What It Takes to Coordinate: Road to Efficiency Through Communication and Commitment*

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Abstract

We examine the effects of an asynchronous revision pre-play phase mechanism in coordination games. Using Calcagno et al. (2014), we derive the theoretical conditions under which the efficient equilibrium is unique and we test our theory in the lab. Our results confirm the positive effect of the treatment on coordination on the common equilibrium and moreover, the Pareto efficient one. The results shed new light on Cheap Talk and reveal that a combination of communication and commitment leads to higher welfare.

JEL Classification: C73, C92, P41; **Keywords:** coordination games, revision games, continuous monitoring.

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1 Introduction

Economic situations involving the need for people to coordinate their actions are pervasive in society. For instance, if firms have to make investment decisions, but their returns also depend on the amount invested by other firms, coordination failure may limit economic activity with all firms choosing a sub-optimal investment level (see Rosenstein-Rodan (1943)). A common feature of coordination games is the existence of multiple Pareto ranked equilibria, and thus it is crucial for players to not only coordinate on a common action profile, but also to coordinate on the best action profile.

Much attention has been devoted to the efficiency loss in coordination games that results from miscoordination or from coordination on sub-optimal equilibrium. Experimental evidence[1] highlights that the efficiency loss resulting from miscoordination pales in comparison to the one resulting from coordinating on sub-optimal equilibrium. Recent research has focused on how different institutions can lead to the coordination on a better equilibrium, and a key point has been the introduction of communication among players. On one hand, some experimental evidence suggests that communication among players may increase efficiency, by increasing coordination on the optimal action profile. On the other hand, there are other cases where communication has no significant effect.[2] However, given that the introduction of communication not always impacts the set of equilibria, it is not clear how or why communication would help players coordinate on the Pareto dominant equilibrium.

Calcagno et al. (2014)[3] propose a different communication protocol, and show theoretically that it selects the Pareto dominant equilibrium as *the unique equilibrium* of a coordination game. The protocol consists of introduction of an asynchronous revision pre-play phase in which a player can change chosen action at some random times, and only the strategy chosen in the last instant is payoff relevant. In contrast to the idea of Focal Point, or Cheap Talk,[4] the introduction of a pre-play phase directly affects the set

[1] See Cooper (1999), Devetag and Ortmann (2007) for a review on coordination games, with both theoretical and experimental evidence.

[2] There are some communication protocols, for instance, one-way communication or public announcements, that have been documented to increases coordination. While, other protocols, for example, two-way communication or private advice have lead to coordination failures (see Cooper et al. (1992), Chaudhuri et al. (2009), Charness (2000), Blume and Ortmann (2007), Burton and Sefton (2004), Feltovich and Grossman (2014)).

[3] See also Kamada and Kandori (2009), where the authors first introduce and define revision games.

[4] Focal Point is one particular equilibrium that players will tend to play, given that it seems natural, or special, to them (see Schelling (1980)). While Cheap Talk is the capacity of players to communicate in a non-binding way (see Farrell (1995), Farrell and Rabin (1996) and Crawford (1998)).

of equilibria and the Pareto dominant equilibrium of the coordination game becomes the unique equilibrium.

In this paper, we experimentally investigate the efficacy of the introduction of asynchronous revision pre-play communication protocol in improving payoffs in coordination games (we call treatment without pre-play phase *baseline* and with pre-play phase *revision mechanism*). We embed a revision mechanism into a minimum effort game, where players can observe actions of all their group members in real time.[5] The pre-play phase starts off with all group members choosing an initial action, which, if an opportunity arises, they can revise during a preparation period of sixty seconds. Revision opportunities are awarded randomly to each group member according to independent Poisson distributions.[6] At the end of the pre-play phase, the actions most recently revised are played out, thus, as the deadline approaches players are becoming more committed to their choices. In standard Cheap Talk protocols, sent messages have no binding effect on taken actions, while in the revision mechanism setup, the message may become the final choice with some positive probability. Consequently, unlike Cheap Talk, messages in the pre-play phase directly impact final choices, hence, payoffs.

We show that, as predicted by the theory, the introduction of the revision mechanism increases coordination on the Pareto best equilibrium. Actions chosen in the treatment with pre-play phase are significantly higher than in the treatment without the pre-play phase. Furthermore, our results suggest that miscoordination in the revision mechanism treatment is essentially nonexistent as variation in chosen action decreases over periods and is almost absent towards the end. As for efficiency, we calculate the loss by comparing average payoffs earned by our subjects in both treatments compared to the maximum possible payoff. In every period, subjects earn significantly more in the treatment with pre-play phase than without it. Moreover, the revision opportunity treatment is able to restore more than half of the welfare lost in the baseline.

The introduction of an asynchronous revision pre-play phase to the game increases the coordination on the efficient equilibrium profile. To further understand why this protocol improves coordination, we examine the forces behind our main treatment. The Revision Mechanism combines two components: *(i) communication* and *(ii) commit-*

[5] We have summarized information on every group members revision opportunity, every group members posted action and the history of posted actions and revisions in one graph changing over time.

[6] Probability of two group members receiving revision opportunity in the same instant is zero–hence, revisions are asynchronous.

ment. During the pre-play phase, players publicly *communicate* their intended actions, and can change the chosen action when a revision opportunity arrives. The action chosen at the end of the countdown is the action played. Thus, as the deadline approaches, players effectively *commit* to their chosen action. To separate the importance of both components we run an additional treatment, Cheap Talk, where the pre-play revision mechanism is non-binding. Such treatment is identical to the Revision Mechanism except that the action chosen at the end of the countdown is not binding. After the end of the countdown, agents are asked to choose a strategy to be played and get payed based only on that choice . Our results reveal the importance of both communication and commitment for better coordination, as the efficiency loss is significantly smaller in the Revision Mechanism compared to the Cheap Talk treatment.

The Revision Mechanism presented and tested in this paper can be interpreted in two distinct ways. First, it can be understood as a dynamic coordination game in which agents have to prepare their actions and these preparations cannot be changed instantaneously. On the other hand, one can interpret this extended game—including the revision opportunities—as a mechanism to implement the efficient outcome.

Following the first interpretation, the Revision Mechanism is a more realistic depiction of real world coordination settings: before taking an action players have to prepare it. For instance, consider firms investing in a joint project. It is natural to think that the investment is more profitable for a firm when the investments made by other firms are higher. Also, even though there is a deadline for the investments to be made, firms communicate and plan their investments for a long time. While firms make preparations, it is often the case that those preparations cannot be changed in an instant or sometimes cannot be altered at all due to administrative procedures, obligations to other projects, among other reasons. Thus, adjustments can only be made if an opportunity arises.

A distinct interpretation for the pre-play phase is the mechanism design approach: the revision mechanism is not something that is already in place, but a mechanism a central planner could introduce to improve efficiency. Our result on significant increase of coordination on the Pareto optimal equilibrium suggests a possible policy that can be implemented to reduce inefficiency in coordination settings. The inability to coordinate investments could significantly constrain economic development (see, for example, Murphy et al. (1988)) and a government can implement the Revision Mechanism, increasing the coordination on a higher investment equilibrium, and raising welfare. This provides support for Big Push theories (for instance, see Kremer (1993), Rosenstein-Rodan (1943), and Bond and Pande (2007)), however—in contrast to standard Big Push arguments—the government does not need to make big investments, only needs to provide a solid environment, and a credible and binding pre-investment mechanism. Our paper highlights this interpretation, as it shows that implementing the Revision Mechanism leads to higher efficiency than simply letting players communicate before taking an action, as in Cheap Talk.

The rest of the paper is organized in the following way. Section 2 includes an overview of the literature. In Section 3 we introduce our model and the proposition. Section 4 states our implementation of the theory – experimental design. In Section 5 we report our results. Finally, Section 6 concludes the paper.

2 Literature Review

Consider the following minimum effort game: a group of workers have to simultaneously decide how much effort to exert in a joint project. Each worker's payoff depends negatively on her effort choice and positively on the minimum effort exerted by her group members. The rate of return on group minimum effort more than compensates individual investment cost. However, since exerting effort is costly, a player would never like to invest more effort than the minimum effort chosen by the group members. Therefore, as long as all members of the group are choosing the same effort, no player has any incentives to change their effort choice. The minimum effort game presents multiple equilibria, furthermore, there are as many equilibria as there are possible effort choices.

The minimum effort game was first studied in an experimental setting by Van Huyck et al. (1990),[7] where subjects played the game multiple times and after every round they were informed about the minimum effort chosen in their group. The choice of effort presented a clear pattern, declining as rounds progressed and converging to the minimum effort.[8]

The convergence to the Pareto-worst equilibrium led to a rise of a literature, trying to examine robustness of this result to different settings. Treatments range from introducing continuous choices of efforts to group bonding activities preceding the actual game.[9] More aligned with our work are treatments that focus on monitoring group

[7] They consider a game where players choose an effort in the set $E = \{1, 2, 3, 4, 5, 6, 7\}$, and with payoff function $\pi_i(e) = 0.6 - 0.1e_i + 0.2 \min_j\{e_j\}$. Such stage game was repeated 10 times.

[8] This suggests a pattern of risk-dominance selection. For instance, see Carlsson and Van Damme (1993) and Cabrales et al. (2007) for theoretical and experimental evidence.

[9] See Goeree and Holt (2005), Chen and Chen (2011), Bornstein et al. (2002), Weber (2006), and Bern-

members' choices, or communicating their choices to each other. Some treatments proposed in the literature have proven successful in facilitating higher frequency of coordination on the Pareto dominant equilibrium. However, the absence of a theoretical foundation for the treatment choices, makes it difficult to identify the forces leading to better cooperation. In this paper, we provide a theory based treatment, highlighting the importance of communication and commitment in fostering cooperation towards the Pareto dominant equilibrium.

The impact of different monitoring structures on equilibria selection in coordination games has been a point of contention in the literature. Van Huyck et al. (1990) and Devetag (2005) find that better ex-post monitoring devices fail to facilitate coordination on the payoff dominant equilibrium, while Berninghaus and Ehrhart (2001) and Brandts and Cooper (2006) find a positive relationship between ex-post monitoring and coordination on the payoff dominant action profile. In our paper we introduce asynchronous revision pre-play communication phase and show both theoretically and experimentally its positive effect on coordination. A similar extension that has been studied in a minimum game experimental setting is the introduction of a pre-play communication device. Such communication can be *costly*, *costless* or in the form of *intergenerational advice*.

Van Huyck et al. (1993) and Devetag (2005) consider a *costly* form of pre-play communication, a pre-play auction each round, and conclude that such extension enables the players to achieve coordination on the payoff dominant profile. The result agrees with the theoretical prediction, by Crawford and Broseta (1998), that such pre-play costly communication allows the players to use forward induction to coordinate on the best equilibrium profile.

More aligned with our work, Blume and Ortmann (2007) examine an introduction of simultaneous *costless* pre-play communication. Prior to each stage game players were asked to send a message (a number between 1 and 7) indicating how much effort they intended to exert. After observing messages from all group members players had to choose payoff relevant effort levels. In contrast with our main treatment, the messages were cheap talk - not binding in any way. The main result of the paper is that the pre-play cheap talk communication increases coordination on the dominant equilibrium. Observe that, since messages are non-binding, there is no theoretical argument for why cheap talk communication should impact the set of equilibria. In

inghaus and Ehrhart (1998) for how different treatments—from growing group sizes to inter-group competition—affect coordination.

contrast, in the revision mechanism treatment of this paper the message becomes an action and this commitment directly impacts the set of equilibria. Moreover, introducing the revision mechanism reduces the set of equilibria to a singleton containing only Pareto-best action profile. This paper sheds new light on the result in Blume and Ortmann (2007), since we can test the difference between the revision mechanism with and without commitment. Our results suggest that both communication and commitment are important in promoting coordination on Pareto best equilibrium as the efficiency loss in the cheap talk treatment is significantly higher than in the revision mechanism treatment.

Finally, Chaudhuri et al. (2009) introduce *intergenerational advice* as a coordination device. The game is played by non-overlapping generations of players, who can pass on advice to their successors in the game. The paper analyzes different levels of common knowledge of the advice. "High quality" public announcements are shown to induce higher levels of coordination on payoff dominant equilibrium. However, if advice is not sufficiently strong the coordination is very sensitive to the manner of announcement distribution.

The paper by Deck and Nikiforakis (2012) is the first to study interim real-time monitoring in a minimum effort game.[10] Players have exactly one minute to choose an action, and—in contrast to our paper—can switch it at any time. Depending on the monitoring structure, a player's movements might be observed by all players or by only a subset of them. The effort choice at the end of the period is used to determine payoffs. The authors examine various interim monitoring structures, and although there is no difference in the equilibrium set implied by each one of them, they conclude that—only if all players observe everybody's action choices—perfect monitoring increases the coordination on the payoff dominant equilibrium. In Leng et al. (2016), perfect monitoring also increases coordination, even though players' payoffs are determined at each instant. In our paper actions can only be changed when a revision opportunity is awarded, thus at any instant there are two different data points per player: (i) the action the player is currently committed to (that is being observed by all other players), and (ii) the action currently selected by the player. Only after a revision opportunity is awarded, the selected action becomes the action the player is committed to. Our results show that there is more to be done to increase coordination on payoff dominant equilibrium. By comparing Cheap Talk and Revision Mechanism

[10] Real-time monitoring and revisions in a voluntary contributions game was first discussed in Dorsey (1992).

treatments, we show that not only communication, but also commitment, plays an important part in increasing efficiency. This difference is aligned with theoretical results by Calcagno et al. (2014) highlighting the importance of asynchronous revision to the selection of payoff dominant equilibrium.

3 Model

Consider the following normal-form game $(I, (E_i)_{i\in I}, (\pi_i)_{i\in I}))$ in continuous time $-t \in [-T, 0]$, where I is a set of players, E_i is a set of effort levels and $\pi_i(e) = \gamma + \alpha \cdot \min_{j\in I} e_j - \beta \cdot e_i$ is a payoff function for player i.[11] The normal-form game is played once and for all at time $t = 0$. At $-T$ players simultaneously choose an initial action and post it. Between $-T$ and 0 players independently obtain revision opportunities, according to a Poisson process with arrival rate $\lambda_i > 0$, at which point they can change their previously chosen action. At $t = 0$ the action posted is taken and each player receives the payoff that corresponds to it.

Note that a one shot component of the above-mentioned game, i.e. the minimum effort game, has *multiple equilibria*. As long as all players are playing the same pure strategy, it is a Nash equilibrium. However, under certain conditions, all of the dynamic revision minimum effort game equlibria results in the same payoff and last instant actions of the *Pareto-best equilibrium* of the one shot game.

A public history is a sequence of posted actions and the history of revision opportunities for each group member, $\mathcal{H}_t = \big\{\{e_\tau\}_{\tau\in[-T,t)}, \{r_\tau\}_{\tau\in[-T,t)}\big\}$, where $e_\tau = (e^1_\tau, ..., e^{|I|}_\tau)$, $e^i_\tau \in E_i$ and $r_\tau = (r^1_\tau, ..., r^{|I|}_\tau)$, $r^i_\tau \in \{0, 1\}$. Let $\mathcal{H} := \cup_{t\in[-T,0]}\mathcal{H}_t$ be a set of all possible public histories. A history for player i at time t is $h_i(t) = \{(e_\tau, r_\tau)\}_{\tau\in[-T,t]} \in \mathcal{H}_t$. A strategy for player i is a mapping $\sigma_i : \mathcal{H} \to \Delta(E_i)$.

We apply Theorem A.2 from Calcagno et al. (2014) to a minimum effort game vide supra and summarize the statement in the following Proposition.

Proposition. *In an Asynchronous Revision Minimum Effort Game, if*

1. $\alpha > (n-1)\beta$ *(return on investment are sufficiently higher than the cost) and*

2. $r_i = 1/n, \forall i \in I$ *(revision opportunities are equally distributed amongst all players),*

then there exists $T' > 0$ such that for all $T > T'$, the unique revision equilibrium (SPE) has $e_0 = \max E_i$ with probability 1.

[11] In our experiments we take $I = \{1, 2, ..., 6\}$, $E_i = \{1, 2, 3, 4, 5, 6, 7\}$ and $\pi_i(e) = .18 - .04 \cdot e_i + .2 \cdot \min_{j\in I} e_j,\ \forall i \in I$.

Proof of the Proposition 1 is in the appendix A, however, note that our contribution is the result of basic algebra. Nevertheless, the original proof of Theorem 2 from Calcagno et al. (2014) is very intuitive and appeals to relevant ideas for the discussion in this paper. First, note that if all player are choosing the maximum effort at a given instant, there is no reason for any player to ever deviate from it. Thus, all players choosing the maximum effort since the beginning is one equilibrium of the dynamic game. Let's now provide intuition for why it is the unique one. Consider at a given instant, far removed from the deadline, all players but one are choosing the maximum effort (only one player is choosing a different effort). That particular player has the incentive to change her effort choice to the maximum effort, since if she does so her payoff will increase (Her payoff will change to the maximal payoff possible). If there is enough time before the deadline (and revision opportunities are quite common), it is beneficial for the other players to continue choosing the maximal effort, waiting for that particular player to have a revision opportunity. Now, consider that, at a given instant all players but two are choosing the maximum effort. If one of the players that is not choosing the maximum effort receives a revision opportunity, she should revise her effort to the maximum effort, since she will induce the other player to follow her footsteps as described above. That is, she will revise her action because she knows that this will lead to the other player revising his. If revision opportunities are frequent enough for all players, the argument above unravels all other equilibria candidates, as one player changing her effort choice puts in place a chain of events leading to all players choosing the highest effort level.

We design an experiment to closely replicate the conditions of our setup and test the power of pre-play mechanism in aiding coordination. To do so, first let's recognize key challenges and our proposed resolutions. The game is set in continuous time[12] and players need to have perfect information in continuous time. Every team members' revision opportunity, every team members' posted action and access to the history of posted actions and revisions should be available to all players at all times. To put all this information together and make it easily understandable to our subjects we create a graph that summarizes all the key points. We put seconds on x-axes and effort choices on y-axes. All team members have different colors representing their actions. Every time a player receives a revision opportunity a dot shows up on the player's action line

[12] See Friedman and Oprea (2012), Bigoni et al. (2015), and Leng et al. (2016) for recents studies implementing continuous time in the lab. We would like to thank Bigoni et al. (2015) and Friedman and Oprea (2012) for sharing their code with us.

(see Figure 1). A more detailed explanation of our graph and the whole experiment is given in the next section.

4 Experimental Design[13]

The experimental sessions were conducted at the Center for Experimental Social Science (CESS) laboratory at New York University (NYU), using the software z-Tree (Fischbacher (2007)). All participants were NYU students. The experiment lasted about 45 minutes and, on average, subjects received $\$17$ for their participation. The experiment consisted of three different treatments run with different subjects. In each session written instructions were distributed to the subjects and instructions were read out loud.

Participants were randomly divided in groups of six, and they made a sequence of ten decisions as a part of that group. Each group played the minimum effort game with effort levels ranging from 1 to 7 and the payoff function: $\pi_i(e) = .18 - .04 \cdot e_i + .2 \cdot \min_{j \in I} e_j$. The payoffs were described to subjects in matrix form and they were given a short comprehension test to ensure they understood the payoff structure. After ten periods, subjects took a short demographic survey and there were paid the final payoff, which was the sum of payoffs from all ten periods and the show up fee.

In each of three treatments, the period information was different. Let's describe the rules of each treatment one at a time.

Treatment 1 (Baseline)

After every period of playing standard one shot minimum effort game, participants were given a feedback on the minimum number chosen in their group in that period. This was the only history available to the subjects in the baseline treatment.

Treatment 2 (Revision Mechanism)

Every member of the group chose an integer from 1 to 7. Once everybody had made their choice the graph appeared as in Figure 1[14] and a 1-minute countdown began. In Figure 1, the time in seconds is on the horizontal axes and the number chosen by each of the group members on the vertical axes. The initially picked numbers are placed along the vertical line above the zero second mark. Every player is represented in the graph with different colors.

As the countdown progressed every member of the group could change the number

[13] Instructions used in our experiment can be found in Appendix E, F and G.

[14] We explained the graph in greater detail in the Instructions, in Appendix F, and all subjects had a short comprehension test regarding the graph.

chosen at any time, by placing the cursor on the desired number on the left side of the screen. When a subject had chosen a number, it would light up as the number 4 is on Figure 1. The number posted on the graph would only get updated if a revision opportunity was awarded to the player and if this player had changed the choice.

Revision Opportunities: Every second a revision opportunity was awarded to the group with probability $.8$. When a revision opportunity was awarded to the group, it was given to one of the six group members, with equal probability of $1/6$. The chance of any member of the group having a revision opportunity at any second was, thus, equal to approximately 13%.

Only the numbers posted at the end of the countdown mattered for the payoff. The numbers initially picked and all the revisions were payoff irrelevant.

Let's take a closer look at player Green's actions, who's screen we are observing on Figure 1. Along the vertical line above the zero second mark we see a green dot in the interval 2, thus, the initial choice of green player was action 2. A dot on the green line at 5th second mark means that a revision opportunity was awarded to the player Green and as the action after that hasn't been updated—the player Green hadn't changed intended action, still choosing 2. At 15 second mark we see a shift of the green line from the action 2 interval to the action 6 interval. This implies that in the 15th second the player Green had chosen the action 6, thus when the revision opportunity was awarded to the her, the action switched from 2 to 6. And at about 25 second mark there is a green dot on the line notifying that a revision opportunity was awarded but it wasn't used as the green line is still at the interval 6.

On 30th second mark, one can observe every group members current posted actions. Players Green and Blue are at action 6, Purple is at 5, players Light blue and Orange are at action 3 interval and Yellow is at 1. Thus, the current minimum action is 1. Note that on the left side of the graph in Figure 1 that the number 4 is colored in green. This implies that the player who's screen we are observing has switched her intended action from 6 to 4, however, the revision opportunity hasn't arrived yet, thus, the posted action on the graph is still action 6. At every second we collect data on both every player's intended action as well as every player's posted action.

Figure 1: Sample Screen After 30 Seconds

Treatment 3 (Cheap Talk)

Revision Mechanism combines two main forces to promote cooperation. First, it allows agents to communicate their intended actions publicly to each other. Second, it provides a partial commitment to the actions communicated. To separate these two forces we run the Cheap Talk treatment. Treatment 3 follows Treatment 2 protocol, without commitment, i.e. the 1-minute countdown is payoff irrelevant. After the countdown ends, a new screen appears and subjects choose an integer from 1 to 7 as in the Baseline treatment, and get paid accordingly.

Table 1 summarizes our experiment treatments, number of sessions and subjects.

Table 1: Experimental Design

Treatment	Sessions[15]	Task	No. of Subjects
Treatment 1	1-2	Baseline	36
Treatment 2	3-5	Revision Mechanism (RM)	36
Treatment 3	6-8	Cheap Talk (CT)	36

5 Results

In this section, we present our experimental results and shed light on the effects of the introduction of the Revision Mechanism. Let's begin analyzing our data by a simple

[15] One session of Treatment 1 was voided as one of the subjects publicly announced his intended action, and asked others to play the same.

table showing the minimum effort choice by every group in the last period of both Baseline and Revision Mechanism treatments, Table 2. As we see from Table 2, two treatments result in very different outcomes: group minimum effort for 5 out of 6 groups is either 6 or 7 (the maximum possible effort level is 7) for the Revision Mechanism treatment, while no group in Baseline treatment coordinated on an effort level higher than 5. Furthermore, the observations from the Revision Mechanism first order stochastically dominate the observations from the Baseline treatment.

Table 2: Last Period Minimums in Descending Order

Revision Mechanism (RM)	7	7	7	6	6	1
Baseline Treatment (BT)	5	5	3	3	3	1

Table 2 suggests a significant difference between the equilibrium played in the Revision Mechanism and in the Baseline treatment. In the rest of the section, we report different test results to emphasize the statistical difference that is at the core of Table 2. Indeed, all of the tests conclude in the same direction: the introduction of a pre-play phase with asynchronous revision opportunities significantly increases the coordination on the Pareto optimal equilibrium, leading to higher payoffs, as predicted by Calcagno et al. (2014).

First, we focus on the efficiency loss, comparing the Revision Mechanism and the Baseline treatments. Deviations from the efficient equilibrium—all players choosing the Pareto optimal equilibrium profile—reduce efficiency in two distinct ways. First, through miscoordination from the minimum effort, as some players do not respond optimally to other players efforts; and second, through the inefficient minimum effort chosen, which affects all players payoffs. The average payoff function combines both forces, and is thus a good measure of efficiency. Figure 2a presents average payoff over periods for two treatments. Average payoff in Revision Mechanism treatment is significantly higher than average payoff in Baseline treatment at $p < 0.01$. In every period, subjects earn more in Revision Mechanism than in Baseline treatment. In addition, as periods proceed, we see Revision Mechanism treatment leading to higher payoffs, while average payoff in Baseline treatment stays essentially the same. Furthermore, subjects' Revision Mechanism average payoff is 78% of the efficient payoff,[16] while the Baseline treatment is only 53%. Thus, the introduction of the Revision Mechanism treatment was able to restore more than half (54%) of the efficiency lost in the Base-

[16] If all players choose the maximum effort, each player receives $\$1.3$ per period

line treatment. Comparisons of the average payoff of the Revision Mechanism and the

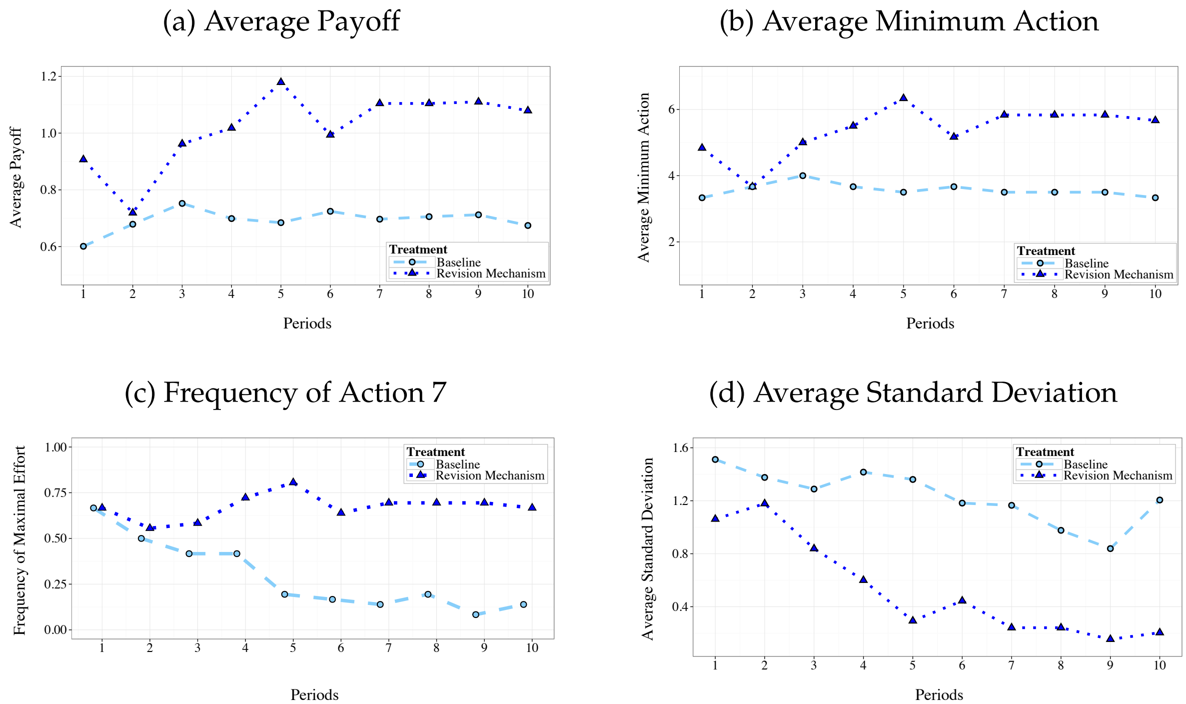

Figure 2: Baseline vs Revision Mechanism Treatment

Baseline treatments highlight that the efficiency loss is significantly smaller in the first. The introduction of a pre-play phase increases players' payoffs, approximating it to the efficient outcome. However, the previous analysis sheds no light over how players actions are affected by the introduction of a pre-play phase. To separate the effects of (i) the increase in coordination in a particular equilibrium, and (ii) the increase in coordination in the optimal equilibrium, that are jointly combined into the payoff increase, we compare actions chosen in Baseline and Revision Mechanism treatments.

We start by analyzing the average minimum efforts. Figure 2b depicts the average minimum action across groups for different periods. The average minimum action chosen in the Revision Mechanism is significantly higher than in the Baseline treatment at $p < 0.01$.[17] Furthermore, note that minimum actions in Revision Mechanism treatment are increasing over periods, which is not observed in Baseline Treatment.

Let us proceed by examining the frequencies of maximal effort, action 7, over 10 periods. Figure 2c summarizes our results. Both the Revision Mechanism and the Baseline treatments start in the first period at the same frequency of maximum effort (around 70%). However, the frequency with which the Pareto optimal equilib-

[17] Group level analysis can be found in Appendix C.

rium effort is chosen in Baseline treatment rapidly decreases over time, while Revision Mechanism frequency stays virtually the same. The difference between both treatments increase over time, and in the last period players in the Revision Mechanism play the maximum effort almost five times more often than players in the Baseline treatment. Finally, we test the null hypothesis of equal distributions of effort choices in Baseline and Revision Mechanism treatments in every period. Hypothesis is rejected using non-parametric test, Wilcoxon–Mann–Whitney (WMW, Wilcoxon (1945), Mann and Whitney (1947)) test, at $p < 0.01$ after Period 4. Figure 4 in Appendix B provides the p-values of two non-parametric tests for different periods.[18]

Our central result is that the introduction of a pre-play phase, in which agents can revise their chosen actions—our Revision Mechanism—reduces the efficiency loss observed in the Baseline treatment. This implies that agents have significantly higher payoffs in the Revision Mechanism than in the baseline treatment. An important part of the payoff difference can be attributed to the fact that agents play higher effort strategies in the first than in the latter. The introduction of the Revision Mechanism increases the coordination on a higher minimum effort and also the minimum effort is not declining over periods.

We now proceed to establish that the Revision Mechanism treatment provides more coordination on any particular equilibrium than the Baseline treatment. To examine this statement we calculate standard deviation of actions in every period for each group in both treatments and average it over groups, as displayed in Figure 2d. Higher standard deviations imply a higher degree of miscoordination among players of the same group, with players choosing very distinct action. As we see in Figure 2d, average standard deviation in the first few periods of both treatments are similar, and as periods progress both standard deviations decrease. However, notice that the standard deviation in Revision Mechanism is always below the one in the Baseline Treatment, and in addition, after Period 5 miscoordination in the Revision Mechanism is essentially nonexistent.

Cheap Talk Analysis

To understand why Revision Mechanism improves both the individuals ability to coordinate and the actual strategy profile players coordinate on, we examine the forces behind our main treatment. The Revision Mechanism combines two distinct forces:

[18] Effort levels are discrete and thus, when we use Kolmogorov-Smirnov test goodness-of-fit is conservative.

first, it improves players capacity to communicate what their chosen actions will be, and second it makes players commit to their words. During the pre-play phase, players publicly communicate their intended actions, by choosing an action and publicizing it. However, players can change the chosen action only if and when a revision opportunity arrives, and the action chosen at the end of the countdown is the action played. Thus, as the deadline approaches, players effectively commit to their chosen action. To understand the relative importance of each of these forces in promoting coordination on Pareto better outcomes, we run the Cheap Talk treatment, where the pre-play revision mechanism is non-binding. The results are discussed below.

First, we focus on the importance of communication—introduced in the Cheap Talk treatment—to achieve a better coordination on Pareto dominant outcomes. Table 3 presents the group minimum effort in the last period for both the Cheap Talk and Baseline treatments, and show that the two treatments result in very different outcomes.

Table 3: Last Period Minimums in Descending Order

Cheap Talk (CT)	7	6	6	5	4	2
Baseline Treatment (BT)	5	5	3	3	3	1

Table 3 shows that the group minimum effort is higher in the Cheap Talk, with only three out of six groups having a minimum effort of 5 or lower (while all groups have a minimum effort of 5 or lower in the Baseline).[19] On average, Cheap Talk implies higher minimum effort in contrast with Baseline treatment, and the test of null hypothesis of equality of minimum efforts is rejected at $p < 0.01$. We also test the null hypothesis of equal distributions of effort choices in these two treatments in every period and the null hypothesis is rejected using WMW test at $p < 0.01$ after Period 5 (see Figure 5 in Appendix B).

Communication among players—as introduced by the Cheap Talk treatment— significantly increases the minimum effort chosen. This suggests that communication is indeed an important part of how the Revision Mechanism works to promote coordination on Pareto better outcomes. However, that only answers part of our question. Next, we try to understand the importance of commitment for how the Revision Mechanism works to promote coordination. We first focus on the average minimum action of each period, for each of our three treatments, displayed in Figure 3b. Figure 3b shows that, although the average minimum action chosen in the Cheap Talk is significantly higher

[19] However, it is worth noting that only one group had a minimum effort lower than 6 in the Revision Mechanism treatment.

than in the Baseline treatment, it is also significantly lower than in the Revision Mechanism. Indeed, the test of the null hypothesis of equality of minimum efforts is rejected at $p < 0.05$. This difference suggests that the introduction of commitment also plays a role in how Revision Mechanism increases the average minimum effort played.

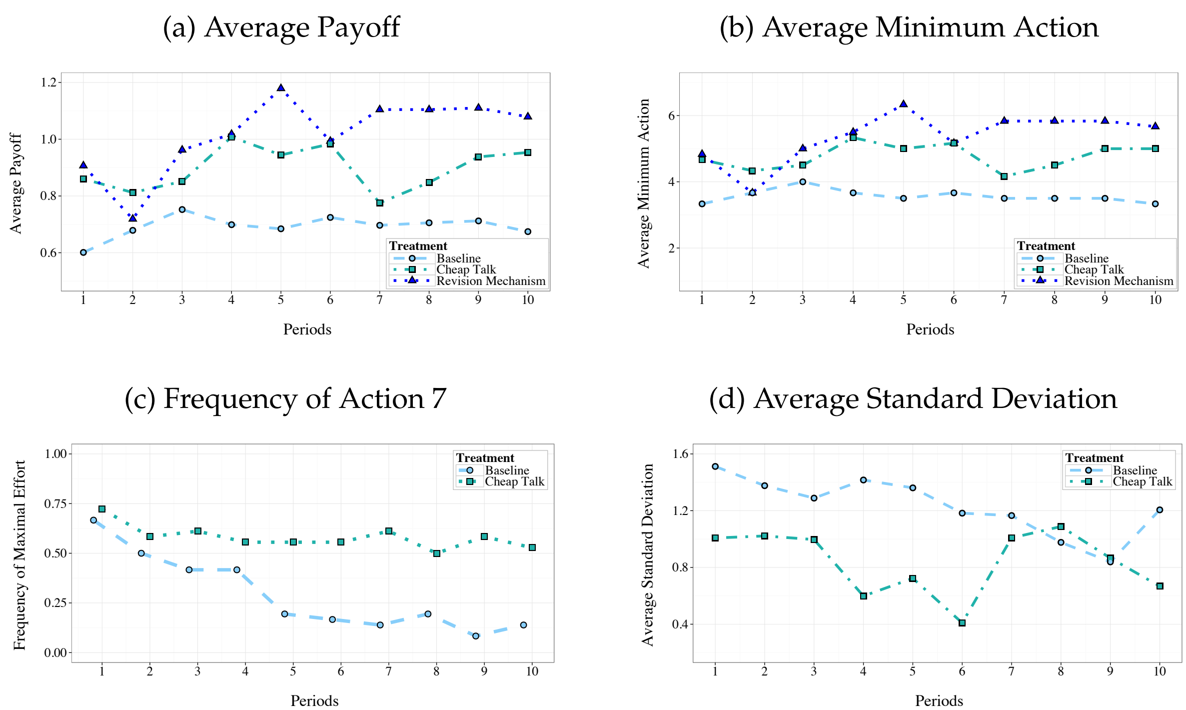

Figure 3: Treatment Comparisons

We can also shed light on the importance of commitment by analyzing how the different mechanisms affect coordination on a strategy profile. As discussed in Figure 2d, the introduction of the pre-play revision phase in the Revision Mechanism drastically reduces miscoordination: the Average Standard Deviation of actions played decreases as periods progress, and it converges to zero in the last periods. Figure 3d compares the Average Standard Deviation of the actions played in the Baseline and in the Cheap Talk treatments. It shows a very different picture. Not only there is no clear declining pattern of standard deviation of actions played, but it doesn't seem to stabilize. Indeed, although the standard deviation is initially smaller in the Cheap Talk than in the Baseline treatment, in the last periods they are similar. This implies that the Revision Mechanism promotes higher degrees of coordination than the Cheap Talk treatment, highlighting the importance of commitment.

Let us finish the analysis of our experimental results by comparing the efficiency loss (measured by the average payoff) associated with each treatment. The efficiency loss encompass both analysis done above, as both a smaller minimum action and players miscoordination decreases efficiency. Figure 3a displays the average payoff of all players of each treatment in each period. The average payoff in Revision Mechanism treatment is significantly higher than the average payoff in Baseline treatment, at $p < 0.01$, and it is also significantly higher than the average payoff in Cheap Talk treatment, at $p < 0.05$. In addition, as periods proceed, we see the Revision Mechanism treatment leading to higher payoffs, while the average payoff in both the Baseline and the Cheap Talk treatment stays essentially the same. The comparison shown in Figure 3a reveals the importance of both communication and commitment to increase coordination on better outcomes, as promoted by the Revision Mechanism. This result highlights the policy implications associated with the Revision Mechanism: the introduction of an asynchronous revision pre-play phase promotes significantly more coordination on a Pareto best equilibrium than Cheap Talk.

6 Concluding Remarks

In this paper we provide experimental evidence shedding light on how the introduction of an asynchronous revision pre-play phase increases the coordination on Pareto superior outcomes in a minimum effort game. The Revision Mechanism tested in this paper is inspired by the Asynchronous Revision Mechanism of Calcagno et al. (2014), shown to reduce the equilibria set to a singleton—the Pareto dominant equilibrium. As predicted by the theory, we show that the introduction of the Revision Mechanism significantly increases coordination on Pareto best outcome. Also, the average payoff significantly increases with such pre-play phase. There are two distinct sources of payoff inefficiencies in the minimum game: First, players may choose an equilibrium profile that is Pareto dominated by other equilibrium profiles, and second, players may miscoordinate around such equilibrium profile. Our results show that the introduction of an asynchronous revision pre-play to the minimum game reduces inefficiencies on both dimensions. Not only is the minimum action chosen significantly higher than in the Baseline treatment, but the standard deviation of the actions played is also significantly lower.

Our results suggest the introduction of a Revision Mechanism as a possible policy. In Coordination Games, both miscoordination and the coordination on sub-optimal equilibria generate efficiency loss. A traditional example lies in multiple firms simultaneously investing in a project. For instance, suppose that firms have to make an investment decision such that the level of investments of a firm positively affect the payoff of the others. This paper suggests that the introduction of a pre-play phase, following our Revision Mechanism, by the government significantly increases the investment and the return of the firms. That is, a government can increase the investment level in a coordination game not by investing, but simply creating a more favorable set of rules.

The introduction of a pre-play phase—the Revision Mechanism—contributes to increased coordination in superior outcomes through two distinct forces. First, it allows players to publicly communicate their intended actions, and second it forces players to commit to their strategies as time progresses, since the likelihood of having a revision opportunity diminishes. In order to disentangle these two forces, we run a Cheap Talk treatment, in which players communicate but do not commit to their words. We first show that, as expected, communication is an important force to understand how the Revision Mechanism works. We show that the Cheap Talk treatment significantly reduces the inefficiency when compared to the Baseline treatment, by significantly increasing the minimum action chosen. However, communication is not the only force at play, and commitment also has an important role. We show that the Revision Mechanism leads to significantly higher payoffs to the agents than the Cheap Talk treatment does.

The interpretation of the Revision Mechanism as a policy suggestion is strengthened by the separation above. Even if pre-play communication occurs in real life, the introduction of a set of rules following the Revision Mechanism improves payoffs. That is, even if firms routinely discuss their investment strategies, the government can still increase both investment level and firm returns, by changing the environment surrounding the decisions.

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Appendices

A Proof of Proposition

We need to recall a Definition 1 and Theorem 2 from Calcagno et al. (2014).

An action profile x^* is strictly Pareto-dominant if $u_i(x^*) > u_i(x)$ for all i and all $x \in X$ with $x \neq x^*$. A game is a *common interest game* if it has a strictly Pareto-dominant action profile.

Definition 1 *A common interest game is said to be a K-coordination game if for any i, $j \in I$ and $x \in X$,*

$$\frac{u_i(x^*) - u_i(x)}{u_i(x^*) - \underline{u}_i} \leq K \frac{u_j(x^*) - u_j(x)}{u_j(x^*) - \underline{u}_j}$$

where $\underline{u}_i = \min_x u_i(x)$.

Let the smallest value of r_i be $\alpha = \min_{i \in I} r_i$ and the second smallest value of r_i be $\beta = \min_{\substack{i \in I \\ i \neq j^*}}$, where j^* is an arbitrary member of $\arg\min_{i \in I} r_i$.

Theorem 2 *Suppose that a common interest game is a K-coordination game with the strict Pareto-dominant action profile x^* and*

$$(1 - \alpha - \beta)K < 1 - \beta$$

Then, for any $\varepsilon > 0$, there exists T' such that for all $T > T'$, in all revision equilibria, $x(0) = x^*$ with probability higher than $1 - \varepsilon$.

Now let's proof the Proposition 1 using Theorem 2

Proof. Rewrite the Theorem 2 condition:

$$1 - \min_{\substack{i \in I \\ i \neq j^*}} r_i - K(1 - \min_{i \in I} r_i - \min_{\substack{i \in I \\ i \neq j^*}} r_i) > 0$$

Note that LHS of the condition is maximized when revision opportunities are equal for all players $r_i = r_j = 1/n, \forall i, j \in I$. Substituting $r_i = r_j = 1/n, \forall i, j \in I$ into the condition above yields to $K < \frac{n-1}{n-2}$.

Condition from the theorem sets an *upper bound* on common interest component $K < \frac{n-1}{n-2}$. Now let's rewrite the upper bound on K in terms of minimum game coefficients. To do so, recall minimum effort game payoff function $\pi_i(e) = \gamma - \beta e_i +$

$\alpha \min_{j \in I} e_j$. Using the symmetry of the payoff function we can rewrite the K-coordination game definition as $\pi_i(x^*) - \pi_i(x) \leq K(\pi_j(x^*) - \pi_j(x))$ for any $i, j \in I$ and $x \in X$. The worst case scenario is such that all other players coordinate on some effort e, while one of the players chooses the maximum effort $e_{\max}$. In such a scenario, the expression can be further rewritten as $\gamma + e_{\max}(\alpha - \beta) - (\gamma - \beta e_{\max} + \alpha e) \leq K(\gamma + e_{\max}(\alpha - \beta) - (\gamma - \beta e + \alpha e))$ and simplified to $\alpha(e_{\max} - e) \leq K\,((\alpha - \beta)(e_{\max} - e)$. Finally, we get $K \geq \frac{\alpha}{\alpha - \beta}$ which provides us with a *lower bound* on coordination coefficient. Let's put together upper bound and lower bound on K, $\frac{\alpha}{\alpha - \beta} < \frac{n-1}{n-2}$ which simplifies to $\alpha > (n-1)\beta$. ■

B P-values over Periods

Figure 4: Baseline vs Revision Mechanism

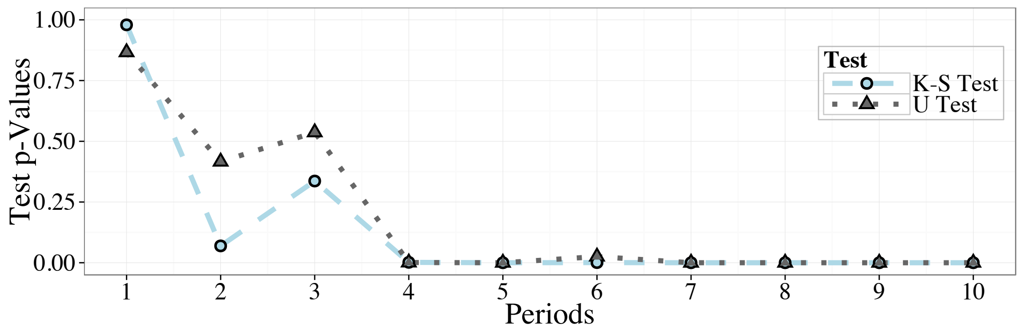
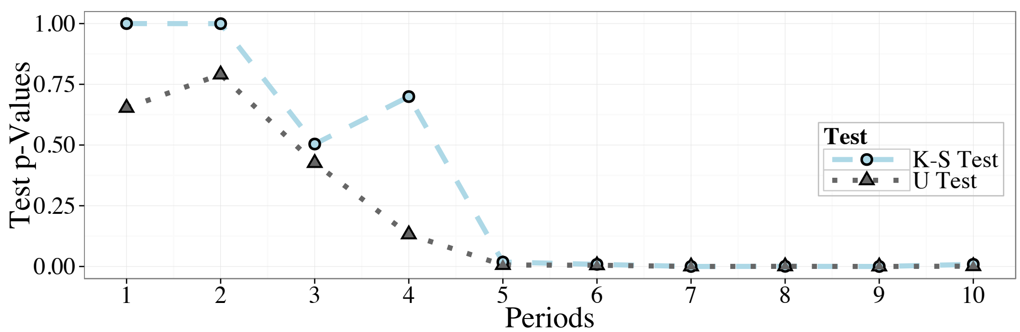


Figure 5: Baseline vs Cheap Talk



C Group Level Analysis

Figure 6: Revision Mechanism Group Minimum

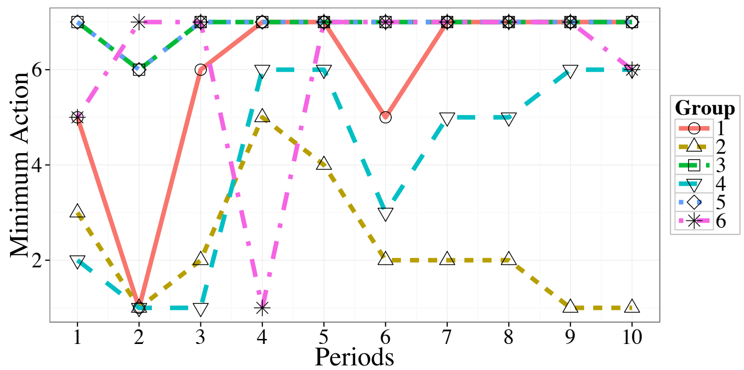


Figure 7: Baseline Group Minimum

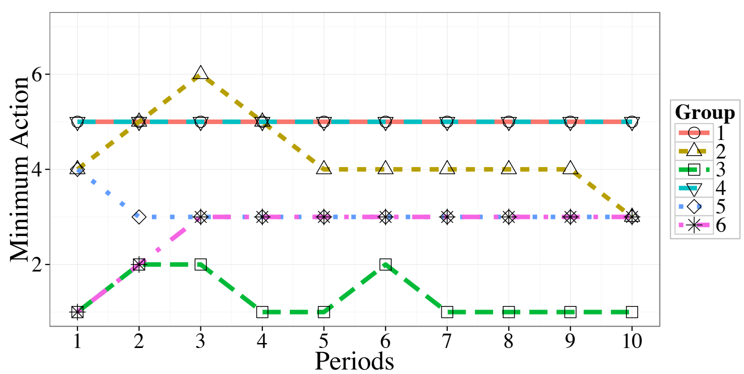
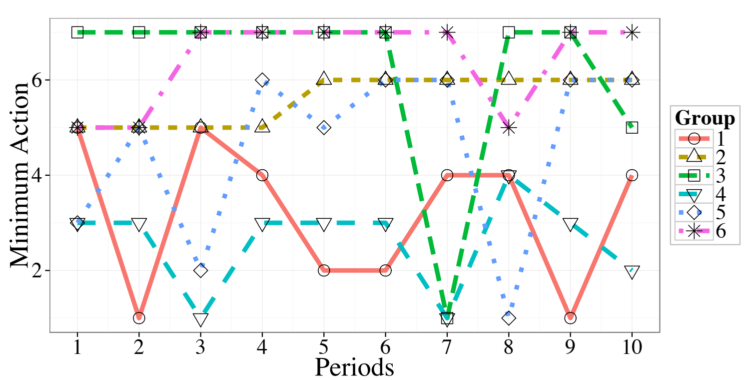


Figure 8: Cheat Talk Group Minimum



D Choice vs Posted Action

Let us evaluate the robustness of our experimental design by examining whether our choices of time interval length and revision probability had impacts over the choices. In order to test that we compare the last instant intended action with the action played. If the time interval was too short, or revisions too infrequent, the players' intended actions would be different than the posted actions, even on the last instant, and agents would have been constrained on their choice process. However, we cannot reject the hypothesis of equal distributions of actions, with a $p = 0.13$. This indicates that our choice of interval length and our choice of revision probability does not bind player's behaviors, aligning our experimental design with the theory in Calcagno et al. (2014).

E Instructions - Baseline

Instructions

This is an experiment in decision making. Funds have been provided to run this experiment. If you follow instructions and make good decisions you may earn a substantial amount of money, that will be paid to you in CASH VOUCHERS at the end of the experiment. What you earn depends partly on your decisions and partly on the decisions of others.

The entire session will take place through computer terminals, and all interactions between you will be done through the computers. Please, do not talk or communicate in any way during the session. Please, turn off your phones now.

You will be randomly divided in groups of **6** persons, and will make a sequence of **10** decisions as a part of that group. After 10 periods, all groups will be disband and the phase will end. This will be the end of the experiment.

Task Description

Each period, you and every member of your group will choose an integer: **1, 2, 3, 4, 5, 6 or 7**. Your choice and the smallest number chosen in your group (**including yours**) will determine your payoff in that period. Table 1 presents your payoffs in all possible scenarios. For example, if you choose number 5 and the smallest number chosen in your group is 4 you will get 78 Cents ($.78).

		Smallest Number Chosen						
		7	6	5	4	3	2	1
Your Choice	7	1.30	1.10	0.90	0.70	0.50	0.30	0.10
	6	—	1.14	0.94	0.74	0.54	0.34	0.14
	5	—	—	0.98	0.78	0.58	0.38	0.18
	4	—	—	—	0.82	0.62	0.42	0.22
	3	—	—	—	—	0.66	0.46	0.26
	2	—	—	—	—	—	0.50	0.30
	1	—	—	—	—	—	—	0.34

Table 1 – Payoff from different actions

Payoffs

Your **final payoff** will be the sum of payoffs from all 10 periods plus the show up fee.

F Instructions - Revision Mechanism

Instructions

This is an experiment in decision making. Funds have been provided to run this experiment. If you follow instructions and make good decisions you may earn a substantial amount of money, that will be paid to you in CASH VOUCHERS at the end of the experiment. What you earn depends partly on your decisions and partly on the decisions of others.

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	3	—	—	—	—	0.66	0.46	0.26
	2	—	—	—	—	—	0.50	0.30
	1	—	—	—	—	—	—	0.34

Table 1 – Payoff from different actions

Once you and all the members of your group have chosen a number, a 1-minute countdown will begin. Only the number posted at the end of the countdown matters for your payoff.

1-minute Countdown

1. *Graph Description*

   Before the 1-minute countdown, you and every member of your group have chosen a number: **1, 2, 3, 4, 5, 6 or 7**. Once every member of your group has made their initial choice, the 1-minute countdown begins.

   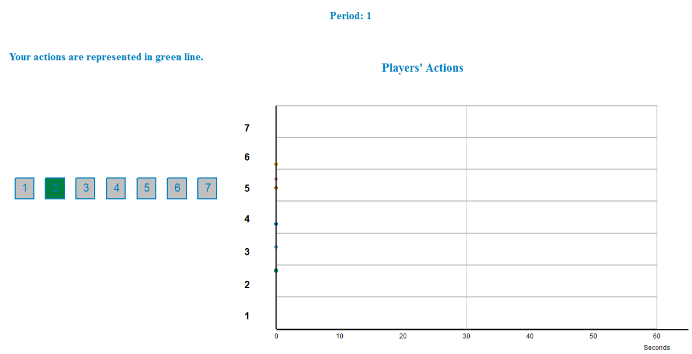

   Figure 1 – Screen-shot of one possible scenario, as soon as the 1-minute countdown begins.

   When the 1-minute countdown begins your screen will appear as in Figure 1. In Figure 1, we have placed time in seconds on the horizontal axes and the number chosen by each of your group members on the vertical axes.

   The initially picked numbers chosen by you and your cohort are place along the vertical line above the zero second mark. You will see the number posted of every participant in your group. For instance, in Figure 1, we see that 2 players have chosen number 5, 1 player has chosen 2, 1 player has chosen 3, 1 player has chosen 4 and 1 player has chosen 6. Your choice is always represented in the graph with the color green, and those of others by other colors. As you can see the player has CHOSEN NUMBER 2.

   As time continues, during the 1 minute, you will be able to change your chosen number at any time by placing your cursor on your desired number to the left of the screen. When you choose a number, it will light up as the number 2 now is.

2. *Revision Opportunities*

   However, the fact that you have changed your choice DOES NOT imply that the number on the graph will change. The number on the graph will only change if a **revision opportunity** is awarded to you. A revision opportunity is awarded at random times.

   Every second a revision opportunity will be awarded to the group with 80% chance. When a revision opportunity is awarded to the group, it will be given to one of the 6 group members, with equal probability of $\frac{1}{6}$. So the chance of any other member of your group having a revision opportunity and being able to change the posted number is exactly equal to yours: $p = .8 \times \frac{1}{6} \approx 13\%$.

If you had changed the number chosen, and received a revision opportunity, your number on the graph will change (the GREEN line will shift). If a revision opportunity is awarded to you, but you had not previously changed your chosen number, the number on the graph will **not** change. Let's call the number that you have chosen (the one that is lit up) which appears on the graph, your NUMBER POSTED on the graph.

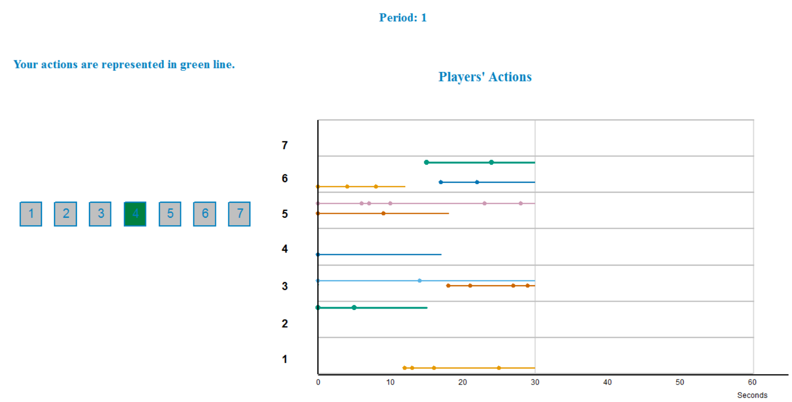

Figure 2 – Screen-shot of one possible scenario, after 1 minute has passed.

When 30 seconds have passed your screen will appear as in Figure 2. You can see how many times any member of your group changed the number posted (the line changes) as well as whether a revision opportunity was awarded (*a dot on the line*). For instance, player PURPLE has not changed the number posted (which is 5) despite having received 5 revision opportunities (5 dot's on light purple line). On the other hand, player ORANGE initially chose number 5, but after about 20 seconds the posted number became 3. Player GREEN has changed the number posted once. Let's take a closer look at player GREEN's actions:

(a) GREEN initially chose to post 2.

(b) Then, in the 4th second, a revision opportunity arrived, but the number posted by player GREEN did not change.

(c) In second 15, a revision opportunity arrived and the number posted changed to 6. Note that this was only possible because he had changed the number chosen prior to the arrival of revision opportunity.

(d) In second 25, revision opportunity arrived, but the number posted didn't change.

Finally, note that player GREEN has chosen the number 4 (it is lit up in green), but given that no revision opportunity has arrived, the NUMBER POSTED on the graph is still 6.

3. *Final Payoffs*

   At the end of the 1 minute countdown, you will receive a payoff that depends on your number posted and on the smallest number posted by a player in your group. *Only the numbers posted at the* **end** of the countdown matter for your payoff. The numbers posted before do not matter at all for your payoff. Your **final payoff** will be the sum of payoffs from all 10 periods plus the show up fee.

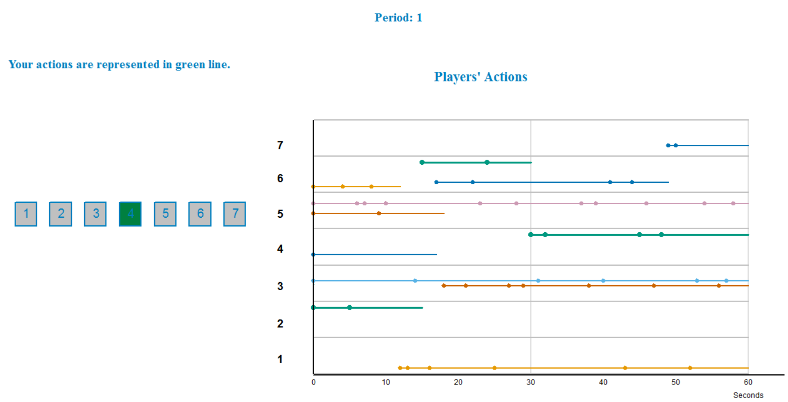

Figure 3 – Screen-shot of one possible scenario, after the 1-minute countdown has finished.

When 1-minutes have passed your screen will appear as in Figure 3. You can see the number posted of every participant in your group. Note that only the number posted as the countdown ends matter for your payoff. For instance, GREEN's payoff depends only on his **last** number posted, and on THE MINIMUM NUMBER POSTED by his group members **at the end of the countdown**.

The following probability facts and calculations may be useful:

1. Each player is expected to receive $.8 \times \frac{1}{6} \times 60 =$ **8 revision** opportunities during the 1-minute countdown.

2. The chance of a player receiving **no revision** opportunity during the 1-minute countdown is approximately $(1 - .8 \times \frac{1}{6})^{60} \approx 0.000$, which is **approximately 0.**

3. For any **10 second interval**, the chance of receiving at least one revision opportunity is of **approximately 75%.**

4. For any **20 second interval**, the chance of receiving at least one revision opportunity is of **approximately 95%.**

G Instructions - Cheap Talk

Instructions

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Table 1 – Payoff from different actions

Once you and all the members of your group have chosen a number, a 1-minute countdown will begin.

1-minute Countdown

1. *Graph Description*

   Before the 1-minute countdown, you and every member of your group have chosen a number: **1, 2, 3, 4, 5, 6 or 7**. Once every member of your group has made their initial choice, the 1-minute countdown begins.

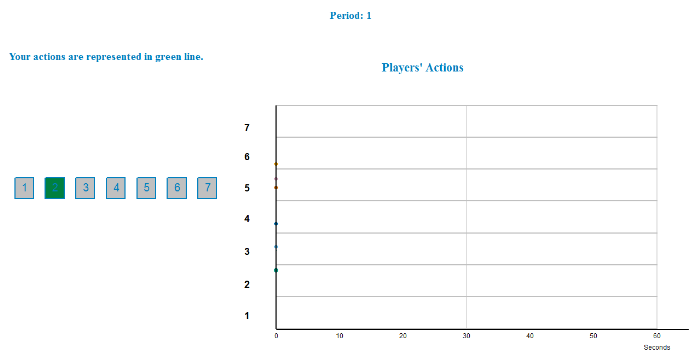


Figure 1 – Screen-shot of one possible scenario, as soon as the 1-minute countdown begins.

   When the 1-minute countdown begins your screen will appear as in Figure 1. In Figure 1, we have placed time in seconds on the horizontal axes and the number chosen by each of your group members on the vertical axes.

   The initially picked numbers chosen by you and your cohort are place along the vertical line above the zero second mark. You will see the number posted of every participant in your group. For instance, in Figure 1, we see that 2 players have chosen number 5, 1 player has chosen 2, 1 player has chosen 3, 1 player has chosen 4 and 1 player has chosen 6. Your choice is always represented in the graph with the color green, and those of others by other colors. As you can see the player has CHOSEN NUMBER 2.

   As time continues, during the 1 minute, you will be able to change your chosen number at any time by placing your cursor on your desired number to the left of the screen. When you choose a number, it will light up as the number 2 now is.

2. *Revision Opportunities*

   However, the fact that you have changed your choice DOES NOT imply that the number on the graph will change. The number on the graph will only change if a **revision opportunity** is awarded to you. A revision opportunity is awarded at random times.

   Every second a revision opportunity will be awarded to the group with 80% chance. When a revision opportunity is awarded to the group, it will be given to one of the 6 group members, with equal probability of $\frac{1}{6}$. So the chance of any other member of your group having a revision opportunity and being able to change the posted number is exactly equal to yours: $p = .8 \times \frac{1}{6} \approx 13\%$.

If you had changed the number chosen, and received a revision opportunity, your number on the graph will change (the GREEN line will shift). If a revision opportunity is awarded to you, but you had not previously changed your chosen number, the number on the graph will **not** change. Let's call the number that you have chosen (the one that is lit up) which appears on the graph, your NUMBER POSTED on the graph.

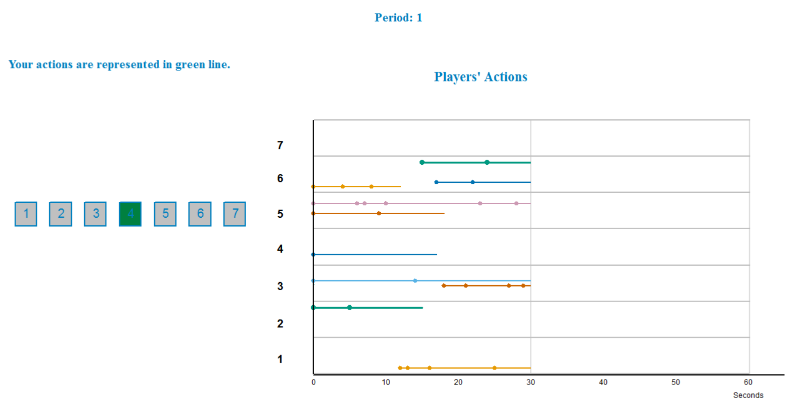


Figure 2 – Screen-shot of one possible scenario, after 1 minute has passed.

When 30 seconds have passed your screen will appear as in Figure 2. You can see how many times any member of your group changed the number posted (the line changes) as well as whether a revision opportunity was awarded (*a dot on the line*). For instance, player PURPLE has not changed the number posted (which is 5) despite having received 5 revision opportunities (5 dot's on light purple line). On the other hand, player ORANGE initially chose number 5, but after about 20 seconds the posted number became 3. Player GREEN has changed the number posted once. Let's take a closer look at player GREEN's actions:

(a) GREEN initially chose to post 2.

(b) Then, in the 4th second, a revision opportunity arrived, but the number posted by player GREEN did not change.

(c) In second 15, a revision opportunity arrived and the number posted changed to 6. Note that this was only possible because he had changed the number chosen prior to the arrival of revision opportunity.

(d) In second 25, revision opportunity arrived, but the number posted didn't change.

Finally, note that player GREEN has chosen the number 4 (it is lit up in green), but given that no revision opportunity has arrived, the NUMBER POSTED on the graph is still 6.

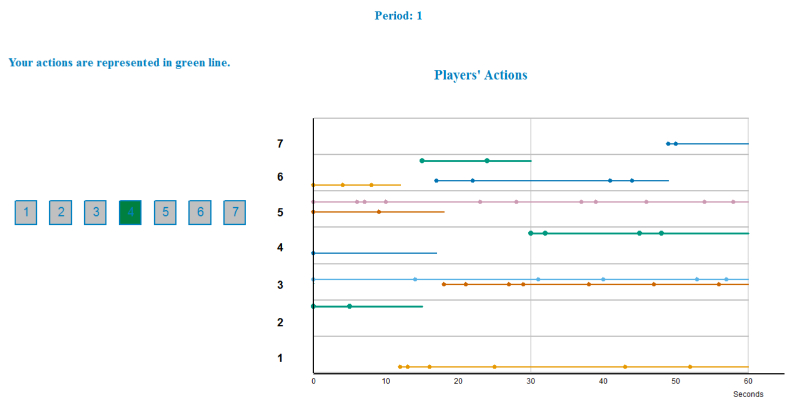
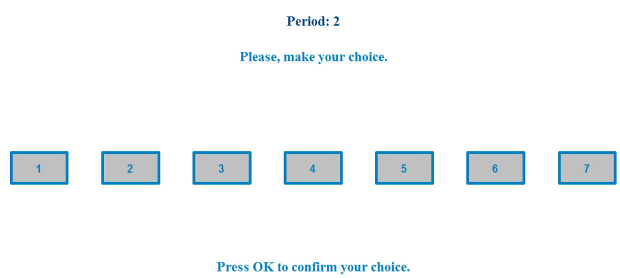


Figure 3 – Screen-shot of one possible scenario, after the 1-minute countdown has finished.

When 1-minute has passed your screen will appear as in Figure 3. You can see the number posted of every participant in your group.

3. *Final Choice*

   Once 1-minute countdown is over you will see a screen like the one bellow. You pick a number and **this number combined with the minimum number chosen in your group will determine you payoff in the period.** Note that only numbers chosen after 1-minute countdown are relevant for your payoff, numbers chosen during the 1-minute countdown *do not* affect your payoff.



4. *Final Payoffs*

   Your **final payoff** will be the sum of payoffs from all 10 periods plus the show up fee.

The following probability facts and calculations may be useful:

1. Each player is expected to receive $.8 \times \frac{1}{6} \times 60 =$ **8 revision** opportunities during the 1-minute countdown.

2. The chance of a player receiving **no revision** opportunity during the 1-minute countdown is approximately $(1 - .8 \times \frac{1}{6})^{60} \approx 0.000$, which is **approximately 0.**

3. For any **10 second interval**, the chance of receiving at least one revision opportunity is of **approximately 75%.**

4. For any **20 second interval**, the chance of receiving at least one revision opportunity is of **approximately 95%.**