff than Y.¹⁵ Now, let $U(t) \subset N$ denote the set of players at time t who have not chosen and do not have an iterated

¹⁴ Clearly players cannot wait for ever and so SPNESS should say how long they wait. This suggests a war of attrition such as that modelled by Bliss and Nalebuff (1984). If we assume that all players have the same level of risk aversion and rate of time discounting then we may be able to detail more precisely how long players should wait. Given, however, that we know that there is considerable heterogeneity in such things it is not clear how much this would really inform. We limit ourselves, therefore, merely to noting that waiting is a crucial part of the equilibrium in a sequential, no information game.

¹⁵ Note that if player i has no information this reduces to

$$x_i + mx_{-i}(t)c_i > y_i + my_{-i}(t)c_i.$$

dominant strategy at time t . In interpretation, $U(t)$ is the set of undecided players that i could potentially persuade to choose his preferred action.

We say that a player i has a *simple* persuasive strategy to choose X if he has full information, no iterated dominant strategy, prefers X and

$$x_j + [mx_{-j}(t) + dx_{-j}^n(t) + 1]c_j > y_j + [my_{-j}(t) + dy_{-j}^n(t)]c_j$$

for all $j \in U(t)$. Thus, if i were to choose X all other players would prefer X. The implication (given SPNESS) will be that if player i does choose X then of all the undecided players will also choose X. This is clearly the best outcome for i and so we should expect i to choose X. Note, however, that it is possible for one player to have a simple persuasive strategy to choose X and another player to simultaneously have a simple persuasive strategy to choose Y. To illustrate we provide a second example.

Example 2: Consider the payoff values in the following matrix.

Player	x_i	y_i	c_i
1	1	0	2
2	0	1	2

Player 1 has a simple (and forward looking) persuasive strategy to choose X and player 2 has a persuasive strategy to choose Y.

We say that player i has a *forward looking* persuasive strategy at time t to choose X if he has full information, no iterated dominant strategy, prefers X and

$$x_i + [2mx_{-i}(t) + dx_{-i}^n(t) + dx_{-i}^{+i}(t)]c_i > y_i + (n - 1)c_i$$

where $dx_{-i}^{+i}(t)$ is the number of players who would have an iterated dominant strategy to choose X if player i were to choose X. Thus, if player i has a forward looking persuasive strategy and chooses X enough of the undecided players will subsequently have an iterated dominant strategy to choose X that player i cannot do no better than choose X. To illustrate we provide a third example:

Example 3: Consider the payoff values in the following matrix:

Player	x_i	y_i	c_i
1	5	0	2
2	3	0	2
3	0	3	2
4	0	5	2

Player 1 has a forward looking persuasive strategy to choose X and player 4 to choose Y. If, for instance player 1 chooses to X then player 2 has a dominant strategy to play X and so player 1 can expect a payoff of at least 7 which is more than he can possibly get from playing Y. Note, however, that player 1 does not have a dominant strategy to

play X. If for, instance, player 4 chooses X then player 3 should choose X which leaves players 1 and 2 in the same game of Example 2.

Note that a player can only have a persuasive strategy if he has full information. The following result, shows that in settings where there is information about payoff values those with persuasive strategies should look to choose first.

Proposition 4: In a sequential game, if, at any time t , there exists a player i with a persuasive strategy to play X (or Y) then any SPNESS requires that he plan to choose X (or Y) weakly before any player without an iterated dominant strategy plans to choose Y (or X).¹⁶

If Proposition 3 suggests an incentive to wait and see when there is no information then Proposition 4 points more towards a race to go first, when there is full information. The reason for this is apparent by looking back at Examples 2 and 3. In Example 2, recall that both players had persuasive strategies but player 1 prefers X and player 2 prefers Y. As Proposition 4 formalises, both should race to commit first so as to bring coordination on the action that they prefer. Example 3 is more complicated but a race all the same. Players 1 and 4 do have persuasive strategies and so should look to commit as quickly as possible because potentially all players could commit to, say, Y if player 4 chooses first.¹⁷

It is noteworthy that in neither examples 2 or 3 does any player have a dominant strategy and so without information they should (according to Proposition 3) wait to see what others do. Information about others payoffs clearly changes this and potentially allows greater coordination as a result. Finally, we consider the half information case. there is an incentive to wait and see for those without information and race for those with information.

Proposition 5: In a sequential, half information game, if, at any time t there exists a player with an iterated dominant or persuasive strategy to play X (or Y), then any SPNESS requires that he plan to choose X (or Y) *weakly* before any fully informed player, and *strictly* before any non informed player, without an iterated dominant strategy plans to choose Y (or X).

We see, therefore, that those with an iterated dominant or persuasive strategy (which is more likely to be those informed) should race while those without should wait. Note that in a full information game there is theoretically no need for a player with an iterated dominant strategy to move early because every player can predict what he will do, but in a half information game things are different.

¹⁶ Recall that he may not be actual be able to choose as planned if several players try to choose at the same time.

¹⁷ Note that players 2 and 3 have less incentive to commit first. For example, if player 2 chooses Y then he should guarantee himself a payoff of 6. If he chooses X then he gets at least 5. But, if player 2 waits to see who wins 'the race' between players 1 and 4 he may get 9.

That those with information generally go first means that roles become somewhat reversed in the sequential compared to simultaneous half information game. This is because, in a simultaneous game the informed are somewhat bound by what they know the uninformed will likely do. For instance, in Example 2 if player 1 is uninformed and player 2 is informed then we should expect both to choose X in a simultaneous game. In a sequential game, by contrast, the informed can influence the uninformed and we should expect both to choose Y. This time player 2 gains from being informed because he can influence player 1 by moving first.

3.5. The Consequences of Information

We shall now look to apply Propositions 1 to 5 in realising our objectives set out in the introduction. Given that our focus will shortly turn to experimental data we shall also state hypothesis rather than propositions but, unless indicated otherwise, they are essentially corollaries of Propositions 1 to 5.

Our first hypothesis concerns the *order* that players choose and says that players with an iterated dominant or persuasive strategy should choose quickly, while others wait. This suggests that we can partition the player set into those who should be in a race to choose, and influence others, and those who should be happy to wait, and see what happens. This partition will be determined by the asymmetries in preferences and information and allows us to predict who should lead and who follow. Thus, we see that *preference and information asymmetries should be a cue for leadership*.

Hypothesis 1, order: In a sequential game, a player with an iterated dominant or persuasive strategy chooses an action before a player without.

Propositions 1 to 5 tell us of the incentive for those with an iterated dominant or persuasive strategy to choose quickly and for those with no information to wait. The first part of Hypothesis 1 fills the gap by suggesting that *all* those *without* an iterated dominant or persuasive strategy will wait. Again, example 3 serves to show that this need not generally be the case (because players 2 and 3 may want to move first). A sufficiently risk averse player would, however, always be willing to wait if he does not have an iterative dominant or persuasive strategy.

Our second hypothesis concerns the *action* that players commit to and says that players should use iterated dominant or persuasive strategies if they have them. This may not seem surprising given the analysis above but it is a relatively strong requirement on actions chosen. For example, an iterated dominant strategy may involve a player choosing an action he does not prefer. Similarly, a persuasive strategy may involve a player choosing an action different to all those players who have chosen. In short, Hypothesis 2 suggests that players take into account both asymmetries in preferences and asymmetries in information.

Hypothesis 2, strategy: If a player commits at time t and has an iterated dominant or persuasive strategy to choose X (or Y) at time t then he chooses X (or Y). Otherwise he chooses the action that he prefers at time t .

The first part of this hypothesis is a direct consequence of Propositions 1 to 5. The second part is conjecture. To see why, we can return to Example 3 and note that it is reasonable for players 2 and 3 to choose the action they do not prefer (because this will result in all players coordinating).

We now turn from behaviour to outcomes and look to quantify the benefits of leadership and/or preference information. At this point we take a simulation approach of randomly generating payoff values and, assuming that players will behave in accordance with Hypothesis 1 and 2, finding the outcome variables of interest. Informally, we can think of this as characterising the outcome variables if play is consistent with SPNESS. To match the experimental data we consider a setting with four players where values can be any integer between 0 and 12. More details on the exact procedure used are provided in Appendix 2.

We begin by looking at average payoffs as a measure of how successful is the group as a whole. This will allow us to see whether leadership really does increase coordination. What we find is summarised in Figure 1. To put this in some context it may be useful to note that the maximum average payoff that players could have achieved was 25.09 and the minimum was 10.11.¹⁸ Also, recall, that the no information, simultaneous case provided an expected benchmark of minimal coordination.

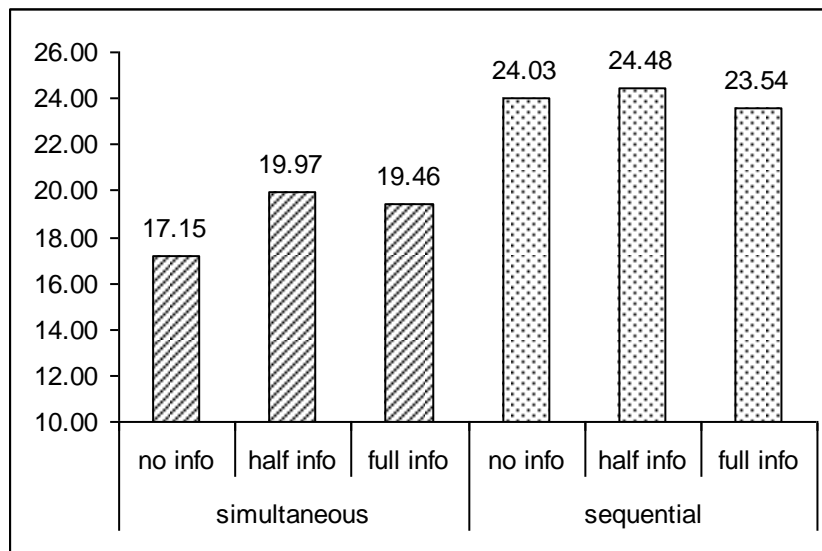


Figure 1: Predicted payoffs if players behave according to Hypotheses 1 and 2.

¹⁸ We also note that all differences are statistically significant, each data point being the mean of 400,000 observations.

The range of observed values (from 17 to 24) shows that coordinating in this game is not easy. We see, however, that payoffs are significantly higher in a sequential game and, what's more, are near to the theoretical maximum of 25. Leadership and sequential choice does, therefore, enable players to coordinate. By contrast, information about preferences has a much smaller effect, particularly in a sequential game. Indeed, we see that payoffs are actually highest in the half information condition and, in the case of a sequential game *lowest* in the full information game.

Hypothesis 3, average payoffs: Payoffs are significantly higher in a sequential than simultaneous game. Information about others payoff values has relatively little effect on average payoffs, except in simultaneous games where payoffs are significantly lower in a no information game.

In Sections 3.1 to 3.4 we suggested, at a more anecdotal level, that sequential decision making may be more beneficial than payoff information. Proposition 2, for instance, highlighted the ambiguity that can arise with full information. It is not so clear why *less* information about others payoff values may be beneficial. To better understand this, we need to delve a little deeper and look at the distribution of payoffs amongst members of the group. Figure 2 summarises data on payoffs relative to sequence order and shows how payoffs can vary considerably within the group, depending on payoff information. In interpreting this data it is important to keep in mind that it is calculated assuming players behave according to Hypotheses 1 and 2. We could not, therefore, infer from this data that there is, say, a payoff disadvantage to being a 1st mover in the no information condition. All that we can say is that those players who, Hypotheses 1 and 2 predict, should move first in the no information condition have relatively low payoffs.

With this caveat in mind we can begin to explain the data. One notable result is how the payoff of the 1st mover is increasing in available information. In the no information condition going first is relatively risky because a player can simply not know whether others would want to follow. In a half and full information game the risk is much less as the first mover can better know whether he will be followed. This is captured by the notion of iterated dominant and persuasive strategy and reflected by the higher payoffs to the first mover in a half and full information games. In particular, when there is no information, players who have more to gain from coordinating should delay their choice in order to guarantee that they will coordinate with others. This goes a long way to explain the difference in first mover payoffs, and will be a point we return to below in looking at the experimental data.

The relatively high payoffs of first movers when there is more payoff information would suggest that increased information allows better coordination. We know, however, that on aggregate, full information does not increase payoffs. That payoffs are *no higher* in the full information case is consistent with the different incentives to wait, alluded to in the previous paragraph, because it means changes in

payoff information may change the *order* of moves without changing choices. To see why payoffs in the full information condition are actually *lower* we need to question why changes in payoff information could change *choices*. The reason is the race to choose first, and influence others, that occurs in the full information case. Such a race can be won by a player who chooses an action not preferred by others. This acts to pull down slightly the aggregate payoffs in the full information case.

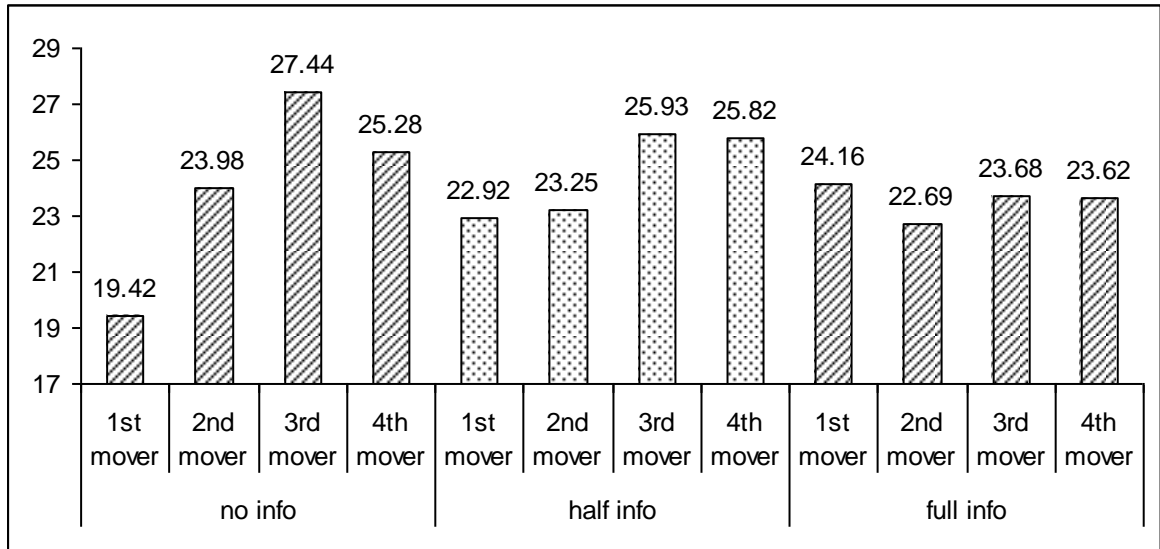


Figure 2: Predicted relative payoffs in sequential games if players behave according to Hypotheses 1 and 2.

Note that in a half information setting going first is less risky (if the first mover is informed) but the first mover does have to take better account of others preferences. This is further illustrated by looking at the relative payoffs of those with information and those without. In simultaneous, half information games we find that those with information earn an average of 20.42 and those without 19.53. There is, therefore, an advantage to being informed but not a particularly large one. In a sequential game we find that those with information earn an average of 24.23 and those without 24.60. There is, therefore, a slight disadvantage to being informed. With this we can state our final hypothesis.

Hypothesis 4, relative payoffs: First movers get relatively low payoffs in a no information game and relatively high payoffs in a full information game. In a full information game payoff is not significantly dependent on order but in no or full information game third and fourth movers earn significantly more than first and second movers. Players with information do not earn significantly more than players without.

4. Experimental Results

We now turn to some experimental results. We ran laboratory experiments in which participants played the coordination game described above for 25 consecutive rounds (the participants were told to expect ‘somewhere between 20 and 30’ rounds). The specific game used, in each round, was one with four players and payoff values uniformly chosen from the set of integers $\{0, \dots, 12\}$.

It is important to clarify that participants were matched with the same participants in each round (and knew this). Technically, therefore, the participants played a repeated game. We took this approach to see if any group effects would arise over the course of the rounds. Note, however, that while participants were formally playing the same game there was never an instance where participants received the same (randomly determined) payoff values. Each round, therefore, constituted a different (realized) coordination problem. Our reading of the data, clarified in Appendix 3, is that this continual changing of values meant there was not any learning over rounds or significant group effects. In the following, we shall therefore treat each round as an independent game.

We used a 2x3 between subject design varying payoff information and action information: In a *no information condition* participants knew only their own values, in a *full information condition* participants knew the values of all the other participants in their group, and in a *half information condition* two of the participants knew only their values and two participants knew everybody’s values. Note that in the half information condition the two participants who knew everybody’s values were randomly determined in each round.¹⁹

In a *simultaneous condition* all four participants made their decisions at the same time, without knowing what the others in their group had chosen. In a *sequential condition* participants could choose an action at any time. When an action was chosen other participants would immediately see the action chosen.²⁰ Note, therefore, that the order in which the participants made their choices was endogenous. Also note that in each round and in all conditions participants were forced to wait 15 seconds after seeing the new payoff values before they could choose.

In all there are 6 potential conditions, as presented in table 1. We did not run the simultaneous, no information condition since we assumed this to be trivial (so trivial that some participants might actually become confused).

¹⁹ Due to a programming error in the first couple of sessions there were three occasions where just one player in the group had complete information about everybody’s values. We have included these games in the analysis because the participants could not have known about the problem so this should not have changed their behavior.

²⁰ The nature of the programme was that two participants could not simultaneously choose an action. Indeed, if a participant typed in an action, but did not press the enter button, before someone else chose, the screen would reset, forcing the participant to re-enter the action, and therefore, presumably, take account of the new information.

	No Information	Full Information	Partial Information
Simultaneous		n = 20	n = 20
Sequential	n = 32	n = 36	n = 32

Table 1: number of sessions (with 4 participants each) for each condition

The experiment was programmed in ztree (Fischbacher, 2007) and run at the University of Kent at Canterbury in May, June and October 2008. Participants were recruited via the university-wide research participation scheme and were randomly assigned to the different conditions. They were paid according to four randomly selected rounds with each point earned in a round earning the participant 10p. In total 140 subjects participated, who earned £9.26 on average. Participation in the experiment took about 45 minutes (Simultaneous) to one hour (Sequential).

4.1. Strategy

First we shall look at the actions participants chose and evaluate Hypothesis 2. That players should use dominant and iterated dominant strategies is a fairly basic requirement of Nash equilibrium play. It is worth noting, however, that it can be a fairly demanding requirement of player's reasoning abilities. In particular, players may need to realise the consequences of others choices for both their own and others payoffs. Table 2 provides relevant data with which to evaluate Hypothesis 2. We see, for example, that 28 first movers in the full information case had a dominant strategy and 26 of them chose the action expected.

We view the figures in Table 2 as support for Hypothesis 2. Perhaps, more precisely, the results suggest that Hypothesis 2 provides a good predictor of what subjects did. In sequential games, for example, 91% of choices were as we would expect given Hypothesis 2. Looking more closely, 74% of those with an iterated dominant, but not dominant strategy, and 84% of those with a persuasive, but not dominant strategy, behaved as expected. This does not, of course, mean that players are necessarily solving for iterated dominant strategies. Nor does it rule out that we could not find a better predictor. Clearly, however, Hypothesis 2 does significantly better than the 50% success rate that would be expected with random choice. Also, in Appendix 4, we look more closely at possible alternative explanations and find they do no better than Hypothesis 2.²¹ We therefore, propose,

Result 1: Hypothesis 2 is supported by the experimental data. Specifically, if a participant had a dominant, iterated dominant or persuasive strategy when making their choice, then they typically used it.

²¹ To briefly comment on the individual level data. We find that 50% (and 70%) of participants behaved contrary to Hypothesis 2 in at most 2 (and 3) rounds, out of 25. The modal number of rounds where behaviour is contrary to Hypothesis 2 is 1 and the median 3. This results in over 60% of the occasions where a participant did not behave according to Hypothesis 2 being accounted for by 30% of the participants.

		Sequential games										Simultaneous	
		1 st mover		2 nd mover		3 rd mover		4 th mover		All players		# with	# use
		# with	# use	# with	# use	# with	# use	# with	# use	# with	# use	# with	# use
Full info	Dominant	28	26 *	75	68 *	185	173 *			511	475 *	50	44 *
	Iterative D.	48	45 *	126	108 *	225	196 *	223	208 *	622	557 *	93	81 *
	Persuasive	189	170 *	241	181 *	223	204 *			849	763 *	-	-
	Prefer	33	22	5	1	0	0	-	-	38	23 *	378	262 *
Half info	Dominant	45	45 *	65	62 *	162	154 *	197	176 *	469	437 *	52	48 *
	Iterative D.	58	57 *	90	85 *	182	162 *			527	480 *	67	59 *
	Persuasive	140	127 *	131	113 *	182	170 *			650	586 *	-	-
	Prefer	54	47 *	66	52 *	16	13	-	-	136	112 *	407	327 *
No info	Dominant	48	47 *	64	59 *	159	152 *	198	182 *	469	440 *		
	Prefer	146	132 *	131	111 *	36	30 *	-	-	313	273 *		
Overall	Dominant	121	118 *	204	189 *	506	479 *			1449	1352 *	102	92 *
	Iterative D.	154	149 *	280	252 *	566	510 *	618	566 *	1618	1477 *	160	140 *
	Persuasive	377	344 *	409	353 *	564	526 *			1968	1789 *	-	-
	Prefer	233	201 *	202	164 *	52	43 *	-	-	487	408 *	785	589 *

Table 2: The number of players that have, and the number of those that use, dominant, iterative dominant and persuasive strategies. ‘Prefer’ refers to whether those without an iterative dominant or persuasive strategy choose the action they prefer. * indicates that the number of players who use the relevant strategy is significantly different from the 50% expected with random choice, at the $p = 0.005$ level (using a likelihood ratio test).

The one situation where there is less support for Hypothesis 2 is a simultaneous, full information game. We hypothesised that those without an iterated dominant strategy should choose the action they prefer. We observe that 69% do this. This success rate is still significantly more than 50%, but is lower than we see in other situations. To try and explain why this is the case, imagine a situation where three players prefer action X and one prefers action Y. It is clear that the player who prefers Y may consider it more sensible to choose X while Hypothesis 2 predicts he chooses Y. What this means is that in assuming players behave according to Hypothesis 2 we may underestimate average payoffs in the simultaneous, full information game.

4.2. Timing

We shall now turn our attention to the order of moves and Hypothesis 1. In doing this we can test whether preference and information asymmetries did indeed cue leadership. Table 3 summarizes the number of times that 4 of the players, 3 of the players etc. had an iterated dominant or persuasive strategy and the number of times that the player who committed had an iterated dominant or persuasive strategy. For example, we read that in full information games there were 76 times that 3 out of 4 players had an iterated dominant or persuasive strategy and on 60 of these occasions the person who committed first had an iterated dominant or persuasive strategy.

The data in Table 3 gives somewhat mixed support for Hypothesis 1. In particular, Hypothesis 1 suggests that a player without an iterated dominant or persuasive strategy should never choose before someone who has. The data in Table 3 would reject this. We do see, however, that players with an iterated dominant or persuasive strategy are significantly more likely to choose than would be expected by pure chance. For example, if we look at the first mover when there is only 1 player who has an iterated dominant or persuasive strategy we see that approximately 50% of the time the player with this strategy moves first. This is clearly not the 100% that Hypothesis 1 would predict is significantly higher than the 25% we would expect with pure chance.

More data with which to judge Hypothesis 1 is provided in Table 4. This looks at how many seconds a player waited (after the start of the game or the previous mover) before choosing.²² This data further supports Hypothesis 1 in that players with an iterated dominant or persuasive strategy commit more quickly than do players without. More formally, we first note that in the full information condition there is no significant difference in waiting time between those with and without an iterated dominant or persuasive strategy ($p = 0.73$ and 0.97 for 1st and 2nd movers respectively, Mann-Whitney).²³ In the no information condition there is a significant difference for 1st and 3rd movers ($p = 0.001$, 0.5 and 0.002 for 1st, 2nd and 3rd movers respectively) and in the half information condition there is marginal evidence of a

²² Recall that participants were forced to wait 15 seconds before making a choice, hence the relatively quick 1st mover data.

²³ This to be expected given the small number of movers who did not have iterated dominant or persuasive strategies (see Table 2).

significant difference for 1st and 3rd movers ($p = 0.1, 0.24, 0.1$). Pooling the data from the half and no information conditions we again find a significant difference for 1st and 3rd movers ($p = 0.001, 0.11$ and 0.001).²⁴

		1 st mover		2 nd mover		3 rd mover	
		# times	# use	# times	# use	# times	# use
Full info	4 players	107	107	-	-	-	-
	3 players	76	60	210	210	-	-
	2 players	34	22*	15	10	225	225
	1 player	8	3	0	0	0	0
	Overall	225	192	225	220	225	225
Half info	4 players	3	3	-	-	-	-
	3 players	29	28 ***	25	25	-	-
	2 players	124	92 ***	95	75 **	159	159
	1 player	40	19 ***	77	31	38	24
	Overall	196	142 ***	197	131 **	197	183
No info	4 players	0	0	-	-	-	-
	3 players	1	1	0	0	-	-
	2 players	20	15 **	23	15	126	126
	1 player	57	32 ***	85	49 ***	48	33 *
	Overall	78	48 ***	108	64 ***	174	159 *
Overall	4 players	110	110	-	-	-	-
	3 players	106	89 *	235	235	-	-
	2 players	178	129 ***	133	100 *	510	510
	1 player	105	54 ***	162	80 ***	86	57 ***
	Overall	499	382 ***	530	415 ***	596	578 ***

Table 3: The number of times that 4, 3, 2 or 1 of players had an iterated dominant or persuasive strategy and the corresponding number of times that the player who moved had an iterated dominant or persuasive strategy. *, ** and *** indicate whether the number of movers who have iterated dominant or persuasive strategies is significantly different from the number expected if leadership is random, with $p = 0.1$, $p = 0.025$, $p = 0.005$ (using a likelihood ratio test).

Despite the evidence that those predicted to wait or move early generally do, Table 3 clearly shows that there are many instances when they do not wait or move early enough. Given the relative speed that choices were made the suggestion would be to focus more on why some participants did not wait long enough, rather than on

²⁴ The null hypothesis that waiting times across all information conditions are drawn from the same distribution is rejected for both 1st and 2nd movers and those with and without iterated dominant and persuasive strategies ($p < 0.01$). The null hypothesis that waiting times in the half and no information conditions are drawn from the same distribution is not rejected for 1st, 2nd and 3rd movers and both those with and without iterated dominant and persuasive strategies ($p = 0.19, 0.48, 0.13$ for 1st, 2nd and 3rd movers with iterated dominant or persuasive strategies and $0.34, 0.88, 0.84$ for those without, Mann-Whitney).

why some waited too long. Table 5, details how often particular participants lead. What we observe is more extreme values than would be predicted if leadership were randomly determined within the group. For example, 5 participants never lead and 7 participants lead 5 or more times. This would be highly unlikely if leadership was random.

		1 st mover	2 nd mover	3 rd mover	4 th mover
Full	Had iterated dom/per	2.43 (8.7)	5.25 (6.13)	4.86 (5.3)	5.45 (5.5)
	No iterated dom/per	2.18 (5.3)	6.00 (5.52)	-	
	Overall	2.40 (8.3)	5.26 (6.11)	4.86 (5.3)	
Half	Had iterated dom/per	3.70 (13.2)	6.61 (8.39)	6.08 (10.4)	5.57 (8.0)
	No iterated dom/per	4.60 (9.9)	8.87 (13.4)	7.53 (7.1)	
	Overall	3.97 (12.3)	7.39 (10.4)	6.20 (10.1)	
No	Had iterated dom/per	1.77 (4.3)	5.69 (5.7)	4.75 (5.2)	5.05 (6.0)
	No iterated dom/per	7.82 (16.2)	8.58 (12.4)	14.59 (24.0)	
	Overall	6.37 (14.5)	7.66 (10.8)	6.77 (12.4)	
Half + No	Had iterated dom/per	3.21 (11.6)	6.31 (7.6)	5.46 (8.4)	5.31 (7.1)
	No iterated dom/per	6.93 (14.7)	8.68 (12.7)	12.52 (20.7)	
	Overall	5.17 (13.5)	7.52 (10.6)	6.48 (11.3)	

Table 4: The number of seconds before a player moves after the start of the game (1st mover), or a previous mover (2nd, 3rd, 4th mover), distinguishing between players that had an iterated dominant or persuasive strategy and those that did not, standard errors in brackets.

Times lead	0	1	2	3	4	5	6	7	8	9	10,11	12,13	14+
Full info	3	4	2	3	4	4	3	2	2	1	1	2	5
Half info	0	3	2	5	1	3	3	4	1	3	5	2	0
No info	2	1	2	1	3	4	4	5	5	1	1	1	2
Overall	0.05	0.08	0.06	0.09	0.08	0.11	0.10	0.11	0.08	0.05	0.07	0.05	0.07
If random	0.00	0.01	0.03	0.06	0.12	0.16	0.18	0.16	0.12	0.08	0.06	0.01	0.00

Table 5: The number of participants that lead a particular number of times during the 25 rounds. Also, the proportion of participants who lead a particular number of times (aggregated over all sequential conditions) and the proportion to be expected if leadership is random.

The data in Table 5 suggests that some participants were eager to lead while others were not. We need, however, to be careful to distinguish whether participants should have been leading or not. In particular, there is nothing in Hypothesis 1 that rules out one player always leading. Figure 3 provides a more informative and detailed picture by comparing the number of times that a participant could have moved 1st or 2nd, in a way consistent with Hypothesis 1 *but did not*, versus the number of times they did move *consistent with*, and *inconsistent with* Hypothesis 1.

The full information condition provides a benchmark because most participants could move have moved 1st or 2nd in most of the rounds (because the greater information leads to more players having iterative dominant or persuasive strategies). This is why we see a very close correlation between the number of times a participant did move 1st or 2nd and the number of times they could have, but did not. Heterogeneity in participant behaviour is clear from the dispersion of the data. For example, one participant had 46 opportunities to move 1st or 2nd but never once did. At the other extreme, one participant moved 1st or 2nd in all 25 rounds (even if there were 7 rounds they could have lead but moved 2nd).

Hypothesis 1 has more bite in half and no information games and so the potential for unpredicted movers is that much higher, particularly if some participants, for whatever reason, always wish to move early and some always wait. What we seem to observe is that participants did react to the different incentives in the half and no information case but not as much as Hypothesis 1 would require. More specifically, the number of times that participants moved 1st or 2nd is more evenly distributed in the half and no information conditions than in the full information condition, but not enough. There are still participants who moved 1st or 2nd more often than we would expect and this resulted in a large number of unpredicted moves. Indeed, over 50% of the unpredicted moves are caused by just 16 subjects.²⁵ The suggestion, therefore, would be that the slightly mixed evidence with regard to Hypothesis 1 reflects some participants being a little eager to move early. We shall return to the consequences of this below. For now we summarise with,

Result 2: There is mixed support for Hypothesis 1. Specifically, on average, participants with iterated dominant and persuasive strategies did chose before those without. There is, however, evidence of some participants moving early more than predicted.

4.3. Average Payoffs

Having seen support for Hypotheses 1 and 2 we would also expect to see some support for Hypotheses 3 and 4. In order to evaluate Hypothesis 3 consider Figure 4 which can be directly compared to Figure 1. This provides the most direct test of

²⁵ Note, however, that some subjects did move 1st or 2nd a lot without moving inconsistent with Hypothesis 1. For example, one participant in the half information condition moved 1st or 2nd 17 times and only twice in a way inconsistent with Hypothesis 1.

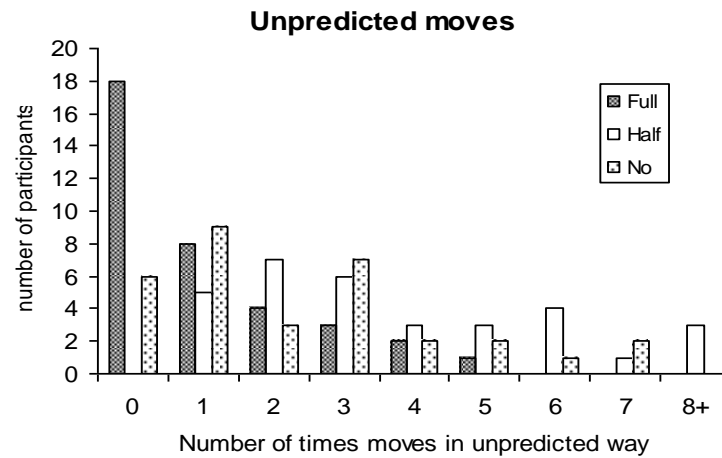
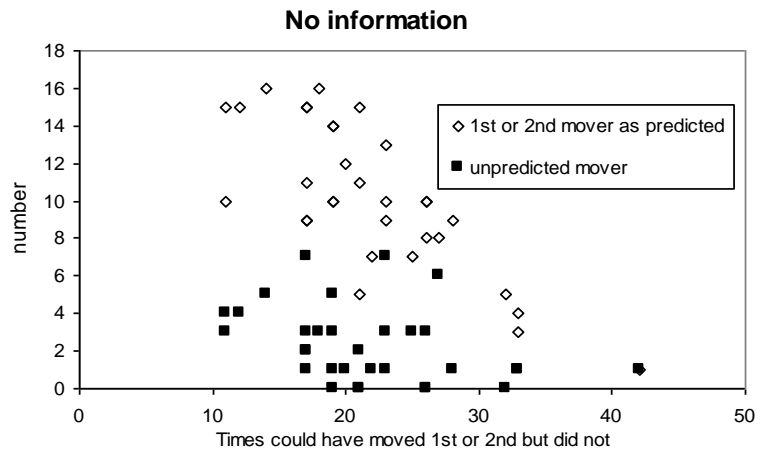
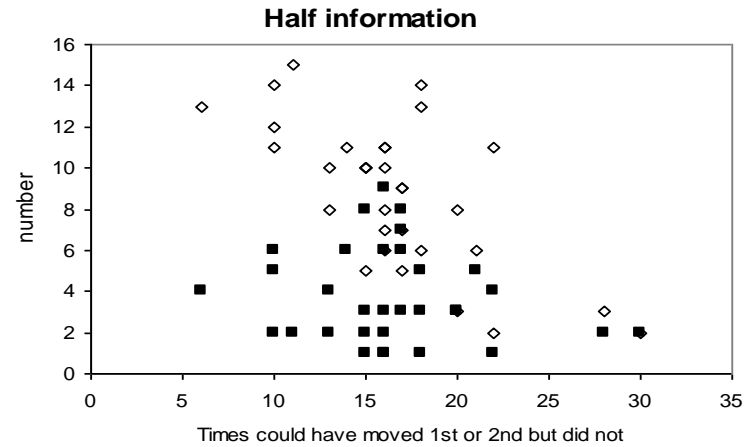
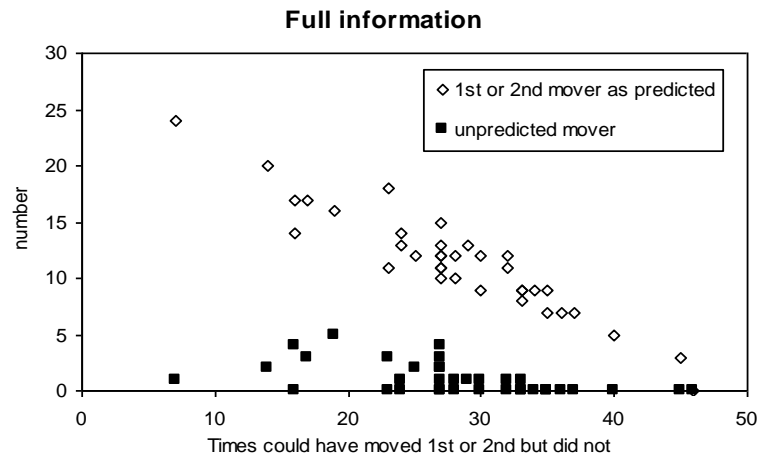


Figure 3: The number of times a participant could have moved 1st or 2nd, consistent with Hypothesis 1, but did not, against the number of times they do move 1st or 2nd, consistent with hypothesis 1, and inconsistent with hypothesis 1. Also a histogram of unpredicted moves.

whether there was a coordination problem and whether information about preferences or actions allowed participants to overcome the problem.

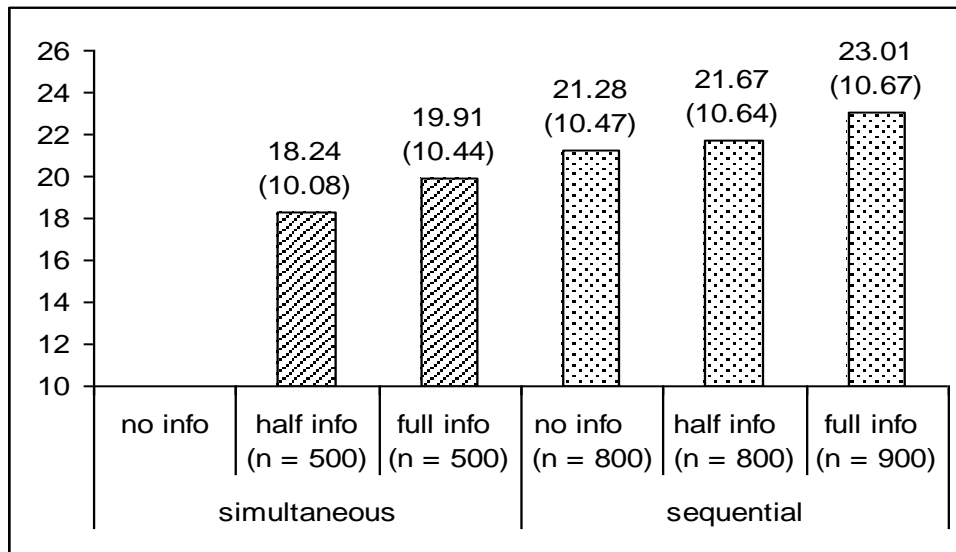


Figure 4: Payoffs in the experimental sessions, standard errors in brackets.

The data confirms that coordinating in this game is difficult with average payoffs being consistently below those predicted, and the theoretical maximum of 25. Information about preferences and actions did help alleviate this with payoffs getting towards the maximum in the sequential, full information game. As expected, payoffs are significantly higher in sequential games compared to simultaneous games (with $p = 0.001$, Mann-Whitney). Leadership and observing others actions does, therefore, help players to coordinate. The effect is not, however, as high as expected because payoffs are lower in the sequential, no and half information conditions than predicted. Indeed, contrary to Hypothesis 3, we see that payoffs are significantly higher in full information conditions. In simultaneous games, payoffs are higher in full information games ($p = 0.007$), while in sequential games, payoffs are similar in half and no information games ($p = 0.484$) but higher in full information games ($p = 0.001$). The evidence, therefore, also points to the benefits of payoff information. In particular, it is only when *all* players are fully informed of others payoffs that we see payoffs as high as the theoretical prediction. Our third result is, therefore,

Result 3: There is mixed support for Hypothesis 3. Specifically, average payoffs are higher in sequential games compared to simultaneous games. Average payoffs are also, however, increasing in payoff information.

It is clearly important to question why payoffs were lower in the no and half information conditions than predicted. Given that participants did choose as predicted most of the time (Result 1) one might expect that it comes from the unpredicted ordering of moves (Result 2). At first sight this seems plausible given how payoffs

were highest in the full information case where unpredicted moves were least. To take this argument further we need to look at the data on relative payoffs.

4.4. Relative Payoffs

Figure 5 plots the payoffs observed in the experiment according to move order and can be directly compared to Figure 2. In qualitative terms the relative payoffs, as given in Figure 5, are remarkably similar to those predicted, in Figure 2. The data, therefore, provides support for Hypothesis 4. More precisely, the realised payoff of first movers are increasing in payoff information ($p = 0.001$, Kruskal Wallis). In the no information condition first movers have significantly lower payoffs than subsequent movers ($p = 0.001$, Mann-Whitney). In the full information condition, by contrast, we cannot reject the null that payoffs are constant over move order ($p = 0.704$, Kruskal Wallis). Finally, in the half information condition, we observe no effect due to payoff information because those players with information earned on average 21.79 (10.53), those without 21.54 (10.75) and the null of no difference cannot be rejected ($p = 0.778$, Mann Whitney). This suggests,

Result 4: There is good support for Hypothesis 4. Specifically, the payoff of first movers is lowest in the no information game and highest in the full information game. Further, in full information games payoff did not depend significantly on move order and in half information games payoff did not depend significantly on information.

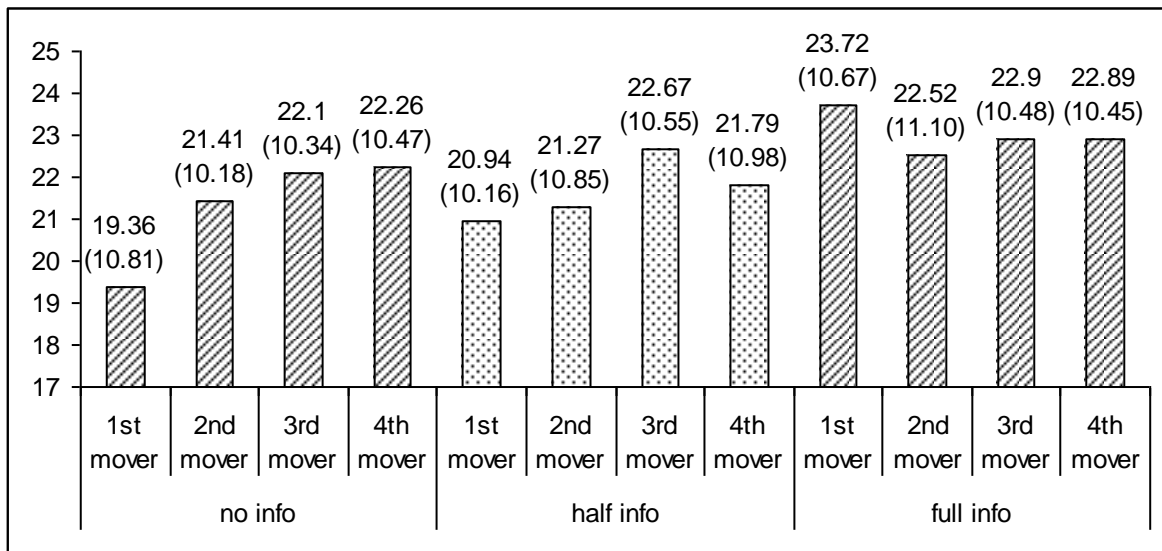


Figure 5: Relative payoffs in the experimental sessions, standard errors in brackets.

If the data lends qualitative support to Hypothesis 4 it is notable that there are quantitative differences in the payoffs observed compared to those predicted. These were to be expected given the relatively low payoffs observed in the no and half information conditions but now it is slightly easier to pinpoint where the differences

lie. For example, we see in the no information condition that 3rd and 4th movers do particularly worse than expected.

At this point we can pick up the discussion, begun at the end of the previous section, about whether the relatively lower payoffs in the no and half information condition are due to some participants moving earlier than predicted. Figure 6 plots how coordination value is predicted to vary with move order and how it did vary with move order in the experiments. Coordination value is a meaningful variable to look at because, as a measure of player's potential gains from coordinating, it is important in determining both optimal strategy and payoff. For example, we see that 3rd and 4th movers are predicted to do so well in the no information condition primarily because they are players with high coordination values who should wait and make sure they coordinate with others.

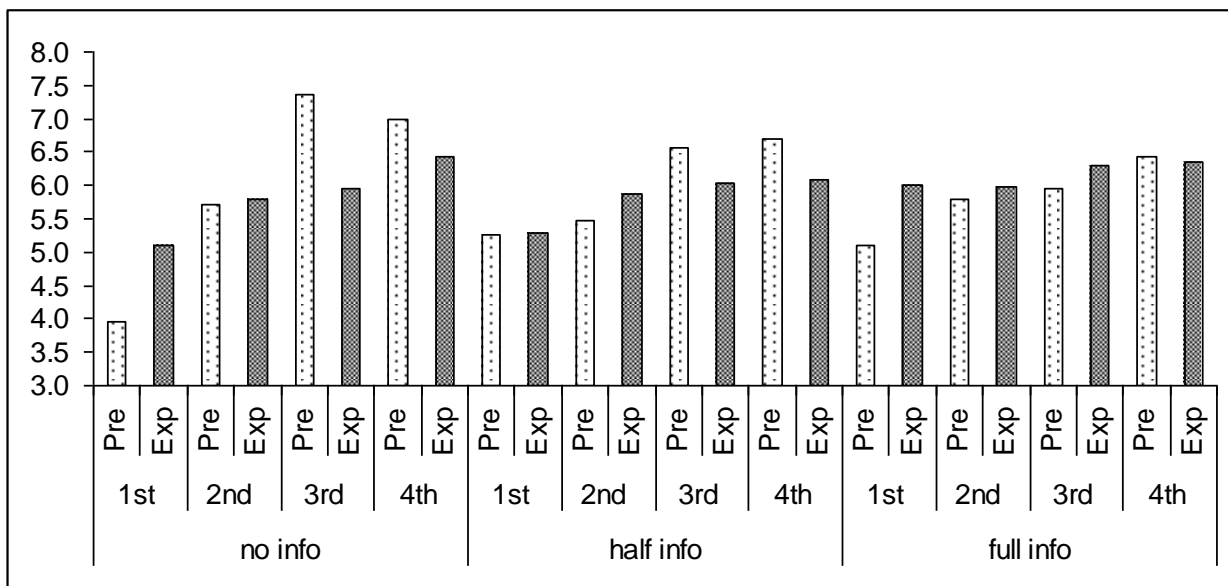


Figure 6: Relative coordination values predicted (Pre) using Hypotheses 1 and 2 and observed in the experiments (Exp).

As with Figure 5, the experimental data is qualitatively very similar to that predicted, but quantitatively a little different. The most significant difference, in interpreting our results, is that it seems in the no and half information conditions, *those participants with a high coordination value simply did not wait long enough before choosing*. Note, they did wait, as shown by the relatively high coordination values for 3rd and 4th movers, but just not long enough, as shown by the observed coordination value falling below that predicted. This would appear to tie in with Result 2 and suggest the lower than predicted payoffs in the half and no information condition are because some participants, with high coordination values, were not coordinating with others as much as they should have because they did not wait long enough.

Support for this conjecture is not hard to find in the data. For instance, we find that participants who moved too early, as judged by Hypothesis 1, had relatively high coordination values in the half and no information conditions (6.92 and 6.97, versus 6.26 in the full information condition) and low information in the half information condition (90% had no information). The consequence of this was a lack of coordination, with those who moved too early only coordinating with 2.1 other participants in the half information condition and 1.8 in the no information condition (against general averages of 2.5 and 2.3).

To translate this into payoffs, an appropriate experiment is to take all the instances where a participant moved too early and, *ceteris paribus*, change their action so as to better coordinate with others.²⁶ Doing this changes only 62 choices, out of a total of 2500, but has a large effect on average payoffs. Specifically, average payoffs now become 23.13 in the full information condition, 22.89 in the half information condition and 21.95 in the no information condition. Clearly, participants are still not doing as well as predicted, but the differences between information conditions are substantially reduced. With this we state our final result,

Result 5: There is evidence that the lower than predicted payoffs in the half and no information games are due to some participants moving too early. These participants had relatively high coordination values (and low information) and by moving early coordinated less with others than they should have done to maximise their payoff (and others payoffs).

5. Conclusion

We have analysed, both theoretically and experimentally, a relatively simple coordination game that is characterised by varying degrees of conflict of interest, incentives to coordinate and asymmetric information. Our main objective for doing this was to test whether leadership, and sequential choice, together with asymmetric preferences and information, can overcome the problems associated with conflict of interest. Our theoretical results strongly suggested that it could with leadership allowing players to realise almost all the possible gains from coordinating while common knowledge about preferences had only a weak benefit. The experimental results showed that leadership did help players to coordinate, but less than expected, while knowledge about preferences helped more than expected. Even so, it is better to have leadership and no preference information than preference information and no leadership.

Leadership works well for two reasons. First, it enables players to coordinate with what they see others doing. Second, those with most to gain or lose can time

²⁶ This may sound a little artificial but we believe a useful exercise. Without wanting to go through each case individually, often we see that a participant who moves too early, according to Hypothesis 1, does not coordinate with others. The SPNESS would be for them to wait and coordinate with others. If, by artificially fixing this, we obtain average payoffs similar to those predicted then we know better where the low payoffs in the half and no information conditions come from. Note that just ignoring games where a participant moved too early is not a useful experiment because of self selection issues.

their choice to best influence or be influenced by others. The first reason was amply demonstrated by Cooper et. al. (1989) for the simple Battle of the Sexes Game and is very intuitive. The second reason is more subtle, but crucial in understanding leadership in coordination games with asymmetries of information and preferences. Indeed, the second objective of this paper was to see whether such asymmetries did provide appropriate cues for leadership. Ultimately, this is why we see leadership not working as well as predicted when preferences were not common knowledge. In theory players should have moved early or not according to payoff and information incentives. In practice we observed some participants who seemed too eager to lead or follow. If preferences are common knowledge the player eager to lead should still do well because he can choose an action he knows others will likely follow, but if preferences are not common knowledge the player eager to lead may do less well. The predicted benefits of leadership were, therefore, not fully realised when preferences were not common knowledge.

Three issues seem apt for further study given our results. First, we have contrasted *endogenous* leadership with simultaneous choice and it may be useful to also consider *exogenous* leadership. There are lots of reasons why we did not want to do that in this paper. Most basically, we feel that leadership does typically arise endogenously, possible in response to strategic incentives, and so this is what we wanted to consider. For example, we wanted to see who leads and follows. We also feel that simultaneous choice provides the most useful and informative comparator because it is the simplest and most transparent. There are settings, however, where leadership need not be endogenous and it would be interesting to consider this. It is noticeable that a large part of the literature on leadership has assumed exogenous leadership and so the differences between exogenous and endogenous leadership are important to understand. Interestingly our prior expectation would be that the optimal strategy in an exogenous leadership setting is much more complicated than that in either a simultaneous or endogenous setting perhaps highlighting an advantage of endogenous leadership.

Another issue that we have not considered is the potential for agents to choose to choose at the same time. In particular, in the sequential setting it was simply impossible for two agents to choose at the same time. In many settings, however, it may be possible that two agents could choose simultaneously. This is important because it increases the risks associated with moving early. If one agent chooses X, for example, and another simultaneously chooses Y then only one is likely to coordinate with followers and overall coordination is likely to be less. The advantages of endogenous leadership may be reduced if this can happen. Such issues have been looked at in some depth in the industrial organization literature (Hamilton and Slutsky 1990) and it would be interesting to take them up in the coordination game modelled here.

A final issue we raise is that of coordination. Cooper et. al. (1989) show that one way communication, which we would interpret as exogenous leadership, is

sufficient to enable coordination in the Battle of the Sexes. It is less clear whether communication would be so helpful in the presence of uncertainty over preferences and/or more than two agents. Would agents, for example, reveal preferences? Even if they do when there are more than two agents, and conflicting interests, the advantages of communication seem less clear. Suppose, for example, that agents can announce once what they intend to choose but choices are ultimately made sequentially after this communication stage. It is not clear whether communication would serve to confuse or help the coordinating process.

Appendix 1: Proofs of Propositions 1-3

Proof of Proposition 1: Consider player $1 \in N$ and suppose that he is uninformed. If all other players have no information and the Nash equilibrium is symmetric then players $2, \dots, n$ will, from the perspective of player 1 (given his lack of information), independently commit to action X with probability 0.5 and Y with probability 0.5. This clearly means that player 1 has a higher expected payoff committing to X if $x_i > y_i$ and Y if $y_i > x_i$. If some players do have information then, from the perspective of player 1, it only increases the likelihood that others will choose X (because these can see that he will choose X). ■

Proof of Proposition 2: Consider a simultaneous, full information game at time t with a non-empty set $U(t)$ of undecided players. It is only interesting if $|U(t)| \geq 2$. Suppose that all players belonging to $U(t)$ have a strategy which says that they should choose Y unless someone chooses X. The fact that no player in $U(t)$ has an iterated dominant strategy to choose X shows that this is consistent with SPNESS. But then, it may also be that all players belonging to $U(t)$ have a strategy which says that they should choose X unless someone chooses Y. This is also a SPNESS. In the first equilibrium a player $i \in U(t)$ would choose Y and the second would choose X.

Proof of Proposition 3: Suppose that no player has so far committed. Further, suppose that player j does not have a dominant strategy and will choose at time t . Given symmetry, from the perspective of player i , player j will choose X with probability 0.5 and Y with probability 0.5. If player i has a dominant strategy to play X then any Nash equilibrium ultimately requires him to choose X and if $c_i > 0$ he would do strictly better if player j also chooses X. If i chooses X before time t then, ceteris paribus, the likelihood of player j choosing X would be strictly greater than the current 0.5. This, and symmetry, means that player i should plan to choose before player j . We still have to check that player j would not want to choose before player i . Clearly, however, player j does better to wait and see what action will be chosen by any player who does have a dominant strategy given that this improves his information.

We have considered the incentives of 1st movers. Now we have to consider 2nd and 3rd movers, etc. It can be seen, however, that the intuition above generalizes to subsequent movers. All that would change is the probability 0.5 that, say, the 2nd

mover would choose X or Y. For instance, if the 1st mover chooses X then this biases incentives in the sense that it is more likely than probability 0.5 that the 2nd mover would choose X. The incentives to choose or wait, however, remain the same.

Proof of Proposition 4: Suppose that there exists a player i with a persuasive strategy to play X. Further, suppose that some player $j \in U(t)$ has a strategy that says they will commit to Y with positive probability at time t . If player i has a simple persuasive strategy then he would have a strictly higher expected payoff if he chooses X before time t than if he waits to choose until after t . This is because, if i chooses X all players in $U(t)$ (including some who may prefer Y) must also commit to X in any SPNESS. In the case of a forward looking persuasive strategy i gets a strictly higher payoff if he chooses X before any player who could be persuaded to choose X would choose Y. If i commits first, then the definition of persuasive strategy guarantees that i does better to commit to X than he can possibly do by waiting. ■

Proof of Proposition 5: This can be proved in an analogous way to Propositions 3 and 4. ■

Appendix 2: The simulation data

To generate the data in Figures 1 and 2 we basically randomly draw payoff values, impose the appropriate information condition, apply Hypothesis 1 and 2 and record payoffs. In a simultaneous game this simply requires finding iterated dominant strategies and assuming that those without an iterated dominant strategy choose the action they prefer. Potential concerns about this have already been raised in Section 3.4. If a player is indifferent as to what to choose then we assume that he chooses each action with probability 0.5.

In a sequential game we find which of the four players have iterated dominant or persuasive strategies. One of these is then randomly chosen, with equal probability, and is the 1st mover. If there is no player with an iterated dominant or persuasive strategy then one player is randomly chosen, again with equal probability, and this player chooses preferred action and is the first mover. This action taken as given, we repeat with the three remaining players and so on.

There are reasons that one could criticise this approach. For example, one might hypothesize that those who ‘nearly’ have a dominant strategy to play X may be more likely to move than those who are relatively indifferent. Our intuition, however, is that such subtleties would not only make little difference but also possibly mislead. For example, the player who is relatively indifferent may actually want to move first in order to commit themselves and increase the chances that others will coordinate. It is, therefore, difficult to make predictions of this nature.

One issue that we did need to address is how to deal with dominant strategies. We use a notion of *weak* dominance rather than strict. To motivate and explain this suppose that player 1 would be indifferent between choosing X and Y if the other three players choose Y. Using weak dominance we assume that player 1 will choose

X. Using strict dominance it could be that player 1 would choose X if the other three players did choose Y. On the one hand, one might think that player 1 could indeed choose X if the other three did choose Y. What we basically seem to observe, however, is that making it possible that player 1 *could* choose X only makes it more likely that the other three would choose Y and hence create the problem in the first place. Because of this, weak dominance seemed to give more intuitive behaviour and hence was adopted. This does make a difference to payoff estimates, but not a large one, and Hypotheses 3 and 4 would remain the same.

Appendix 3: Dynamic effects

Given that participants in the experiment played the game for 25 consecutive rounds and with the same three other participants it seems natural to ask whether there were any dynamic or group effects. The basic answer that we suggest is no there were not. To motivate why this is the case it is important to emphasize that while, from a theoretical perspective, participants played the same game 25 times, in reality they faced 25 different coordination problems, because of the different realized payoff values. For example, in one round participants might face a difficult problem where two prefer X and two prefer Y, but in the next round they may face a simple problem where all prefer X. This seems to limit group and dynamic effects.

There are lots of places that one can look for group and dynamic effects. To lend some support to the argument that there are no effects, we shall look at two pieces of data of interest in its own right. First, we look at average payoffs over the 25 rounds. If participants do get better at coordinating, because of group or learning effects, then we should expect this to show up in average payoffs. Figure A1 shows that, with the exception of a small rise in the first 3 or 4 periods, there is no significant change in average payoffs over time. We obtain a very similar picture if to look at the standard deviation (which is a measure of inequality in the group) and other relevant statistics.

One direct way to test for learning is to look at whether players increasingly play dominant and persuasive strategies over rounds. Figure 2A shows that, again with the exception of a small rise in the first few periods, there is no significant change in the proportion playing dominant, iterated dominant and persuasive strategies.

We have discussed in some detail one piece of evidence that might suggest group effects, namely, some participants who consistently lead or followed. If one participant always leads, for example, this may cause a group effect where others coordinate on his or her lead. The evidence, however, is contrary to this. First, if it is the case then it should show up in average payoffs, or more likely, the standard deviation of payoffs, over rounds; we have seen that it does not. Second, we have argued in the above that those who consistently lead actually lowered their own payoff and that of the group.

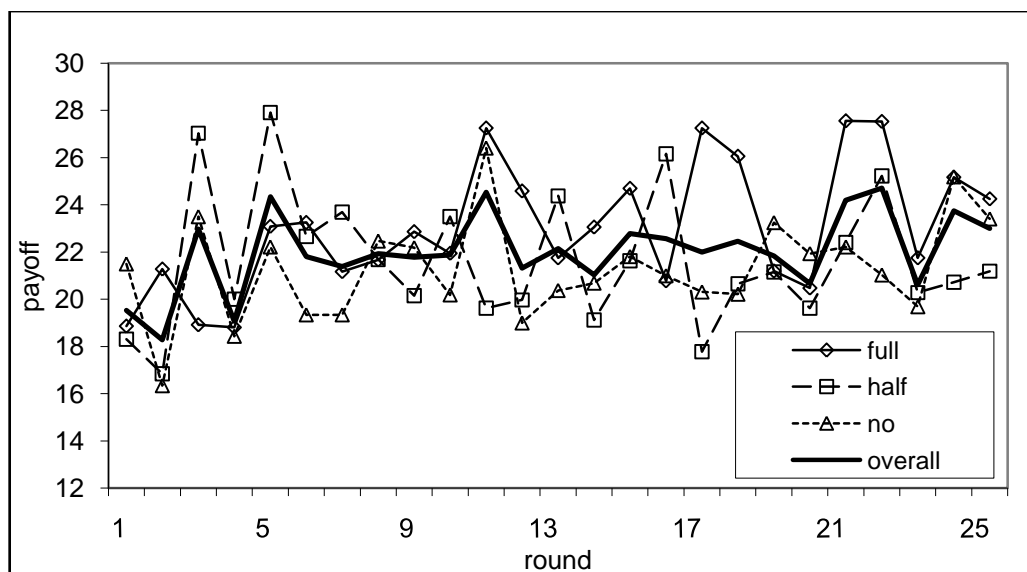


Figure A1: Average payoffs across the 25 rounds.

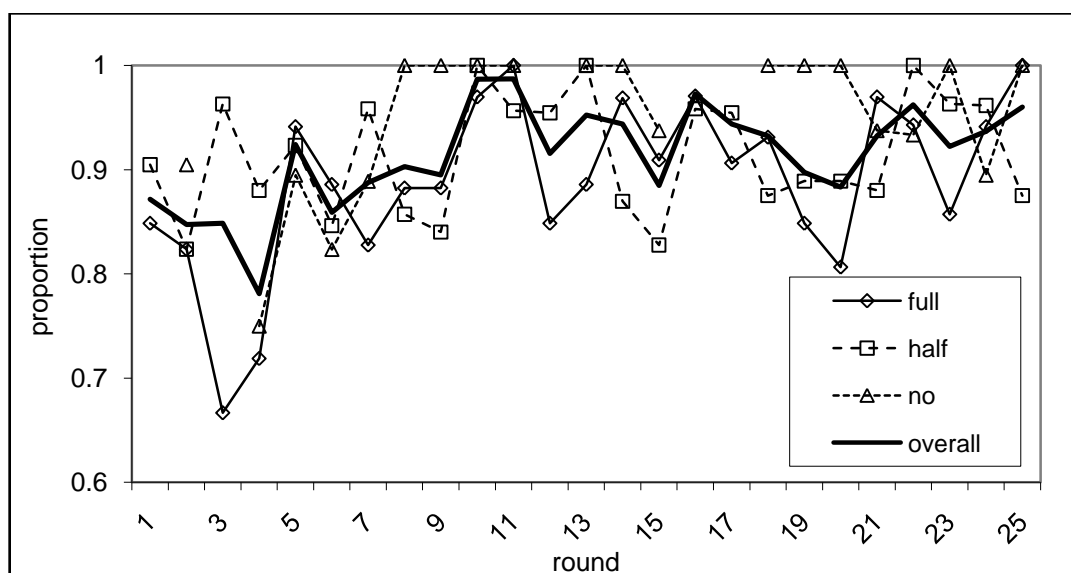


Figure A2: The proportion of times, in each round, that a player chose a dominant, iterated dominant or persuasive strategy, if he or she had one.

Appendix 4: Alternatives to Hypothesis 2

We consider three alternatives to Hypothesis 2 and look at how well these do at explaining the data. These can be summarised as follows: (i) If a player chooses at time t then he chooses the action that he prefers at time t . (ii) A player always chooses the action that he intrinsically prefers. (iii) A player always chooses the same action as the majority of players who have already chosen, if such a majority exists. Intuitively, these seem like plausible ways that players could behave. Table 1A summarizes the data.

Table A1: The number of players that have (A), and the number that use (B), dominant, iterative dominant and persuasive strategies compared to the number that choose ‘as if’ choosing preferred (C), intrinsically preferred (D) or majority (E) action.

		1 st mover			2 nd mover					3 rd mover				
		A	B	C	A	B	C	D	E	A	B	C	D	E
Full info	Dominant	28	26	26	75	68	68	68	65	185	173	173	111	161
	Iterative D.	48	45	43	126	108	108	98	105	225	196	202	137	168
	Persuasive	189	170	162	241	181	180	158	177	223	204	200	135	168
	Prefer	33	22	22	5	1	1	1	4	0	0	0	0	0
Half info	Dominant	45	45	45	65	62	62	62	55	162	154	154	102	143
	Iterative D.	58	57	57	90	85	83	76	79	182	162	170	116	146
	Persuasive	140	127	128	131	113	110	100	106	182	170	170	116	146
	Prefer	54	47	47	66	52	52	56	50	16	13	13	14	1
No info	Dominant	48	47	47	64	59	59	59	47	159	152	152	102	122
	Prefer	146	132	132	131	111	111	99	101	36	30	30	28	8
Overall	Dominant	121	118	118	204	189	189	189	167	506	479	479	315	426
	Iterative D.	154	149	148	280	252	250	233	231	566	510	524	355	436
	Persuasive	377	344	348	409	353	349	317	330	564	526	522	353	436
	Prefer	233	201	211	202	164	164	156	155	52	43	43	42	9

		4th mover					All players				
		A	B	C	D	E	A	B	C	D	E
Full info	Dominant						511	475	475	318	435
	Iterative D.	223	208	208	113	209	622	557	562	392	482
	Persuasive						876	763	761	558	554
	Prefer	-	-	-	-	-	38	23	23	23	4
Half info	Dominant						469	437	437	301	390
	Iterative D.	197	176	176	92	192	527	480	486	341	417
	Persuasive						650	586	584	436	444
	Prefer	-	-	-	-	-	136	112	112	121	51
No info	Dominant	198	182	182	86	182	469	440	440	264	351
	Prefer	-	-	-	-	-	313	273	273	265	109
Overall	Dominant						1449	1352	1352	883	1176
	Iterative D.	618	566	566	291	583	1618	1477	1488	997	1250
	Persuasive						1968	1789	1785	1258	1349
	Prefer	-	-	-	-	-	487	408	408	409	164

The easiest alternative to dismiss is (ii), that subjects choose actions they intrinsically prefer. A player behaving in this way would fail to account for past choices and not anticipate future choices. As such, we might think of it as the most naïve type of behaviour. We reiterate, however, that subjects were only informed of their values and the choices made by those who moved before them, and so anything other than this naïve behaviour would require a mental updating of payoff values. It seems that subjects were able to do this. Indeed, 4th movers actually chose the intrinsically preferred action less than 50% of the time.

If subjects do account for past choices then there are two ways they could do so: first, to just copy the majority (iii) and second update payoff values (i). Copy the majority fails to take account of the relative size of the coordination payoff and so can be seen as slightly more naïve. In practice, it does a good job of fitting 4th mover behaviour, but not so well with 3rd or 2nd mover. To choose preferred action (i), does take account of all past information and so is relatively sophisticated. It only differs from the behaviour predicted in Hypothesis 1 by failing to anticipate future actions. Specifically, a player with a dominant or persuasive strategy at time t by definition should choose preferred action at time t , so (iii) can only differ from Hypothesis 2 in respect of iterated dominant strategies. Given this, it is not surprising that (iii) is largely indistinguishable from Hypothesis 2 in fitting the data. Incidentally, we do not see this as a problem with our experimental design because our objective was to see whether players can coordinate, and not whether or not they play iterated dominant strategies.

Appendix 5: Experiment Instructions

We provide the instructions for the sequential, half information condition. From this it is simple to see what the instructions from the full or no information and simultaneous conditions would have been.

In this experiment you will be able to earn money. How much you'll earn depends on your choices and the choices of the **three other players** in the experiment.

You will play for *points* during the experiment. At the end of the experiment we will pay out your earnings of **four randomly selected rounds**. One point earned in these rounds will be worth 10 pence.

In each round you are asked to **choose between two alternatives**, X and Y. Each alternative will earn you a particular number of points. These values will be different every round and are randomly drawn from between 0 and 12.

The other players also choose between X and Y (but it is quite likely that they have different values assigned to the two options). **You will earn an additional number of points for each other player that chooses the same option as you.** This so-called *coordination value* is also randomly drawn from between 0 and 12 and will be

different every round. The other players will also get a particular number of points for every player that makes the same decision as them.

At the start of each round you will learn your values of X and Y and your coordination value. Additionally there is a **chance that you'll also learn the values the other players** will receive for their choices. Two players will know everybody else's values and two players will only know their own values. Who knows what will be determined randomly in every round. For an *all knowing* player the screen will look like this [note: the numbers used in this example are just that, an example]

Round		Remaining time (sec): 7		
1		X	Y	coordination
You	11	4	2	
Player A	4	4	9	
Player B	4	11	1	
Player C	6	6	12	

If you are a player who only knows their own value your screen will look like this:

Round		Remaining time (sec): 13		
1		X	Y	coordination
You	11	4	2	
Player A	-	-	-	
Player B	-	-	-	
Player C	-	-	-	

In this particular situation you can see you'll get 11 points for choosing X. Choosing Y will get you 4 points. Since your coordination value is 2 you will receive 2 points for every player that chooses the same option as you.

You'll get some time to think about your choice. After 15 seconds you will start to be able to make your decision. The screen will look like this:

The screenshot shows a game interface with a yellow border. At the top left, it says "Round 1". At the top right, it says "Remaining time [sec]: 152". In the center is a payoff matrix table:

	X	Y	coordination
You	11	4	2
Player A	4	4	9
Player B	4	11	1
Player C	6	6	12

Below the table, the status of other players is shown:

- Player A has't chosen yet
- Player B has't chosen yet
- Player C has't chosen yet

Your choice is indicated by two radio buttons:

Your choice X Y

An "OK" button is located in the bottom right corner.

You make a decision by simply ticking the alternative of your choice and clicking OK.

In the top right-hand corner of the screen you see how much time there is left in this round.

If one of the other players chooses before you, you can see what they have chosen. And the other way around: when you have chosen the other players will see your choice. This will look like this [note: again, this is just an example]

Round 1 Remaining time [sec]: 135

	X	Y	coordination
You	11	4	2
Player A	4	4	9
Player B	4	11	1
Player C	6	6	12

Player A hasn't chosen yet
 Player B hasn't chosen yet
 Player C has chosen X
 Your choice X Y

OK

In this particular situation player C has chosen X. You haven't made a decision yet. Neither have players A and B.

The order in which these choices are made has no effect on your earnings.

You'll have 3 minutes to make your choice. Once you have made a choice in a particular round you can't change it.

When everybody has made their decision we will show how much you have earned and how many points the other players have earned. In this particular (as said: random) example you seem to have chosen Y. This earns you 4 points. One other player has chosen Y as well. Since your *coordination value* is 2 you'll receive an additional 2 points. This brings your total earnings in this round at 6.

Round 1 Remaining time [sec]: 55

Your choice Y
 This earns you 4
 Player A has chosen X
 Player B has chosen Y
 Player C has chosen X

Number of players who made the same decision as you 1
 Your Coordination Value 2
 Your Coordination Earnings 2
Your Total Earnings This Round 6
 Player A's Earnings This Round 13
 Player B's Earnings This Round 12
 Player C's Earnings This Round 18
Total Points Earned So Far 6

OK

The other players in the experiment are always the same people. Player A is always the same person as are Players B and C.

We'll play somewhere between 20 and 30 rounds. We'll pay you your earnings of 4 randomly selected rounds. When the experiment is done you are asked to close the program. Behind it you'll find a questionnaire. When you're finished filling this in you can open your door to signal that you're finished.

References

- Abele, S., H. Bless and K-M. Ehrhart (2004) 'Social information processing in strategic decision-making: Why timing matters', *Organizational Behavior and Human Decision Processes* 93: 28-46.
- Amir, R. and A. Stepanova (2006) 'Second-mover advantage and price leadership in Bertrand duopoly' *Games and Economic Behavior* 55: 1-20.
- Bliss, C. and B. Nalebuff (1984) 'Dragon slaying and ballroom dancing: The private supply of a public good', *Journal of Public Economics* 25: 1-12.
- Brandts, J., D. Cooper and E. Fatas (2007) 'Leadership and overcoming coordination failure with asymmetric costs', *Experimental Economics* 10: 269-284.
- Brandts, J. and C. Holt (1995) 'Limitations of dominance and forward induction: Experimental evidence', *Economics Letters* 49: 391-395.
- Camerer, C. (2003) *Behavioral Game Theory: Experiments in Strategic Interaction* Russell Sage Foundation.
- Chamley, C. (2003) *Rational Models of Economic and Social Learning* CUP.
- Cooper, R. (1999) *Coordination Games* CUP.
- Cooper, R. D. DeJong, B. Forsythe, and T. Ross (1989) 'Communication in the Battle of the Sexes Game', *Rand Journal of Economics* 20: 568-587.
- Cooper, R. D. DeJong, B. Forsythe, and T. Ross (1993) 'Forward induction in the Battle-of-the-Sexes Games' *American Economic Review* 83: 1303-1316.
- Couzin, I. D., J. Krause, N. Franks and S. Levin (2005) 'Effective leadership and decision-making in animal groups on the move', *Nature* 433: 513-516.
- Crawford, V. P., U. Gneezy and Y. Rottenstreich (2008) 'The power of focal points is limited: Even minute payoff asymmetry may yield large coordination failures', *American Economic Review* 98: 1443-1458.
- Crawford, V. P. (2001) 'Learning Dynamics, Lock-in, and Equilibrium Selection in Experimental Coordination Games,' in U. Pagano and A. Nicita, editors, *The Evolution of Economic Diversity* (papers from Workshop X, International School of Economic Research, University of Siena), London and New York: Routledge.
- Data, S. and E. Dechenaux (2007) 'Price leadership and firm size asymmetry: An experimental analysis', working paper.
- J. Duffy and E. Hopkins (2005) 'Learning, entry and sorting in market entry games', *Games and Economic Behavior* 51: 31-62.
- Farrell, J. (1987) 'Cheap talk communication and entry', *The Rand Journal of Economics* 18: 34-39.

- Fischbacher, U. (2007) 'z-Tree: Zurich toolbox for ready-made economic experiments', *Experimental Economics* 10: 171-178.
- Fonseca, M., S. Huck and H.-T. Normann (2005) 'Playing Cournot although they shouldn't: endogenous timing in experimental duopolies with asymmetric cost', *Economic Theory* 25: 669-677.
- Fonseca, M., W. Muller and H.-T. Normann (2006) 'Endogenous timing in duopoly: experimental evidence', *International Journal of Game Theory* 34: 443-456.
- Gale, D. (1995) 'Dynamic Coordination Games', *Economic Theory* 5: 1-18.
- Hamilton, J. and S. Slutsky (1990) 'Endogenous timing in duopoly games: Stackleberg or Cournot equilibrium', *Games and Economic Behavior* 2: 29-46.
- Huck, S., W. Muller and H.-T. Normann (2002) 'To commit or not to commit: Endogenous timing in experimental duopoly markets', *Games and Economic Behavior* 38: 240-264.
- Katz, M. and C. Shaprio (1994) 'Systems competition and network effects', *Journal of Economic Perspectives* 8: 93-115.
- Lau, S-H. and V-L. 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.
- Manzini, P., Sadrieh, A., & Vriend, N.J. (2009). On Smiles, Winks, and Handshakes as Coordination Devices. *Economic Journal*, 119: 826-854.
- Ochs, J. (1995) 'Coordination Problems' in J. Kagel and A. Roth (Eds.) *The Handbook of Experimental Economics* Princeton University Press.
- Nosenzo, D. and M. Sefton (2009) 'Endogenous move structure and voluntary provision of public goods: Theory and experiment', CEDEX Discussion Paper No 2009-09.
- Potters, J., M. Sefton and L. Vesterlund (2005) 'After you: Endogenous sequencing in voluntary contribution games', *Journal of Public Economics* 89: 1399-1419.
- Rapoport, A. (1997) 'Order of play in strategically equivalent games in extensive form', *International Journal of Game Theory* 26: 113-136.
- Rapoport, A., D. Seale and E. Winter (2002) 'Coordination and learning behaviour in large groups with asymmetric players', *Games and Economic Behavior* 39: 137-166.
- Santos-Pinto, L. (2008) 'Making sense of the experimental evidence on endogenous timing in duopoly markets', *Journal of Economic Behavior and Organization* 68: 657-666.
- Schelling, T. C. (1960) *The Strategy of Conflict* Harvard University Press.
- Tykocinski, O. and B. Ruffle (2003) 'Reasonable reasons for waiting', *Journal of Behavior and Decision Making* 16: 1-11.
- Van Damme, E. and S. Hurkens (1999) 'Endogenous Stackleberg leadership', *Games and Economic Behavior* 28: 105-129.
- Van Damme, E. and S. Hurkens (2004) 'Endogenous price leadership', *Games and Economic Behavior* 47: 404-420.
- Van Huyck, J., R. Battalio and F. Rankin (2007) 'Evidence on learning in coordination games', *Experimental Economics* 10: 205-220.

Van Vugt, M., (2006) 'The evolutionary origins of leadership and followership', *Personality and Social Psychology Review* 10: 354-371.

Weber, R., C. Camerer and M. Knez (2004) 'First-mover advantage and virtual observability in ultimatum bargaining and "weak-link" games', *Experimental Economics* 7: 25-48.