

Language and Government Coordination: An Experimental Study of Communication in the Announcement Game

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March 2013

Abstract

One of the key roles of government is to coordinate the activities of citizens. One reason why governments are efficient facilitators of coordinated action, in addition to their ability to force compliance or tax, is that they are typically endowed with more information than the individuals they govern. This advantage creates a dilemma for them, however, since it forces them to decide on how they should distribute the information in their possession to the population. This paper investigates this question. We investigate the "Announcement Game" defined by the government and those it governs and focus on communication strategy that government uses to communicate private information to the citizens. This communication strategy involves (1) partitioning the state space in an attempt to mask the true state of the world and (2) choosing what type of language to use in order to communicate elements of this partition. We present evidence that the language used to execute a communication strategy does affect the efficiency of the equilibrium convergence process and also demonstrate that subjects playing the role of the government exhibit a great deal of sophistication in the communication strategies they employ and the language they use to execute them.

JEL Classification: C7, D8, C9

Key Words: Announcement Game, Communication, Language

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1 Introduction

One of the key roles of government is to coordinate the activities of citizens. For example, governments tax and redistribute in an effort to reallocate resources to ends that they deem desirable. They design mechanisms to help citizens coordinate their contributions to public goods in a truthful manner. On a macro level governments jawbone in an effort to get firms to take collective actions that none of them is likely to take on their own and set monetary policy in an effort to encourage or discourage joint investment behavior as the state of the economy changes.

One reason why governments are efficient facilitators of coordinated action, in addition to their ability to force compliance or tax, is that they are typically endowed with more information than the individuals they govern. Governments collect information about the state of the economy (unemployment rates, capital investment, housing starts, job vacancies, etc.) and, as a result, possess an informational advantage. This advantage creates a dilemma for them, however, since it forces them to decide on how they should distribute the information in their possession to the population.

This paper investigates this question. More precisely, let us assume that the government observes the true value of the state of the economy or some other relevant economic variable, x . Further, assume that it is a benevolent utilitarian social planner whose aim is to maximize the sum of the utility payoffs of the agents it oversees. If it engaged in a strategy of truthfully announcing the information it receives, then, given that information, the agents would engage in a game whose payoffs are state dependent and, assuming rationality, play to a Nash equilibrium of the game defined by the announcement. The problem, as we know from Crawford-Sobel (1982), who study Sender-Receiver games with one Receiver, is that the resulting equilibrium may not be the outcome that maximizes the planner's preferences and hence he would have an incentive to garble his message so as to mislead the agents who rely on him. This may involve the government being vague about the exact value of the state of nature by partitioning the state space and offering messages that do not precisely pin down what x is.¹

Such a communication strategy is composed of two parts. One is a strategic component we described above in which the leader attempts to partition the state space and communicate the optimal partition to his agents. Once this strategy is chosen the leader has to decide on how to execute his strategy, i.e., choose how to communicate this partition. This second component is typically ignored since, in equilibrium, once the strategic component is figured out, it does not matter how the equilibrium partition is communicated to agents, i.e., it does not matter whether the leader says "the state is 5", "the state is between 46", "the state is a star", or "the state is low", since, in equilibrium, all agents are able to invert the language used and understand what the messages mean.

¹There are many situations in which a sender who possesses private information about the payoff-relevant state of nature can benefit from lying about its precise value to influence action taken by a receiver. Examples include income tax evasion (see Alingham-Sandmo (1972)), financial advice (see Morgan-Stocken (2003)), electoral competition (Heidhues-Lagerlof (2003)) and fundraising with a random number of potential contributors (see Baca-Bag (2003)).

In this paper we focus on these two aspects of the communication game played by the government and its economic actors. First we investigate whether live human subjects, who play the role of the leaders in our communication game are capable of solving for the optimal information partition and can do so given the restrictions we place on them about the form of the language they can use. Note that these subjects are not required to use truthful strategies so they are free to dissemble as much as they would like. Second, we ask whether agents who receive information from efficient social planners, i.e., those using an optimal truthful and verifiable announcement strategy, are capable of achieving efficient outcomes given that optimal strategy. For this part of our experiment we replace the subjects acting as social planners with computers which employ a truthful and verifiable communication strategy but are capable of using different languages in its execution. In some cases the planner is constrained to report the true value of the state as he observes it. In others he must truthfully report the interval into which the state falls, while in others he uses natural language in reporting the state. We use computers here since we are interested in how the way an optimal communication strategy is executed (how it is communicated) matters in terms of welfare. The focus is on those who receive announcements.

The question of the welfare efficiency of different execution strategies, we feel, is important for a number of inter-related reasons. First, as a society we tend to communicate using natural language.² While this may be no impediment to efficient coordination in equilibrium, where the meaning of words is known, it may significantly slow the rate of convergence to the equilibrium since when natural language is used the meaning of words must be common knowledge amongst the agents if efficiency is to be attained.³ Hence, to the extent that we spend a considerable amount of time out of equilibrium or converging to it, the way we communicate matters.

To be more precise, consider a game in which one player (the Leader) privately observes a state of nature, $x \in X$, which is randomly realized from a commonly known distribution F and must make a public announcement m about x to two other Players (the Followers). The Followers, upon hearing m , play a finite strategy simultaneous move game, the payoffs of which depend on the state of nature x and actions chosen by both Followers. The Leader represents the benevolent planner and his interests are to maximize the sum of the Followers' payoffs (total surplus). We call such games "Announcement Games" and focus on a sub-class of such games, in which preferences of the Leader and the Followers are aligned for some values of x but diverge for others.

²One of the examples of vague communication are the announcements made by the Federal Reserve Bank regarding the state of the economy. In the monetary policy of the United States, the term Fedspeak (also known as Greenspeak) is what Alan Blinder called "a turgid dialect of English" used by Federal Reserve Board chairmen in making intentionally wordy, vague, and ambiguous statements. This strategy was used most prominently by Alan Greenspan, the previous chairman.

³Recent paper by Blume and Board (2013) investigates the problem of communication when message meanings are imperfectly shared by agents.

In the first set of experiments we employ real human Leaders in an effort to see if live subject are capable of figuring out the optimal communication strategy. In these experiments the human Leader, upon observing the state of nature, $x \in X$, can report any value to the two other Followers, $x' \in X$.⁴ We call this communication strategy Strategic Values. Even though the Leader is not constrained to report the truth, the repeated interaction with the Followers may serve as a disciplining device and prevent the real Leaders from lying too often.⁵

In the second set of experiments, we concentrate on the behavior of the Followers when intervals or word strategies are used to communicate. Thus, in these experiments, we deliberately abstract from the behavior of the Leader and use the computerized Leader whose strategy is programmed. Subjects participating in these experiments perform the roles of the Followers only, and they are informed of which type of strategy the computer is using to announce the value of x . When the intervals or the words are used, the programmed partition is the one that maximizes the sum of the Followers' payoffs for all $x \in X$ and participants are aware of that. When words are used, subjects are informed of the number of words used but not the cutoff that separates them; this is what they have to figure out by playing the game repeatedly. Before subjects engaged in these treatments they engaged in an experiment where the computerized Leader was constrained to report truthful values. This was done to give our subject experience with the game being played. We call this communication strategy Truthful Values and, while not an optimal communication strategy, we use it to compare the performance of the Followers in these games to those where the Leader uses intervals and words.⁶

We study two parameterizations of the announcement game with the only difference between them being the relative size of the disagreement region (i.e., how closely aligned the preference of the Leader and Followers are). This exercise is done to understand whether the performance of various

⁴These experiments are similar to the way the standard Crawford-Sobel cheap-talk game is usually implemented in the laboratory setting (see Section 5 for a discussion of the literature).

⁵The problem of how the meaning of the words is constructed when agents interact repeatedly deserves a separate investigation and we leave it for the future research.

⁶The thought experiment that motivates our second set of experiments is as follows. Say that two benevolent Leaders, both using the same communication strategy in which they partition the state space into intervals and communicate those intervals to the players, are forced to execute them in two different ways. One Leader is constrained to simply report the sub interval into which the state x falls while the other is constrained to describe each sub interval using words. The difference between the intervals and words is equivalent to the difference between being ambiguous and being vague. More precisely, intervals are ambiguous since, while they tell the Followers the interval into which x falls, they do not tell the exact value of x ; if $x \in [0, 3]$ then x can be any number between 0 and 3. Words, on the other hand, create vagueness in communication since, unless one knows where the interval associated with the word "low" stops and "medium" starts, such statements lack meaning. While ambiguous statements have multiple meanings, vague statements may be deficient in meaning unless one knows exactly where the boundaries between words lie (see Fine (1975) and Sainsbury (1990)). Since the theoretical literature in this area is only interested in studying the properties of optimal communication strategies, the distinction between vagueness and ambiguity is irrelevant because, in equilibrium, the same behavior will be observed once the communication strategy is known whether one uses words, intervals, hand signs or smoke signals. However, if we have learned anything from experimental economics it is that people rarely jump to equilibrium deductively but rather learn their way to it over time. It is in this convergence process that we expect that the type of language used to communicate may make a difference and in which the use of natural language, words, might be disadvantaged.

communication strategies depends on the properties of the announcement game being played.

Our experimental results are summarized below.

1. In our Strategic Values Treatment where subject leaders are free to communicate using values but are not constrained to be truthful, subjects that perform the role of the leaders exhibit a great deal of strategic sophistication. More than 80% of the subjects use the optimal communication strategy and about 10% truthfully reveal the state of nature x to their followers. Under these circumstances, subjects that perform the role of the followers tend to treat the announcements as if they were truthful. When the disagreement region is relatively large the leaders that use the optimal strategies achieve similar levels of efficiency as the leaders that use the truth-telling strategy. When the disagreement region is relatively small the optimal strategies strictly outperform truth-telling strategy.
2. The human leaders that use optimal partitions of the state space (those that theoretically achieve the socially optimal outcomes for all values of x) obtain (weakly) higher efficiency levels than the computerized leaders that are programmed to use the same partitions.
3. When we compare the performance of different communication strategies in the computerized leader treatments, we find that:
 - (a) In general, words function on par with the intervals but only when the leader uses the minimally necessary number of words.
 - (b) A vocabulary that uses more than the minimal number of words required to achieve the socially optimal outcome for any value of x (in our experiments four words rather than two), even when optimal, tends to confuse subjects. Reaching a common interpretation of words is an important determinant of performance: those subjects that converge on a common meaning of words achieve higher efficiency levels than those that do not.
 - (c) Even though theoretically we expect intervals to outperform the truthful values strategy in both games, behaviorally it is true only when the disagreement region is relatively small. When the disagreement region is large, using intervals fails to be advantageous.

We will proceed as follows. In Section 2 we describe the Announcement Game which will serve as the underlying structure for our experiments. Section 3 describes our experimental design and Section 4 presents the results. We discuss related literature in Section 5. Section 6 offers some conclusions. The instructions for the experiment are presented in the Appendix.

2 The announcement games: parametrization

Consider Game 1, in which there are three players: the Leader and two Followers. The Leader privately observes the state of nature x randomly drawn from the known distribution $F[x] =$

| | | | |
|------------|----------|-----------------|--------------------------|
| | | Follower 2 | |
| | | option A | option B |
| Follower 1 | option A | $2x + 3, x + 3$ | $2x + 8, 3$ |
| | option B | $x + 6, 1.5x$ | $1.75x + 8.75, 6 - 0.5x$ |

Table 1: Payoff matrix for Game 1

$U[0.2, 6.2]$ and makes a public announcement M describing the value of x to the two Followers. The Followers, upon hearing the announcement, play a simultaneous-move game the payoffs of which are described in Table 1. The Leader receives the sum of the Followers' payoffs.⁷

As we see in Table 1, the payoffs of both Followers, as well as the Leader, depend on the value of x and actions taken by the Followers. Two features of this game are worth noting. First, consider the simplified version of the announcement game described above in which the Followers observe the value of x and then simultaneously choose option A or B faced with the payoff matrix depicted in Table 1. This simplified game has a unique Nash equilibrium in pure strategies for every $x \in [0.2, 3) \cup (3, 6.2]$, which is (A,A) if $x > 3$ and (B,B) if $x < 3$. When $x = 3$, there are two Nash equilibria in pure strategies: (A,A) and (B,A). We will use the term "Followers preferences" to informally refer to the Nash equilibrium of this simplified version of the announcement game, in which the Followers observe the realization of x before making their choice. Second, the outcome of the matrix game depicted in Table 1 that maximizes the total surplus (which is the payoff of the Leader) does not always coincide with the Nash equilibrium of the matrix game, in which the Followers know the realization of x before choosing their actions. In fact, the total surplus is highest when the (A,A) outcome occurs when $x \geq 5$ and the (B,B) outcome occurs when $x < 5$. Figure 1 below presents graphically these two features of the simplified version of the announcement game, in which the Followers observe the realization of x before making their choice.

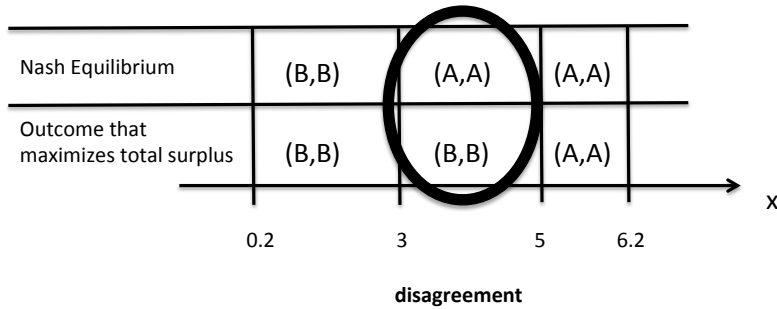


Figure 1: Preferences of the Leader and the Nash equilibrium of Simplified Game 1

As you can see in Figure 1, while the preferences of the Followers and the Leader coincide for low (below 3) and high (above 5) values of x , they differ in the region where x is between 3 and 5. We

⁷Our announcement game relates to a Sender-Receiver cheap talk game of Crawford-Sobel (1982). We discuss in Section 5 the differences between the announcement game and the Crawford-Sobel model.

| | | | |
|------------|----------|-----------------|-------------------------|
| | | Follower 2 | |
| | | option A | option B |
| Follower 1 | option A | $2x + 5, x + 5$ | $2.16x + 10, 5$ |
| | option B | $x + 10, 1.5x$ | $0.16x + 20, 10 - 0.5x$ |

Table 2: Payoff matrix for Game 2

call this region the "disagreement region". In order to achieve the Leader's most preferred outcome for all values of x , the Leader will have to, in some way, disguise the value of x when it falls in the disagreement region.

Because we are interested in investigating whether the performance of various communication strategies depends on the properties of the underlying announcement game being played, we introduce in our experiment a second announcement game (Game 2), which is similar to Game 1 with the only difference being that the relative size of the disagreement region in the simplified version of Game 2 (in which the Followers observe the realization of x before making their choice) is smaller than the one in Game 1. Table 2 describes the payoffs of the Followers in Game 2, where the state of the world is drawn from $F[x] = U[0, 9]$, while Figure 2 depicts the preferences of the Leader and the Nash equilibrium of the simplified version of Game 2 for every possible value of x . Note that for Game 2 the disagreement region is much smaller than it is in Game 1, especially relative to the support of x .

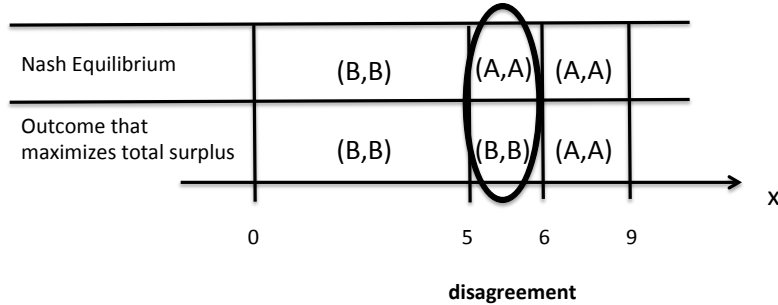


Figure 2: Preferences of the Leader and the Nash equilibrium of Simplified Game 2

2.1 The announcement game with socially optimal communication strategies

The question raised above is whether it is possible for the Leader to obtain the socially optimal outcome for all values of x . The answer is yes. One way to do so in Game 1 is to partition the state space into two subintervals $[0.2, 5]$, $(5, 6.2]$ and make announcement m_1 if $x \in [0.2, 5]$ and m_2 if x

$\in (5, 6.2]$.⁸ Given the linearity of the Followers' payoffs in x and assuming $F[x]$ is uniform, Bayesian updating leads to the following estimates of x conditional on m_i : $Ex|m_1 = 2.6$ and $Ex|m_2 = 5.6$. Therefore, upon hearing the announcement m_1 , the Followers believe that the expected value of x is below 3, and it is in their best interests to play equilibrium (B,B). Similarly, after the announcement m_2 , the Followers believe that x is above 5 and, thus, play equilibrium (A,A). In other words, by using the coarse partition of the state space, the Leader is able to trick the Followers into playing the socially optimal outcome for all $x \in X$.⁹ While using two subintervals is the minimal partition necessary to achieve an optimal outcome, it is not the only one. For example, the following partition also achieves the socially optimal outcome: m_1 if $x \in [0.2, 0.8]$, m_2 if $x \in (0.8, 5]$, m_3 if $x \in (5, 5.5]$ and m_4 if $x \in (5.5, 6.2]$.¹⁰ Note that in this partition the additional subintervals are redundant because they split up the agreement regions in inconsequential ways.

These partitions solve the strategic problem faced by the Leader. The remaining question is whether it matters what language the Leader uses to communicate the elements of the partitions to the Followers. For example, the Leader can use an "interval strategy" and simply report the subinterval into which x falls, or a "words strategy" and assign a word to the subinterval into which x falls (i.e., announce " x is low" or " x is high")¹¹. As we noted above, in the equilibrium of this game, it makes no difference how this strategy is executed since Followers should be able to invert any consistent set of messages and play accordingly. While this claim may be true for the equilibrium of the game, it is still an open question as to whether words or intervals are equally effective in the convergence process. For example, if intervals are used and all Followers know that the Leader has divided the interval into two subintervals and is announcing the true subinterval when he/she speaks, then when it is announced that $x \in [0.2, 5]$ it is immediately obvious what subinterval x lies in, and each Follower can assume that the other Follower knows this as well. The only uncertainty remaining is the strategic uncertainty of thinking about how one's opponent will choose, given that both subjects have heard the same announcement. When words are used, whether two or four, things are more complex. When the two-words strategy described above is used, our subjects know that the Leader has partitioned the interval into two subintervals and has associated a word to each one, but they do not know what these intervals are. That they will have to learn. In addition, they do not know what interpretation their opponent is giving to each announced word. While Follower 1 has a dominant strategy to choose action A when he believes that $x > 3$ and B otherwise, Follower 2's best response depends on the action of Follower 1. So there is a "common

⁸Similarly, in Game 2, one can partition the state space into two subintervals $[0, 6]$, $(6, 9]$ and make announcement m_1 if $x \in [0, 6]$ and m_2 if $x \in (6, 9]$.

⁹Of course, in equilibrium, no one is "tricked" as the Followers behave optimally given the information available to them (the announcement of the Leader). However, we use the word "tricked" to highlight the fact that the Leader is able to partition the state space in such a way that the Followers play the socially optimal outcome for *all* values of x including the ones for which Nash Equilibrium of the game with known x does not coincide with the socially optimal outcome.

¹⁰The following four subinterval partitions will achieve the efficient outcome in Game 2 for all values of $x \in X$: $[0, 2]$, $(2, 6]$, $(6, 8]$ and $(8, 9]$.

¹¹In this paper the words used are assumed to have natural meanings so that when we say " x is low" it is assumed that people understand that x takes a smaller value than when the announcement is " x is high".

interpretation” problem when words are used: the Followers may interpret the message “ x is low” differently, and, thus, update the value of x differently and, essentially, play different subgames. This common interpretation problem is the reason that we expect our subjects to have a more difficult time reaching equilibrium when words (especially four words) are used¹². Obviously, once the Followers have converged on a common interpretation and have learned the Leader’s vocabulary, all of these concerns vanish and words are equivalent to intervals.

3 Experimental Design

As we mentioned in the Introduction, we are interested in two related questions in our experiments. First is whether live subject leaders who communicate using values but without the constraint that they communicate truthfully are capable of converging on the optimal communication strategy. Second, we are interested in the behavior of the followers who receive truthful and optimal messages from computerized leaders. Here we are interested in seeing whether they are capable of coordinating their behavior on the announcements they hear and are able to interpret these messages efficiently.

The experimental design was structured to capture the salient features of the announcement games described in section 2 and to answer our main questions of interest. We ran 4 different experiments in which a total of 201 subjects participated. The subjects were recruited from the general undergraduate population of New York University and were inexperienced in this task. The experiments were run at the experimental laboratory of the Center for Experimental Social Science. In each experiment subjects were recruited and brought into the lab where they were randomly assigned to groups of three (in Experiments 1 and 2) and groups of two (in Experiments 3 and 4). In Experiments 1 and 2, real subjects played the role of Leaders; in Experiments 3 and 4 the role of the Leader was performed by the computer and this was announced to the participants. The payoffs to the subjects varied depending on the experiment, with average payoffs ranging from \$22 for Experiments 1 and 2 which lasted for an hour and fifteen minutes to \$35 for Experiments 3 and 4 which lasted for about two hours.¹³

Experiments 1 and 2 used the parameters of Game 1 and Game 2, respectively, and were conducted in an identical manner. All subjects participating in these experiments were divided into groups of three: one subject was assigned the role of the Leader and the other two were assigned the roles of Players 1 and 2. The group and role assignments were fixed for the duration of the experiment, which consisted of 20 identical decision rounds. At the beginning of each round, the value of x was

¹²If two words are used and the Players know that the goal of the Announcer is to maximize the sum of the payoffs of the Players (which is the case in our experiment), then all Players should be able to figure out how the Announcer will divide X . However, when the Announcer uses more than the minimal number of words, how he splits up X can be arbitrary and hence, it will be far harder for the subjects to infer his use of language.

¹³We present the complete instructions for Experiment 2 (Game 2) in Appendix A and for Experiment 3 (Game 1) in Appendix B.

drawn by the computer and revealed to the Leader but not to the Players in a group.¹⁴ The task of the Leader was to make an announcement regarding the value of x , which could be any number from the support of x . Both Players observed the (same) announcement made by the Leader and were prompted to choose a strategy A or B. At the end of the round, the Players observed the realization of x , the announcement made by the Leader about x , the action they and the other Player chose and their payoffs. The Leader was not constrained to report truthfully, and thus we will call this experiment the *Strategic Values treatment*.

Experiments 3 and 4 consisted of four parts (treatments) each with 20 rounds. The instructions of each part were read to the subjects only after they had finished the previous part so the subjects had no idea of what was going to transpire in subsequent parts of the experiment. Subjects were randomly matched into pairs for each part of the experiment. Once a part of the experiment (20 rounds) was over, subjects were randomly re-matched to form new pairs for the next 20 rounds of the experiment. Experiment 3 used the parameters of Game 1, while Experiment 4 used the parameters of Game 2 described in section 2.

In Part I of Experiment 3 (Experiment 4) the subjects played the game depicted in Table 1 (Table 2) for 20 rounds, each round with a new and commonly known value of x . More precisely, in each round they first were informed of the true value of x for that round. The payoff matrix with that value of x substituted in was then shown to them. They were next prompted to choose a strategy A or B. After the round was completed they were reminded of what they chose, informed of what their opponent chose and shown their payoffs and those of their pair member. The next round then started with a new value of x being chosen and displayed to them along with the relevant payoff matrix. We call this part of the experiment the *Truthful Values treatment*.

In Part II of Experiment 3 (Experiment 4) at the beginning of each round a value of x was randomly determined. Here, however, instead of having the value of x announced, a computerized Leader used a word from a two-word vocabulary consisting of the words "low" and "high" to describe it. The computer used an announcement strategy that, in theory, should achieve a socially optimal outcome as a Nash equilibrium (the sum of Follower payoffs) by stating " x is low" whenever x was between 0.2 and 5 (0 and 6) and announcing " x is high" when x was between 5 and 6.2 (6 and 9). The subjects were not told the actual strategy but were told that the computer was using a fixed strategy with two words (i.e. a strategy that did not change as a result of what happened in the play of the game) whose aim was to maximize the sum of their payoffs. After hearing the announcement the Followers were prompted to choose a strategy, A or B, and then were given the same feedback as the Followers in Part I; i.e., they were told the true value of x in that round, their strategy choice, that of the opponent, and both payoffs. We call this part of the experiment the *Two Words treatment*.

¹⁴In each round the value of x was chosen in an iid fashion for each group of subjects using a uniform probability defined over the support $[0.2, 6.2]$ in Game 1 and $[0, 9]$ in Game 2.

Part III of Experiment 3 (Experiment 4) was identical to Part II except that the computerized Leader used four rather than two words. Here for the intervals $[0.2, 0.8]$, $[0.8, 5]$, $[5, 5.5]$ and $[5.5, 6.2]$ ($[0, 2]$, $[2, 6]$, $[6, 8]$ and $[8, 9]$) the Leader used the words "lowest", "higher", "even higher", and "highest", respectively. We call this part of the experiment the *Four Words treatment*.

Part IV of Experiment 3 (Experiment 4) had the subjects play the same announcement game, but this time instead of the computerized Leader using a words strategy he announced which of two intervals the value of x lay in; i.e., he announced " x is between 0.2 and 5" or " x is between 5 and 6.2" (" x is between 0 and 6" or " x is between 6 and 9"). In other words the computer was programmed to use the intervals strategy. The intervals used were the same as those attached to the words "low" and "high" but now there was no need for the subjects to jointly interpret words because the underlying intervals were reported to them. We call this part the *Intervals treatment*.

There were two more tasks that the subjects performed during Experiments 3 and 4. In Parts II and III they were asked in rounds 5, 10, 15 and 20 to predict the intervals associated with the words being used by the Leader and also to predict the intervals they thought their pair member was using to describe the Leader's strategy. In other words, for the two-word treatment in Part II they were asked to state the cutoff value that differentiated the words "low" and "high" in the interval $[0.2, 6.2]$ ($[0, 9]$). For Part III they were asked to choose three cutoffs demarcating the boundaries of the sub-intervals separating the words $[0.2, 0.8]$, $[0.8, 5]$, $[5, 5.5]$ and $[5.5, 6.2]$ ($[0, 2]$, $[2, 6]$, $[6, 8]$ and $[8, 9]$). Subjects were rewarded for this task using a quadratic scoring rule which penalized them for deviations from the true cutoffs. This task was included since we were interested in seeing if the subjects converged on a common understanding of the words being used by the computerized Leader and whether such convergence could predict how well they performed. Obviously the language used by the Leader could only be efficient if it was interpreted identically by the people listening to it and this elicitation was done to see how easy it was for pairs to come to a common understanding of the language of the Leader.¹⁵

In both human and computerized Leaders experiments we used fixed matching.¹⁶ The reason we used this design is that in human Leaders treatments, as well as in the words treatments, subjects have to establish the convention of what the announcements mean in order to have a shot at reaching coordination when hearing those announcements. The alternative way, in which subjects

¹⁵The notion of common knowledge between subjects requires observing not just the first-order beliefs but also the second-order, third-order and other higher-order beliefs. In our experiments, we are focusing on the first-order beliefs. More precisely, we can identify whether subjects have identical beliefs about the cutoff used by the computerized social planner and whether their beliefs about each other's beliefs are correct. Thus, we use the term "common interpretation" instead of "common knowledge" to describe whether subjects have common understanding of the communication strategy used by the computerized social planner.

¹⁶In the computerized Leaders treatments (Experiments 3 and 4) subjects were in fixed pairs for the duration of each treatment (truthful values, two words, four words and intervals); however, they were rematched to form new pairs between these treatments.

are rematched into new groups after every period, we feel, is extremely hard as it complicates significantly learning the meaning of the announcements made. Moreover, in the human Leaders treatments, our data suggests that different Leaders use different announcement strategies, the performance of which would be hard to assess if we were to implement a random matching design. In addition, in the two-words treatment, some pairs of the Followers converged on the common interpretation of the meaning of the words used by the computerized Leader, while others did not. Fixed matching in this part of the experiment allows us to identify those pairs and compare their performance. We kept the fixed matching in the remaining parts of the experiments for consistency.¹⁷

Our experimental design is summarized in Table 3.

| Experiment | Leader | Game | Leader's strategy | # of subjects |
|--------------|----------|--------|---|---------------|
| Experiment 1 | Human | Game 1 | Strategic Values | 72 |
| Experiment 2 | Human | Game 2 | Strategic Values | 45 |
| Experiment 3 | Computer | Game 1 | Part I Truthful Values Part II Two Words Part III Four Words Part IV Intervals | 46 |
| Experiment 4 | Computer | Game 2 | Part I Truthful Values Part II Two Words Part III Four Words Part IV Intervals | 38 |
| Total | | | | 201 |

Table 3: Experimental Design

¹⁷One may be concerned about multiple simultaneous changes when we compare results from Experiments 1 and 2 (human Leaders) to Experiments 3 and 4 (computerized Leaders). The differences between these two sets of experiments are the identity of the Leader (human versus computerized Leader) and the strategy space of the Leaders. In fact, strategy space of the Leaders in Experiments 1 and 2 seems inferior to the ones studied in Experiments 3 and 4 because human Leaders cannot easily replicate the interval strategy, which requires common knowledge of the cutoffs. Strategic values of the human Leaders in Experiments 1 and 2 are equivalent to the words strategy in Experiments 3 and 4, which requires both Followers to learn the meaning of the messages used by the Leader. However, as we will show in the results section, despite the fact that the intervals strategy was not available to the human Leaders, their performance is (weakly) better than the performance of any of the computerized strategies studied in Experiments 3 and 4. In other words, our results suggest that human Leaders do not suffer much from not being able to commit to a partition of the state space as computerized Leaders who use the Intervals strategy.

4 Results

Structure

We present our experimental results in the following order. First, we consider Experiments 1 and 2 and ask whether human Leaders are capable of figuring out the optimal communication strategy in our setup. We classify the behavior of the Leaders according to the announcement strategies they use and compare their performance in terms of the efficiency. We then look at the behavior of the Followers to document whether they followed the announcements of the Leaders. Second, we ask what can be done to improve the coordination of the Followers and overall welfare over the one observed in Experiments 1 and 2. For this purpose, we consider Experiments 3 and 4, in which the role of the Leaders is performed by the computers that are programmed to use specific optimal communication strategies; the Followers are aware of that. Among the strategies we investigate are the truthful communication strategy and several socially optimal strategies executed using either intervals or words. Put differently, in this part we investigate whether a society in which a computerized Leader uses a socially optimal strategy can achieve higher levels of efficiency than the ones achieved by the human Leaders.

Before we start presenting our results, let us discuss both the efficiency measures we use and the regressions we run to evaluate the impact of treatments on efficiency.

Efficiency Measures

To evaluate the performance of different communication strategies we consider two efficiency measures. One, called "Fraction Efficiency" (FE), calculates the fraction of time the Followers choose the strategy profile that maximizes the total surplus (sum of their payoffs); i.e.,

$$FE = \frac{\text{Number of times pairs played outcome that maximizes their payoff sum}}{\text{Total number of choices made}}$$

The other, which we call the "Surplus Efficiency" (SE), measures the fraction of the potential surplus available that is captured, i.e., for a given value of x

$$SE = \frac{\text{Actual surplus captured} - \text{Smallest surplus available}}{\text{Highest surplus available} - \text{Smallest surplus available}}$$

Both measures are maximized when the pair of subjects plays the socially optimal outcome in each period. While the two measures are positively correlated, they are not identical and capture slightly different aspects of subjects' behavior. For a given value of x , the FE indicates whether subjects played the socially optimal outcome or not and ignores what kind of mistakes were made if subjects played some other outcome. The surplus efficiency, on the other hand, takes into account how subjects deviated from the efficient outcome and how costly such deviations were.¹⁸

¹⁸While we feel that weight must be attached to both measures, there is some appeal of FE in that it is robust to changes in the game being played while the SE can vary greatly, and arbitrarily, depending on the payoff functions used in the game and the actual realizations of x in the experiment. In addition, since the objective of the Leader

Statistical Analysis

To test the impact of our various treatments on fraction efficiencies we estimate the following Logit model with random effects:

$$y_{ij} = \alpha + \beta \cdot \textit{treatment} + \epsilon_{ij}$$

where y_{ij} is a dichotomous variable taking on a value of 1 if a pair of subjects that were matched together (indexed by i) played the welfare maximizing outcome in period j and 0 otherwise and $\textit{treatment}$ is a dummy variable for the treatment. When we report p values in our discussion below, they represent the significance of the β coefficient in the regression.

To compare surplus efficiencies between treatments we use an identical random effects GLS regression except for the fact that y_{ij} variable is now a continuous variable taking values between 0 and 1. In both cases the pair of subjects that were matched together for the whole duration of the treatment serves as the panel (group) id variable and we report the results at 5% level of significance.

4.1 Human Leaders: Leaders' types

Recall that the subjects that performed the role of the Leaders in Experiments 1 and 2 were restricted to announcing a value for each observed value of x . Despite this restriction, there is quite a large amount of strategic freedom here.¹⁹ For example, the Leader can mimic the truthful-values strategy by simply reporting the value of x he or she sees each period. On the other hand, the Leader can mimic a word strategy by dividing the state space into sub intervals and announcing one value of x , say x' , when x lies in one subinterval and another, say x'' , when x lies in the other. A babbling strategy can be achieved by announcing the same value of x no matter what is observed. We start by exploring how the subjects that performed the role of the Leaders use this strategic freedom. We then investigate whether the Followers believed the announcements made by their Leaders and, finally, we compare the efficiency implications of using various communication strategies.

Given that Leader subjects have a fair degree of strategic freedom in Experiments 1 and 2, we start by classifying each of these subjects by the type of announcement behavior they exhibited. We will do this in two steps. First note that any strategy in which the Leader announces the *same* value of x less than 3 (5) when x is below 5 (6) and an x above 5 (6) when x is above 5 (6) in Game 1 (Game 2), respectively, is outcome equivalent to the interval strategy as we have defined it. We will call

is to get the Followers to choose as he likes, the FE should be appealing since it measures exactly that. Finally, since the Leader has no way to control what happens out of equilibrium where people make mistakes, he might as well concentrate on getting the players to do as he wishes and then take his chances with their out-of-equilibrium behavior. For him to consider the surplus efficiency measure when he designs his communication strategy would involve the creation of an "out-of-equilibrium" theory of behavior which is, needless to say, extremely difficult.

¹⁹Notice that in terms of cardinality of the strategy space, having values as messages is exactly as permissive as having intervals.

such a strategy "optimal" because it implements socially optimal outcomes for every value of x . In addition, any strategy that reports the true value of $x \pm 0.5$ will be called "truth telling" while any strategy that always reports the same value of x , say $\bar{x} \pm 0.5$, no matter what x is observed, we will call a "babbling" strategy. Those subject strategies that fall into none of the categories we propose will be called "unclassified".

In order to classify subject Leaders into these three categories, we will look at the behavior of each Leader over the 20 rounds of the experiment and, for each strategy, ask how many observations would have to be removed from the data set in order to exactly fit the strategies described above. A subject will be classified as belonging to a type if that type best describes his or her behavior (minimizes the number of removed observations). The results of this calculation are presented in Table 4.

| | Strategy Types | | | |
|-----------------------|----------------|---------------|-----------|--------------|
| | Optimal | Truth-Telling | Babbling | Unclassified |
| Game 1 (Experiment 1) | 20 [3.2 obs] | 2 [4 obs] | 0 | 2 |
| Game 2 (Experiment 2) | 12 [1.1 obs] | 2 [6 obs] | 1 [4 obs] | 0 |
| Total | 32 (82%) | 4 (10%) | 1 (3%) | 2 (5%) |

Table 4: Strategy types of the Leaders in Experiments 1 and 2
 Square brackets list the average # of removed observations out of 20 to fit the strategy exactly
 Round brackets in the last line list the percentage of the total population

As we can see in Table 4, in the combined Game 1 - Game 2 sample, the vast majority of our subjects (82%) employed an optimal strategy, while only 10% used a truth telling strategy and 3% babbled. This behavior is remarkably sophisticated. The strategy we select as the best fitting strategy for the Leaders requires removing rather a small number of observations: on average about 3 (1) out of 20 observations for the optimal strategy and 4 (6) out of 20 observations for the truthful strategy depending on the Game played. Furthermore, as a general rule, the best fitting strategies for the Leaders also performed significantly better than the second best fitting strategy according to our metric. For example, in order to make the second best strategy fit the data as well as our first best, one would have had to, on average, eliminate an additional 6.87 observations out of 20 observations in Game 1 (Experiment 1) and an extra 8.38 observations out of 20 observations in Game 2 (Experiment 2). This indicates that our type classification is rather precise in that it clearly differentiates between Leader types. Finally, there were two Leaders in Experiment 1, for which the best-fitting strategy required removing 13 or 15 observations out of 20 available. We separate these two Leaders in the category of unclassified strategies as we detect no pattern in the announcements made by these two subjects.

Since the overwhelming bulk of our Leaders are types that use an optimal strategy, we will further classify these optimal types into the exact type of strategy they employed. Consider the following

three strategies depicted in Figures 3a-3c for Game 1.

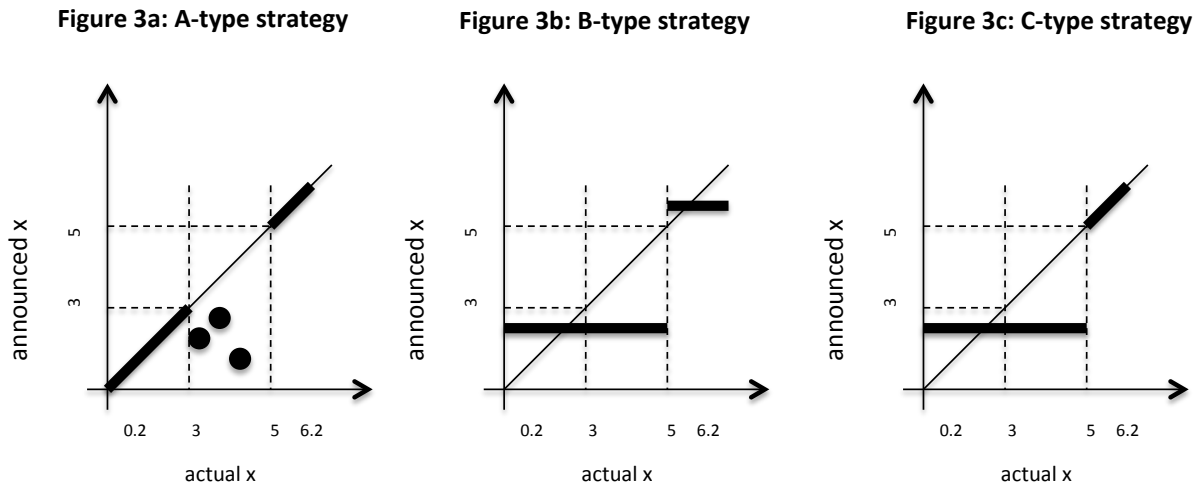


Figure 3: Optimal Announcement Strategies in Game 1

In Figure 3a we see a Leader who tells the truth about x in those regions where his preferences and those of the Followers coincide but, where they do not, he announces an x whose value is below 3. We call this strategy an A-type strategy, which is truth-telling with an optimal lie in the disagreement region. In Figure 3b we see a Leader who perfectly replicates the partition used in the intervals and two-words strategies by announcing the same value for all x less than 5 and a different value for all values above 5; we call this a B-type strategy. Finally, in Figure 3c we see a convex combination of these strategies since the Leader uses an interval strategy for values below 5 and tells the truth for all values above; we call this a C-type strategy.

To demonstrate what these strategies look like in our actual data set consider Figures 4a-4c which, in some sense, mimic these idealized types.

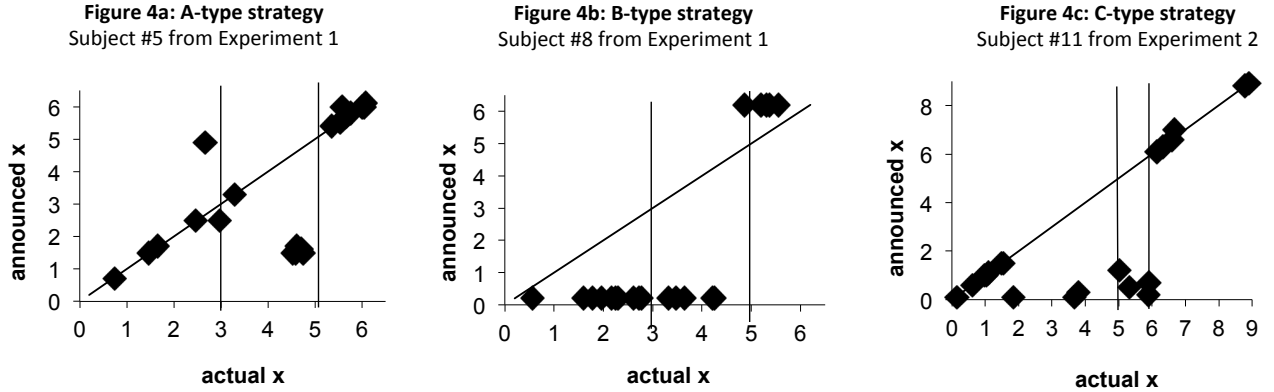


Figure 4: Three examples of Optimal Strategies used by subjects in Experiments 1 and 2

For example, in Figure 4a we see a subject who is engaging in A-type behavior similar to that depicted in Figure 3a where he basically tells the truth except for values in the disagreement regions where he reports a value below 3. Figure 4b depicts the behavior of a subject who engages in B-type behavior in which he replicates an interval strategy in a very precise manner, announcing 0.2 for all values below 5 and 6.2 for all values above 5. Finally, in a slightly messier manner, the subject depicted in Figure 4c is behaving as a C-type. All of these strategies, in equilibrium, would implement socially optimal outcomes. Our task is to try to further classify the subjects who employed an optimal strategy into these three categories. To do that we calculated the sum of the squared deviations of observed and predicted announcements for each of our strategies (A-type, B-type and C-type) and chose that strategy which minimized such deviations. The results of this classification are presented in Table 5.

| | Strategy Types | | |
|-----------------------|----------------|------------|----------|
| | A-type | B-type | C-type |
| Game 1 (Experiment 1) | 14 | 6 | 0 |
| Game 2 (Experiment 2) | 4 | 5 | 3 |
| Total | 18 (56%) | 11 (34.5%) | 3 (9.5%) |

Table 5: Types of Optimal Strategies Used in Experiments 1 and 2

What's interesting is that of the 32 subjects who chose an optimal strategy, 56% used an A-type strategy, 34.5% used a B-type strategy and 9.5% used a C-type strategy. In essence, there seemed to have been a preference for subjects to tell the truth whenever possible and do the minimal amount of lying necessary to get their preferred outcome. What these results indicate is that our subjects were very skillful in using numbers to construct a wide variety of sophisticated strategies, many of which were optimal under the circumstances.

Conclusion 1 *Most of the human Leaders (82%) use **optimal** communication strategies in Experiments 1 and 2. More than 50% of Leaders that use the optimal communication strategies misrepresent the value of the state x only for those x for which the preferences of the Leader diverge from the equilibrium of the matrix game and tell the truth in all other circumstances.*

It is instructive at this point to relate our first result to the existing experimental literature that studies the cheap-talk model of Crawford-Sobel (1982). The general message that emerges from this literature is that while the main comparative statics of the Crawford and Sobel model holds true (see Dickhaut-McCabe-Mukherji (1995) who show that more information is transmitted when the degree of conflict between the Sender and the Receiver is smaller), Senders tend to reveal too much information to the Receivers relative to the equilibrium prediction. In particular, Cai-Wang (2006) and Wang-Spezio-Camerer (2010) report excessive truth-telling by the senders and suggest a level-k behavioral model as one possible explanation for this phenomenon. Sanchez-Pages and Vorsatz (2007) explain this over communication by estimating the type distribution of their subject pool and finding that while one subset of subjects seem to have a preference for honesty, other subjects only communicate honestly when it is in their interest to do so.²⁰ Contrary to these results, we rarely observe overcommunication on the part of the Leaders: only 4 out of 39 Leaders truthfully report the value of x to their Followers. Further, the vast majority of the Leaders (more than 80%) used communication strategies that transmitted the "right" (equilibrium) amount of information.

4.2 Human Leaders: Followers' Behavior

Given the behavior of our subject Leaders the next obvious question is whether the Followers believed the announcements made by the Leaders and how they did behave based on these announcements. Table 6 reports how often the Followers believed the Leaders and acted as the Leader desired given the announcement. This means that in Game 1 (Game 2) when x was announced below 3 (below 5) they chose strategy B and when x was announced above 5 (above 6) they chose strategy A.

| Game 1 (Experiment 1) | |
|--------------------------|----------------------------|
| announced x is below 3 | 80% [501 out of 628 cases] |
| announced x is above 5 | 90% [221 out of 246 cases] |
| Game 2 (Experiment 2) | |
| announced x is below 5 | 90% [334 out of 372 cases] |
| announced x is above 6 | 91% [189 out of 208 cases] |

Table 6: Behavior of the Followers
How often welfare maximizing action is taken given the announcement

²⁰See also Battaglini and Makarov (2011) who experimentally study the Farrell and Gibbons (1989) model with one Sender and multiple Receivers whose payoffs are independent from each other's actions. The authors find that there is a sizable fraction of senders who are excessively honest.

As Table 6 shows, the Followers followed the announcements of the Leaders 80% or more in both Experiments 1 and 2.

Notice that when the Leader reports x is below 3 (below 5), the Followers cannot distinguish between the case where x is indeed below 3 (below 5) or the case where it is between 3 and 5 (between 5 and 6) (where the Leader is trying to misrepresent x in order to trick them into playing the BB equilibrium). Therefore, theoretically, the precise value of x reported by the Leader when x is below 5 in Experiment 1 and below 6 in Experiment 2 does not matter as long as the Followers interpret this message correctly. However, the Followers in our experiments, in a majority of cases, behaved as if the announcement made by the Leader was truthful. Indeed, on rare occasions in which the Leader announced x as taking a value in the disagreement region (between 3 and 5 in Experiment 1 and between 5 and 6 in Experiment 2) Followers took action A most of the time: 85% in Experiment 1 (73 out of 86 cases) and 70% in Experiment 2 (14 out of 20 cases).²¹ This explains why most of the Leaders that employed the optimal communication strategy chose to shed the announced value of x down when trying to disguise the disagreement region.

Conclusion 2 *Followers trust the Leaders and follow their announcements by taking welfare maximizing actions given the reported value of x at least in 80% of all the cases.*

Our observation that the Followers often “believe” the Leader and behave accordingly is related to the sucker behavior observed by Blume et al (2001) and Dickson (2010). Blume et al. study the evolution of messages in the discrete version of the communication game, in which the Sender and the Receiver have partially aligned interests. In their study one out of three types of the Senders prefers to pool with the lower type to influence the action of the Receiver. Although this type often sends the message that fully identifies him- or herself, the Receivers chose, with positive probability, an action that is best for the Sender and not for them. This behavior does not disappear with experience. The difference between the Blume et al. (2001) framework and our strategic values treatment is that in our game the Followers cannot distinguish when the Leader is lying before taking an action. In a different setting, Dickson (2010) finds that followers trust leaders too much, which indicates that followers do not fully account for the leader’s strategic incentives to misrepresent the state of the world.²²

²¹Put differently, it is impossible to distinguish whether the Followers believe the Leader is telling the truth or the Followers know that the Leaders use the optimal strategy and best-respond to that *if* one looks at the behavior of the Followers after observing on-equilibrium-path messages. However, out-of-equilibrium messages may help us distinguish these two interpretations. While we don’t have enough data to pin the interpretation precisely, our data suggests that Followers behave as if the Leaders’ reports are truthful. This is because when they hear an out-of-equilibrium message that x takes value in the disagreement region, they take action A most of the time.

²²See also Vespa-Wilson (2012) who study Battaglini’s (2002) two-dimensional model with two Senders and one Receiver. While there are significant differences between their setup and the announcement game we study here, the authors find that in some situations Receivers trust one of the Senders too much. More precisely, the authors observe that the Receivers tend to identify a more trustworthy Sender (the one that exaggerates less on one dimension) and follow his message at face value without discounting the Sender’s bias, which is what the equilibrium strategy prescribes to do.

4.3 Human Leaders: Overall Performance

Finally, in this section we compare the overall efficiency levels achieved by various communication strategies used by human Leaders in our experiments. Table 7 presents two measures of efficiency: fraction efficiency (FE) which indicates how often the welfare maximizing outcome was played and surplus efficiency (SE) which measures how much subjects lose by taking action different from the socially preferred one.

| Type of Communication Strategy | Game 1 (Experiment 1) | | Game 2 (Experiment 2) | |
|--------------------------------|-----------------------|-----|-----------------------|-----|
| | FE | SE | FE | SE |
| All strategies | 58% | 69% | 73% | 78% |
| All optimal strategies | 62% | 71% | 82% | 85% |
| A-type strategies | 61% | 70% | 71% | 77% |
| B-type strategies | 63% | 75% | 84% | 87% |
| C-type strategies | | | 92% | 93% |
| Truth-telling strategy | 55% | 74% | 45% | 57% |
| Babbling strategy | | | 25% | 43% |
| Unclassified strategies | 23% | 38% | | |

Table 7: Efficiency Levels in the Strategic Values Treatment

Consider first Game 1, in which the disagreement region is relatively big. In this game, optimal strategies perform significantly better than the unclassified ones: optimal outcome occurs 61.5% of the time when the Leader uses one of the optimal strategies, compared to 22.5% of the time when one of the unclassified strategies is used.²³ At the same time, the Leaders that use optimal strategies achieve similar levels of efficiency to those that use truth-telling strategy: FE index is between 55% and 65%, while SE index is between 70% and 75% depending on the type of communication strategy used by the Leader.²⁴ Further, there is no significant difference between type A and type B optimal strategies in terms of both fraction and surplus efficiency.²⁵

The picture is different in Game 2, in which the disagreement region is relatively small. In this game, optimal strategies perform significantly better than the truth-telling or the babbling strategies using any of the two measures of efficiency. While truth-telling and babbling strategies select socially optimal outcomes no more than 45% of the time, the optimal strategies do so more than 80% of the time. These fractions are statistically significant at 1% level. Moreover, amongst optimal strategies, type C strategy achieves significantly higher levels of efficiency than type A strategy²⁶

²³The difference is statistically significant at 5% level ($p = 0.002$). We reach the same conclusion if we compare our SE indices ($p < 0.001$).

²⁴Statistical tests cannot reject the hypothesis that both FE and SE indices are statistically indistinguishable ($p > 0.10$).

²⁵Both FE and SE indices are not statistically different ($p > 0.10$).

²⁶ $p = 0.02$ for FE comparisons and $p = 0.06$ for SE comparisons.

and performs on par with type B strategy²⁷, while types A and B strategies are statistically indistinguishable.²⁸

Conclusion 3 *When the disagreement region is relatively large (Game 1) Leaders that use the optimal strategies achieve similar levels of efficiency as Leaders that use the truth-telling strategy and achieve strictly higher levels of efficiency than Leaders that use the unclassified strategies. When the disagreement is relatively small (Game 2) the optimal strategies outperform both truth-telling and babbling strategies.*

4.4 Computerized Leaders versus Human Leaders: Overall Performance

The results in the previous section suggest that human Leaders that use optimal communication strategies can achieve high levels of efficiency in both games. The question we ask now is whether one can improve upon these levels of efficiency by substituting the computerized Leaders for the human ones. The answer will obviously depend on the type of communication strategy used by the artificial Leaders. We consider the following alternatives:

- Truthful Strategy - in each round the computer simply reports the actual realization of state of nature x and both Followers observe this information prior to making their decisions.
- Intervals Strategy - computerized Leaders partition the state space into two subintervals ($[0.2, 5]$ and $[5, 6.2]$ for Game 1 and $[0, 6]$ and $[6, 9]$ for Game 2) and report the subinterval into which the realized value of x falls.
- Two Words Strategy - the state space is partitioned in the same way as when the Intervals Strategy is used; however, the computerized Leaders use the words "low" and "high" to describe the subinterval into which actual x falls.
- Four Words Strategy - the state space is partitioned into four subintervals and the words "lowest", "higher", "even higher" and "highest" are used to report the realization of x .

Notice that even though the truth-telling strategy is not optimal for the Leader, it is the easiest one amongst all the communication strategies we consider since it does not require any updating on the part of the Followers. The other three strategies (Intervals, Two Words and Four Words) are all theoretically equivalent as they achieve a socially optimal outcome for all values of x , and, thus, one could expect them to perform equally well. However, these strategies require different levels of sophistication from the Followers. Indeed, the Intervals Strategy is the simplest amongst three optimal communication strategies, since for its successful performance the only thing the Followers need to do is to be able to update on the expected value of x given that it falls into each of the two subintervals reported by the computer and to play to the equilibrium of the matrix game given the expected value of x . The Two-Words Strategy is more demanding as, in addition to the updating

²⁷ $p > 0.10$ for both FE and SE comparisons.

²⁸ $p > 0.10$ for both FE and SE comparisons.

required by the Intervals Strategy, it also requires that (1) each Follower learns the cutoff between "low" and "high" used by the computer and (2) Follower 2 learns what Follower 1 believes the cutoff is since Follower 2's best response depends on the action of Follower 1 (this is the common interpretation problem that we described in Section 2). Finally, the Four-Words Strategy seems to be the most complicated among the optimal communication strategies, as it requires Followers to learn three cutoffs and update accordingly.

Table 8 compares efficiency levels of different communication strategies used by the human and computerized Leaders.

| Types of Communication Strategies | Game 1 | | Game 2 | |
|-----------------------------------|--------|-----|--------|-----|
| | FE | SE | FE | SE |
| <i>Human Leaders</i> | | | | |
| All Strategies | 58% | 69% | 73% | 78% |
| Optimal Strategies | 62% | 71% | 82% | 85% |
| <i>Computerized Leaders</i> | | | | |
| Truth-Telling Strategy | 52% | 75% | 71% | 82% |
| Intervals Strategy | 42% | 59% | 82% | 85% |
| Two-Words Strategy | 42% | 61% | 77% | 80% |
| Four-Words Strategy | 30% | 51% | 61% | 69% |

Table 8: Efficiency Levels Achieved by Human and Computerized Leaders

As Table 8 indicates, there is no communication strategy executed by the computerized Leader (among the ones we considered in Experiments 3 and 4) that would outperform optimal communication strategy employed by the human Leader. Indeed, in Game 1 human Leaders that use optimal communication strategies achieve FE of 62%, while the truthful strategy performed by the artificial Leader (which is the best amongst the strategies executed by the computer) obtains a lower FE of 52%. These fractions are statistically different at 6% level ($p = 0.06$).²⁹ In Game 2, optimal communication strategies employed by the human Leaders obtain the same FE levels of 82% as the Intervals Strategy executed by the artificial Leaders ($p > 0.10$).³⁰

The performance of optimal communication strategies is connected to whether the Followers "trust" the announcements made by the Leaders. In Section 4.2 we have shown that the Followers believed the announcement made by the human Leaders a vast majority of the time and chose actions which are part of the equilibrium strategy for the announced value of x . Table 9 compares this measure for the human Leaders treatment and computerized Leaders treatment when computerized social planners use intervals and two-words communication strategies. In Game 1 (Game 2), we say that

²⁹The surplus efficiency measures are not statistically different between optimal strategies of the human Leaders treatments and truthful strategy of the artificial Leaders treatments ($p > 0.10$).

³⁰The surplus efficiency measures are not statistically different between optimal strategies executed by the human Leaders and intervals strategy executed by the artificial Leaders ($p > 0.10$).

the Followers trusted the Leader if they chose strategy B when they heard an announcements " x is low" or " x is between 0.2 and 5" (" x is between 0 and 6") and they chose strategy A when they heard an announcement " x is high" or " x is between 5 and 6.2" (" x is between 6 and 9"), respectively.

| Game 1 | | Game 2 | |
|-----------------------------|-----|-----------------------------|-----|
| <i>Human Leaders</i> | | <i>Human Leaders</i> | |
| announced x is below 3 | 80% | announced x is below 5 | 90% |
| announced x is above 5 | 90% | announced x is above 6 | 91% |
| <i>Computerized Leaders</i> | | <i>Computerized Leaders</i> | |
| Intervals strategy | | Intervals strategy | |
| " x is between 0.2 and 5" | 52% | " x is between 0 and 6" | 77% |
| " x is between 5 and 6.2" | 90% | " x is between 6 and 9" | 93% |
| Two-Words strategy | | Two-Words strategy | |
| " x is low" | 51% | " x is low" | 76% |
| " x is high" | 90% | " x is high" | 92% |

Table 9: Behavior of Followers in Human Leaders versus Computerized Leaders
How often welfare maximizing action is taken given the announcement

As Table 9 shows, the Followers tend to follow the announcement made by the human Leaders more often than they follow the announcement made by the computerized social planner, especially for low values of x that include the disagreement region. For example, in Game 1 when human Leaders announced value of x below 3 (the announcement which was made when x took values below 5), the Followers played action B 80% of the time. However, when the computer announced that " x is between 0.2 and 5" or " x is low" - the event which is informationally equivalent to stating x below 3 every time x takes values below 5 - the Followers played action B only about 50% of the time.

Conclusion 4 *Optimal strategies employed by the human Leaders perform (weakly) better than any of the communication strategies executed by the computerized Leaders.*

4.5 Computerized Leaders: Intervals versus Truth-Telling

The second observation that emerges from Table 8 is that the efficiency ranking of the truthful and intervals strategies depends on the relative size of the disagreement region as captured by Game 1 and Game 2. We will now investigate in more detail why this is the case.

Figures 5a and 5b present the fraction and the surplus efficiencies achieved by our subjects in Game 1 when the computerized Leader employed the truthful values strategy (Part I) and the intervals strategy (Part IV). The data is broken down into three intervals: one where the preferences of the Leader and the Followers coincide on (B,B), one where they disagree (Followers want (A,A) and

the Leader wants (B,B)), and one where their preferences coincide again on (A,A).

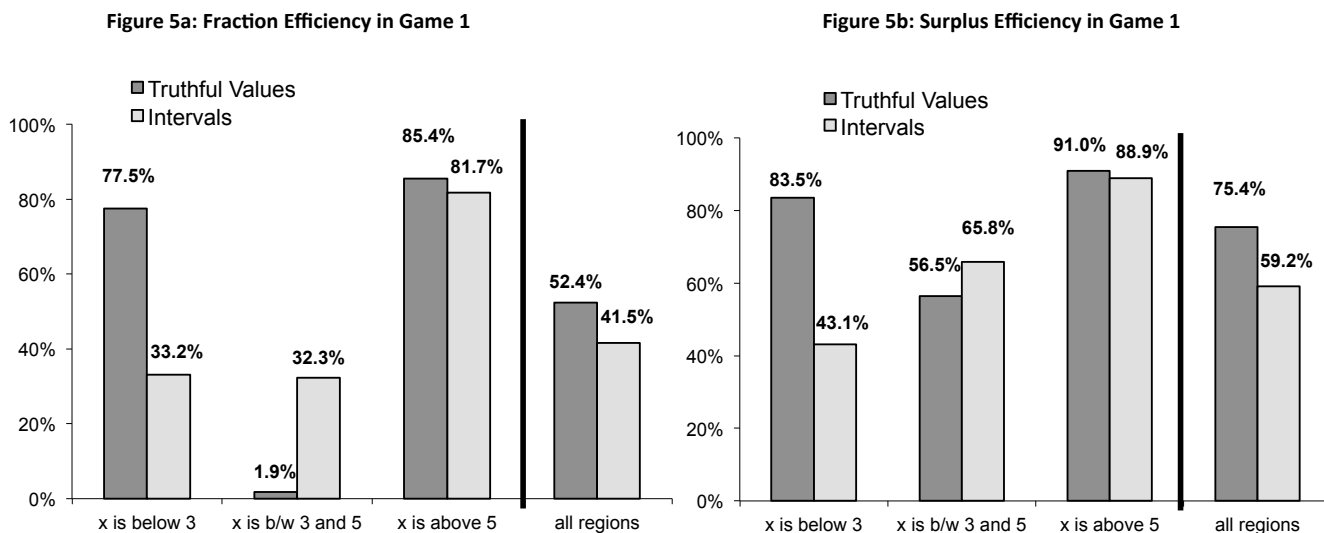


Figure 5: Truthful Values versus Intervals in Game 1

Figure 5a shows that for realizations of x in the region where the Leader would like to trick the Followers and get them to choose (B,B) (interval $(3, 5]$) the use of ambiguous intervals strongly outperforms the truthful reporting of values. While the optimal (B,B) outcome occurs 32.3% of the time when intervals are used, it only occurs 1.9% of the time when true values are reported. Hence being ambiguous does succeed in tricking the Followers exactly in the interval where the Leader wants to trick them. However, our results indicate that ambiguity is a two-edged sword. While in the disagreement region $[3, 5]$ ambiguity is desirable, in the region $[0.2, 3]$ precision is desirable since in that region the preferences of the Leader and the Followers coincide. Here ambiguity is a liability and in our game it is costly since in that region precise values strongly outperform the use of intervals (they choose (B,B) 77.5% of the time compared to only 33.2% of the time when intervals are announced). In other words, since the announcement " x is in the interval $[0.2, 5]$ " was used for all values in that interval, the Followers could not differentiate when the Leader wanted them to choose (B,B), because it was in their joint interest, from the times he was trying to trick them into doing it when they would otherwise choose (A,A), which is the Nash equilibrium in that region. More importantly, since that region where they were being tricked was relatively large, Followers often chose strategy A hoping that x would be realized in the disagreement region where that was a Nash choice. Over all intervals in Game 1, the advantages of being precise appear to outweigh those of being ambiguous and using intervals 52.4% to 41.5% using our FE index. This difference is significant at the 5% ($p = 0.001$).³¹

³¹This result is also seen in the surplus efficiency (Figure 5b) since over all intervals the surplus efficiency involved in using truthful values was 75.4% whereas it was only 59.2% when intervals were used, which is significantly less

One conjecture that explains why ambiguity failed in our Game 1 is that if the disagreement region had been smaller, then a Leader using an optimal announcement strategy would have had an easier time in tricking the Followers, since, although the Followers would know that he was trying to trick them part of the time, it would not be that often and therefore not worth deviating from the prescribed equilibrium.³² Figures 6a and 6b demonstrate that our conjecture is correct using Game 2: intervals strategy outperforms truthful values strategy when the disagreement region is relatively small.³³

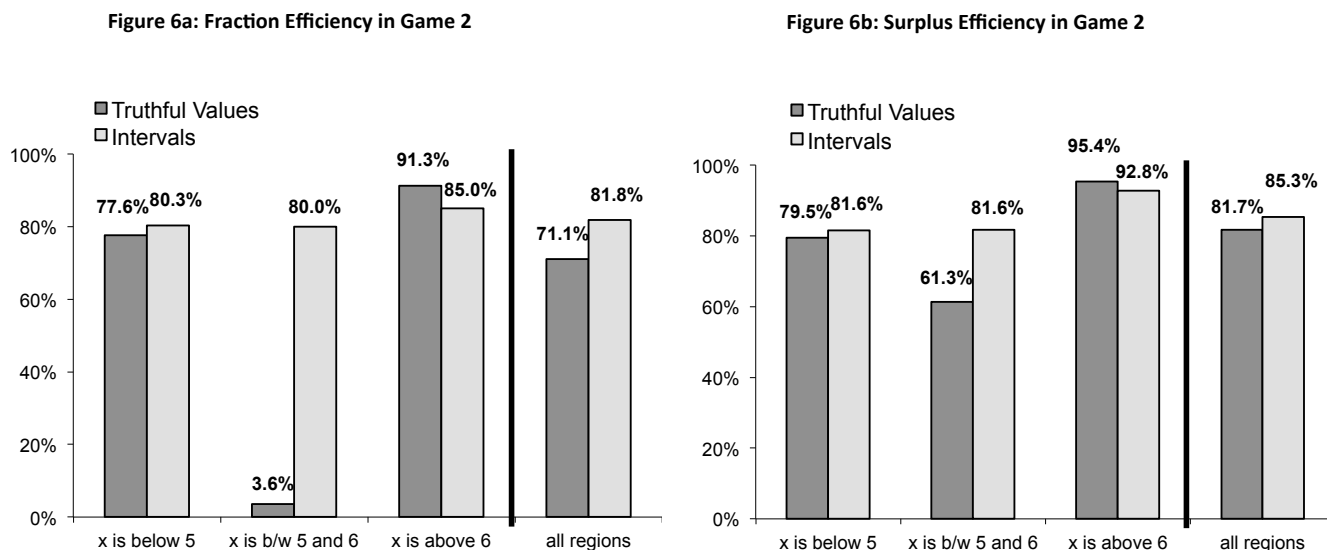


Figure 6: Truthful Values versus Intervals in Game 2

Our data from the computerized Leaders treatments show that ambiguity, at least in the form of intervals, may indeed be desirable but the conditions under which this is true are more behaviorally subtle than we had previously thought. These results echo the ones we observed in the human Leaders treatments (albeit the small number of groups, in which human Leaders used the truth-telling

($p < 0.001$).

³²Think of the case where the disagreement region was only $(4.8, 5]$. In this case, most of the time when the lower interval was announced the Players would know that they were not being tricked. Of course, the efficiency gain here would be small since the disagreement region is so tiny.

³³In Game 2 the advantages of being ambiguous are apparent. For instance, just as was true in Game 1, for realizations of x in the disagreement region $[5, 6]$, where ambiguity is desirable, the use of intervals far outperforms that of truthful values 80% to 3.6% and over all regions by 81.8% to 71.1%, using our FE index. This difference is significant ($p < 0.001$). The big difference is that in the region from 0 to 5, where the preferences of the Leader and the Followers agree, the intervals perform on par with the truthful values while they were dramatically worse in Game 1. Including the fact that in the upper region $[6, 9]$ we see almost equivalent results from both truthful values and intervals, we see that the overall result is that intervals outperform truthful values. With respect to the surplus measure, we observe the same qualitative result: intervals generate higher SE levels than truthful values (85.3% versus 81.7%), even though this difference is not statistically significant ($p = 0.114$).

strategy). As we discussed in section 4.1.3, optimal communication strategies employed by the human Leaders fail to outperform the truth-telling strategy in Game 1, in which the disagreement region is relatively big and at the same time achieved strictly higher efficiency levels in Game 2, in which the disagreement region is relatively small.

Conclusion 5 *When the disagreement region in the announcement game is relatively small, employing the interval strategy yields higher fraction and surplus efficiency levels than does the strategy of reporting the true value of x . On the other hand, when the disagreement region is relatively large, the interval strategies fail to be advantageous.*

4.6 Computerized Leaders: Optimal Communication Strategies

In this section we ask which of the optimal communication strategies executed by the computerized Leaders performs best.

Despite the common interpretation problem described above, it appears as if the overall performance of the Followers was equally efficient when either two words or intervals were used. For example, in Game 1 the overall fraction efficiencies when either the two words or the intervals were used were not significantly different from each other and both equal to 42% ($p = 0.944$). For Game 2 these percentages were 77% and 82% respectively for the two-words and the intervals; this difference is not statistically significant ($p = 0.119$). There is also no significant difference in the surplus efficiencies in both Games ($p = 0.454$ in Game 1 and $p = 0.144$ in Game 2).³⁴ Hence we see no difference in the performance of subjects when two words (minimal vocabularies) and intervals are used, which suggests that in our simple laboratory game the use of natural language does not seem to be a bar to efficiency.

The situation changes when we look at four words.³⁵ Here there is a definite decrease in efficiency when the Leader shifts from using two to using four words. More precisely, in Game 1 while the overall fraction efficiency for two-words was 42%, it fell to 30% when four words were used. This difference is significant ($p < 0.001$). In Game 2, the overall fraction efficiency for two-words was 77% and it fell to 61% when four words were used, which is significantly less ($p < 0.001$). The surplus efficiency measure follows the same trend: the use of the four words leads to a decrease in the captured surplus in both Games ($p = 0.006$ in Game 1 and $p < 0.001$ in Game 2).

We finish this section by noting that when human Leaders used optimal communication strategies they achieved fraction efficiencies of 62% and 82% and surplus efficiencies of 71% and 85% in Games

³⁴Further there appears to be no difference between the performance of the Followers over any sub-interval between 0.2 and 6.2 in Game 1 (or between 0 and 9 in Game 2) using both measures of efficiency. Results of these tests are omitted for brevity and available upon request from the authors.

³⁵Blume et al. (1998) also find that the performance of players may differ depending on the number of signals (or words) available for the Sender to use, although in their case the effect depends upon the relationship of the number of signals and the number of types existing for the Sender. In our game, in essence, the number of types is infinite.

1 and 2 respectively, which are (weakly) higher than any of the optimal communication strategies used by the computerized Leaders. This suggests that there is an added value to human Leaders beyond the partition of the state space underlying the communication strategy they use, which is not captured by the game-theoretic analysis of the announcement game.

Conclusion 6 *In the computerized Leaders treatments, words perform as well as intervals as long as the minimally optimal number of words is used. Excessive vocabularies (four words rather than two) cut down on the efficiency of words.*

4.7 Computerized Leaders: Common Interpretation of Words

While in equilibrium words and intervals should be equally efficient, when words are used subjects are faced with the additional challenge of converging to a common understanding of what they mean. In particular, in Game 1 (Game 2) while Follower 1 has a dominant strategy to choose action A when he believes that $x > 3$ ($x > 5$) and B otherwise, Follower 2's best response depends on the action of Follower 1. Put differently, Follower 2 faces a "common interpretation" problem when words are used. In the two-words treatment, what must become common knowledge is the cutoff that the computer uses to differentiate between those x signals that will be called "low" and those that will be called "high". Such common agreement involves two things: agreement on the cutoff used by the Leader, and agreement on what Follower 2 thinks Follower 1 thinks the cutoff used by the Leader is. The first asks if the Followers can recognize the optimal language when they hear it, while the second asks if Follower 2 knows that they are both speaking the same language (Follower 1 does not care what Follower 2 thinks since, given his dominant strategy, he only cares what the Leader means by "low" and "high"). In this section we are interested in comparing the performance of those Follower pairs that share a common interpretation of what words mean and those that fail to converge.³⁶

We focus on the two-words treatment and divide all pairs into two groups: those pairs that converged to the optimal two word vocabulary (i.e. the optimal cutoff value being used by the computer) by round 15 and those that did not. By convergence we mean that all three conditions below are satisfied:

1. Follower 1's assessment of the Leader's cutoff is within 5% (\pm) of what the Leader is using
2. Follower 2's assessment of the Leader's cutoff is within 5% (\pm) of what the Leader is using
3. Follower 2's assessment is within 5% (\pm) of what his/her pair member (Follower 1) thought.³⁷

³⁶The Followers could have a common interpretation of words without that interpretation being common knowledge. For instance, both Followers might have the correct belief about the cutoff between words "low" and "high" used by the computerized leader, but they both may believe that their pair-member thinks the cutoff is different. We don't observe many pairs that fall into this category in our experiments.

³⁷There were two pairs in Game 1 that converged to the wrong cutoff and one pair that did the same in Game 2. These pairs were classified as the non-converging pairs.

Table 10 presents each group’s performance over the last five rounds (rounds 16 – 20) of their interaction.

| Game 1 | | | Game 2 | | |
|-----------------------------|-------|-------|-----------------------------|-------|-------|
| | FE | SE | | FE | SE |
| Pairs that converged | 54.3% | 70.7% | Pairs that converged | 100% | 100% |
| Pairs that did not converge | 26.7% | 45.8% | Pairs that did not converge | 83.3% | 87.4% |

Table 10: Performance of converging and non-converging pairs in periods 16-20
convergence is determined at period 15

As Table 10 shows, those pairs that converged performed far better than those that did not. For example, in Game 1 those pairs that converged achieved an average fraction efficiency of 54.3% as opposed to those who did not, where the fraction efficiency was 26.7%. These percentages are significantly different at the 5% level ($p = 0.03$). For the surplus efficiency the numbers are 70.7% and 45.8%, respectively, which are significantly different at the 5% level ($p = 0.05$). The results are even stronger in Game 2 where converging pairs chose the surplus maximizing choice 100% of the time as opposed to only 83.3% of subjects who did not converge. The corresponding surplus efficiencies for converging and non-converging pairs in Game 2 are 100% and 87.4%, respectively. According to the Wilcoxon signrank test, fraction efficiency achieved by subjects who did not converge in Game 2 is significantly different from 100% ($p = 0.0467$); the same is true for the surplus efficiency of 87.4% ($p = 0.0467$).

Conclusion 7 *When two words were used by the computerized Leaders, those pairs of Followers who converged on a common and correct understanding of the vocabulary used performed better than those who did not.*

5 Related literature

The Announcement Game introduced in this paper is closely related to a Sender-Receiver cheap talk game (see Crawford-Sobel (1982)).³⁸ However, our announcement game differs from this game in two ways. First, instead of there being only one Receiver, in the Announcement Game there is a set of two Followers who receive the announcement of the Sender (the Leader) and play a 2-person finite strategy game whose payoffs depend on x . In other words, (some) Followers care not only about their own interpretation of the announcement but also about how the other Follower interprets the announcement and behaves upon hearing it. Second, the relationship between the preferences of the Sender (the Leader) and the Followers is more complicated since for some values of x preferences coincide while for others they diverge.

³⁸For an excellent survey of experimental work on communication see Crawford (1998).

There is a body of experimental papers that test predictions of Crawford-Sobel cheap talk games (see Dickhaut-McCabe-Mukherji (1995), Sopher-Zapater (1993) and Cai-Wang (2006) and Wang-Spezio-Camerer (2010)). Starting from the paper by Dickhaut-McCabe-Mukherji (1995) this literature finds that the main comparative statics of the model holds true; that is, more information is transmitted when the degree of conflict between the Sender and the Receiver is smaller. As we discussed in Section 4.1, Cai-Wang (2006) and Wang-Spezio-Camerer (2010) report that the Senders tend to reveal too much information to the Receivers relative to the equilibrium prediction and estimate level- k behavioral model that accounts for this trend.³⁹ Contrary to these papers we find that a vast majority of the Leaders communicate the optimal amount of information to the Followers and only about 10% of the Leaders truthfully reveal the value of x to the Followers. At the same time, consistent with these papers, we find that most of the Followers tend to believe announcements made by their Leaders.

Experimentally our paper is closely related to the seminal work of Blume-DeJong-Kim-Sprinkle (1998, 2001). In these papers the authors study finite signal Sender-Receiver games which are either common or divergent interest games (see Blume et al. (1998)) where the interests of the Sender and the Receiver are either aligned or opposite, or partial common interest games, (Blume et al. (2001)), where the interests of the Sender and the Receiver are more complicated and are aligned for some types and opposed for others. They investigate whether the Sender and Receiver converge on a separating or pooling equilibrium and demonstrate that this depends on the relationship between the number of signals available to be sent by the Announcer and the number of actions available to the Receiver. In addition they investigate whether the fact that the announcements made have a predetermined meaning, like $\{1, 2, 3, 4, 5\}$, or are meaningless, like $\{\%, \sim, *, \#\}$ and have to have meaning attached to them, has a consequence for how quickly the players converge on a common understanding of the message space being used. They discover that while there is no meaningful difference in the incidence of pooling or separating equilibria in these games, the players converge on their eventual equilibrium faster when there are preestablished meanings to the words used.

As Blume et al. (2001) suggest in the introduction, one of the difficulties of the experimental tests of the Crawford-Sobel cheap talk model is implementing continuous types (state space), messages and action spaces. To avoid this problem Blume et al discretize the type space by representing classes of types by a single type whose incentives represent those of a typical member in that class. We take a different approach. Our paper does the first step towards resolving this difficulty by implementing continuous state space in all our experiments: in Game 1 state of nature x is distributed uniformly between 0.2 and 6.2, while in Game 2 x is distributed uniformly between 0 and 9. Moreover, in the Strategic Values treatment, human Leaders are free to announce any value of x from the set of all possible states X after observing the actual realization of x , which means that the message space is continuous as well.

³⁹See also Gneezy (2005) that finds a trade-off between the benefits and costs of truthful communication

There are other noticeable connections between our results and those reported in Blume et al. (2001). We discuss below three such results. First, in both Blume et al. (2001) and our paper the pooling action was (almost) never observed: Blume et al. report that pooling action was never taken in the last five periods of play, while we detect only one human Leader that used babbling strategy in the Strategic Values treatment. Second, in both papers the partition of the state space that most of the Senders (Leaders) used is consistent with partial common interest (PCI) condition. This is the condition that Blume et al. introduce to analyze communication in the games with partial common interests. A partition of the state space satisfies the PCI condition, if for any subinterval of the partition, the types that belong to the same subinterval prefer to be identified as the members of this subinterval and there is no finer partition that satisfies this property. The PCI condition is much weaker than the equilibrium. Blume et al report that in the last five periods senders nearly always partition according to the PCI condition. Our results are similar: we observe more than 80% of the human Leaders using the communication strategies with the optimal partitions of the state space. Third, Blume et al document that frequency of observing the equilibrium play depends on the degree of the alignment of incentives between the Sender and the Receiver. In Game 2, in which there is only a slight departure from perfect incentive alignment, Blume et al report that 88% of the outcomes are consistent with a separating equilibrium. In Game 3, in which the misalignment is made more severe, this percentage is 50% for the separating equilibrium and 70% for the pooling equilibrium. At last, in Game 4, in which the misalignments of incentives are even stronger than in Game 3, only 37% of the outcomes are consistent with a partial pooling equilibrium and none with a pooling equilibrium. Consistent with these results, we find that the size of the disagreement region between the Leader and the Followers is negatively correlated with the efficiency achieved by the communication: in Game 2, in which the disagreement region is relatively small, human Leaders achieve fraction efficiency of 73% and surplus efficiency of 78%, while in Game 1, in which the disagreement region is relatively large, these percentages drop to 58% and 69%, respectively.

While our paper owes a great deal to the Blume et al. (1998, 2001) papers, there are some important differences. First, in our paper there is an additional layer of complexity resulting from the fact that our game is played with multiple Receivers (Followers), one of which cares not only about his/her own interpretation of the words being used by the Leader but also about the interpretation used by his/her opponent. This creates a common knowledge problem not present in Blume-DeJong-Kim-Sprinkle (1998, 2001). Second, the purpose of our paper is different than that of Blume et al. (1998, 2001) since we are neither interested here in how people attach meanings to symbols (although, as you saw, we do elicit the meaning subjects attach to the announcements made by our Leader) nor on whether they evolve a signaling or pooling equilibrium since in our game the pooling equilibrium is of little significance. We concentrate more on the efficiency achieved by different communication strategies. Despite these differences, however, we share a focus on the properties of language as used strategically in games.

Finally, there are three recent experimental papers by Dickson (2010), Serra-Garcia, van Damme and Potters (2012) and Agranov and Schotter (2012) that relate to our study. Dickson (2010) explores the effects of a leader's communications on followers' beliefs about the state of the world, which is known only to the leader. In his framework, followers are uncertain about the state of the world and upon hearing the message from the leader play a coordination game, the payoffs of which are state-dependent. Similar to our announcement game, the preferences of the leaders and those of the followers are only partially aligned: leaders sometimes have an incentive to misrepresent the state of the world in order to enhance coordination. Dickson finds that leaders' communication strongly influence followers' beliefs about the state of the world even when the rational updating dictates that these messages are not credible. In other words, followers seem to trust leaders' messages too much and not fully account for leaders' strategic incentives to misrepresent the state of the world.

Serra-Garcia-van Damme-Potters (2012) study the effects of communication in a sequential public good game. In their game, the leader has private information about the return from contributing to the public account and he contributes first; the follower observes the leader's choice before making his own. When the leader has a communication channel he can report the return precisely (not necessarily truthfully) or be vague about it. Revealing truthfully the exact return may distort the follower's incentives to invest. Thus, similar to our Announcement Game, in some states of the world the leader has an incentive to lie to the follower about the state of the world. Using vague messages allows the leader to avoid lying. The authors document that when leaders are forced to be precise, they lie in an optimal manner. However, when vague messages are allowed, leaders fail to optimally use them: vague messages are used more often in the disagreement than in the agreement region. This can potentially give followers a way to distinguish when leaders are trying to trick them, but such behavior was not observed in the experiment, in which followers often ignore vague messages and simply mimic the behavior of the leaders.

Finally, Agranov and Schotter (2012) study an Announcement Game with multiple equilibria. They demonstrate experimentally that in a coordination game with multiple equilibria, payoff asymmetries and aligned Sender-Receiver incentives, it may still be advantageous to communicate in a coarse manner. This is true because such coarse communication may be able to mask existing payoff asymmetries and thereby facilitate coordination if people find it hard to coordinate in games with unequal equilibrium payoffs.

With respect to other disciplines, there is considerable interest in vagueness and the vagueness properties of natural language among philosophers (see Sainsbury (1990), Fine (1975), and Keefe-Smith (1996) among others) and psychologists (see Erev-Wallsten-Neal (1991), Wallstein-Budescu-Rapoport-Zwick-Forsythe (1986) and Clark (1990)). Finally, Bart Lipman (2003) and (2006) theoretically investigates the vagueness properties of natural language. While Lipman focuses on the properties of vagueness in an equilibrium framework, we investigate how one achieves equilibrium

outcomes using vague communication strategies.

6 Conclusion

In this paper we investigate how a Leader (the Government) that has information in his possession that is payoff relevant for the individuals he governs (the Followers), should distribute this information. To shed light on this question, we experimentally study the performance of various communication strategies in the Announcement Games. These are the games in which one player, called the Leader, knows the value of the state of the world, x , and, upon seeing it, makes an announcement concerning its value to a set of Followers who then engage in a game of strategy whose payoffs depend on the true value of x . The Leader is a benevolent planner whose interests are to maximize the sum of the Followers' payoffs. We focus on announcement games, in which the preferences of the Leader and those of the Followers coincide for some values of x and diverge for the others and ask:

1. What form of communication between the Leader and the Followers is efficient where the efficiency is defined as maximizing the sum of the Followers' payoffs?
2. How does the performance of different communication strategies depend on the properties of the underlying announcement game and, in particular, the size of the disagreement region?
3. How effective are our subjects, when playing the role of the Leader (Government), in executing the optimal communication strategy?

In the experimental setting we consider several communication strategies, some performed by the subjects participating in the experiment and others performed by the computerized Leaders. We find that informed subjects (human Leaders) systematically and effectively conceal information and, in fact, more than 80% of them use the optimal communication strategy. The Followers tend to believe the announcement made by their Leaders. Moreover, human Leaders that employ one of the optimal communication strategies perform (weakly) better than any of the communication strategies executed by the computerized Leaders. For both human and computerized Leaders, the relative performance of truthful values and intervals strategies depends on the size of the disagreement region in the announcement game being played. When preferences of the Leader and the Followers differ over a relatively large portion of the state space, interval strategies, which are theoretically optimal, fail to outperform the truthful values strategies; however, when the disagreement region is relatively small, interval strategies achieve significantly higher efficiency levels than the truthful values strategy. We also find that words perform as well as intervals as long as the computerized Leader uses the minimum number of them to communicate. Finally, when the number of words used by the computerized Leader is small, subjects seem capable of solving the common interpretation problem they entail and those pairs that converged on a common meaning of the words performed better than those who did not.

Acknowledgements

This research was partially supported by grant SES: 0721111 of the National Science Foundation and also by the Center for Experimental Social Science at New York University. We'd like to thank Ariel Rubinstein, Kfir Eliaz, Guillaume Frechette, and anonymous referees for their help, and Anwar Ruff and Raj Advani for writing the computer program we used in our experiments.

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Appendix A - NOT FOR PUBLICATION

Instructions for Experiment 2

This is an experiment in decision-making. If you follow the instructions and make good decisions, you can earn a substantial amount of money, which will be paid to you at the end of the session.

The experiment consists of 20 identical decision rounds. At the beginning of the experiment you will be randomly matched with two other subjects participating in the experiment. One subject in your group will be assigned to be player GREEN; the other subject will be player RED and the third subject – player BLUE. At the top of the screen you will be told whether you are acting as player GREEN, RED or BLUE. Subjects in your group and the roles assigned to them will not change for the whole experiment. The identity of the subjects in your group will never be revealed to you and subjects in your group will never know your identity.

The currency in this experiment is called tokens. All payoffs are denominated in this currency. The total amount of tokens you earn in the experiment will be converted into US dollars and paid to you at the end of the experiment. For RED player the conversion rate is 7 tokens = \$1, for BLUE player the conversion rate is 15 tokens = \$1, for GREEN player the conversion rate is 22 tokens = \$1.

Your decision in each round.

Each round of this experiment has the following flow of events:

- At the beginning of each round the computer will choose a number between 0 and 9 at random with equal probability. This means that the probability that 1.5 is chosen is equal to the probability that 6.25 is chosen, which is equal to the probability that 7.7 is chosen, etc... We will call the random number chosen x .
- Number x chosen by the computer is observed only by the player GREEN. Players BLUE and RED don't get to see the value of x drawn.
- After GREEN observes the value of x , he makes an announcement about the value of x , which is observed by both RED and BLUE players. The announcement can be any number between 0 and 9.
- After the announcement is made, RED and BLUE each chooses one of two available options labeled A or B. Each subject (RED or BLUE) in the group will make his/her choice without knowing what the other subject chooses.
- The payoffs of all players in the group depend on the actual value of x chosen by the computer, and the choices made by players RED and BLUE. We will describe those in detail in

the next section.

Payoffs

The payoff of each subject in a particular round depends on the number x chosen by the computer, and the options chosen by the RED and BLUE players. The table below summarizes the payoffs of players RED and BLUE.

The payoff of player GREEN is the sum of the payoffs of RED and BLUE:

| | | RED choice | |
|-------------|----------|-----------------|-------------------------|
| | | option A | option B |
| BLUE choice | option A | $2x + 5, x + 5$ | $2.16x + 10, 5$ |
| | option B | $x + 10, 1.5x$ | $0.16x + 20, 10 - 0.5x$ |

Here is how to read this payoff table.

The table has four cells or boxes each determined by the choices made by BLUE and RED. For example, if BLUE and RED both choose option A, then payoffs are given by the cell in the upper left hand corner of the table. In this cell there are two payoffs, one on the left and one on the right. The first payoff, $(2 * x + 5)$, is the payoff to BLUE, while the second payoff, $(x + 5)$, is the payoff to RED (this is also indicated by the color of the payoff). The payoff of player GREEN is the sum of the payoffs of BLUE and RED: $2 * x + 5 + x + 5 = 3 * x + 10$. If BLUE chose option A and RED chose B, the relevant cell would be the upper right hand corner cell with payoff of $2.16 * x + 10$ to BLUE, 5 to RED and $2.16 * x + 15$ for GREEN.

The payoffs of all players depend on the x that was chosen by the computer. For example, say that player BLUE chose option A, player RED chose option A and the computer randomly chose $x = 5.5$. Then relevant payoffs are in the upper left hand corner of the matrix: BLUE gets $2 * 5.5 + 5 = 16$ tokens, RED gets $5.5 + 5 = 10.5$ tokens, and GREEN gets $16 + 10.5 = 26.5$ tokens. If, on the other hand, both BLUE and RED were to choose option B, then BLUE would get $0.16 * 5.5 + 20 = 20.88$ tokens, RED would get $10 - 0.5 * 5.5 = 7.25$ tokens and GREEN would get $20.88 + 7.25 = 28.13$ tokens. In other words, player GREEN gets higher payoff when $x = 5.5$ and both BLUE and RED players choose option B, than when they both choose option A.

Let's do one more example: say computer randomly chose $x = 8$ and both players BLUE and RED chose option A, then the relevant payoffs are in the upper left cell: BLUE will get $2 * 8 + 5 = 21$ tokens, RED will get $8 + 5 = 13$ tokens and GREEN will get $21 + 13 = 34$ tokens. If, instead, BLUE

were to choose option B, the relevant payoffs are in the bottom left cell: BLUE gets $8 + 10 = 18$ tokens, RED gets $1.5 * 8 = 12$ tokens and GREEN gets $18 + 12 = 30$ tokens. That is, GREEN gets a higher payoff when $x = 8$ and both BLUE and RED players choose option A, then when BLUE chooses B and RED chooses A.

However, RED and BLUE will not know the exact value of x before you get to choose between option A and B. Instead, they will observe an announcement describing x , made by GREEN.

Player GREEN can make any announcement describing the value of x . Recall that GREEN observes the actual value of x drawn randomly by the computer. Also, recall that the payoff of GREEN equals the sum of the payoffs of RED and BLUE, which depend on the actual value of x chosen by the computer and options chosen by RED and BLUE.

What your screen looks like:

On the top of the screen you will see whether you are acting as player BLUE, RED or GREEN. All players in the group will also observe the payoff matrix described above.

Player GREEN will also observe the actual value of x that the computer chose at random and the payoff matrix with the actual value of x substituted in. Before player GREEN will be prompted to make an announcement describing x , he will be able to use the built-in calculator. This calculator works as follows: for each value of x GREEN enters, it shows the payoff matrix with this x substituted in. This is the matrix that will be shown to BLUE and RED players if GREEN will choose to announce this value of x . GREEN can try as many values of x as he/she wants. When GREEN ready to make an announcement, he should simply press the “confirm announcement” button. Recall that announced x should be a number between 0 and 9.

Here is how the screen will look for player GREEN:

[SCREEN SHOT FOR PLAYER GREEN]

After announcement is made, BLUE and RED both see the announcement and they also see the payoff matrix with announced x substituted in. RED and BLUE then choose between option A and B by clicking on the box A or B on the bottom of the screen and then “confirm” button.

Here is how the screen for players BLUE and RED looks like:

[SCREEN SHOT FOR PLAYERS BLUE AND RED]

After both RED and BLUE have made their choices about option A or B, the following information will be observed by all players:

1. actual value of x chosen by computer
2. announced value of x made by GREEN
3. payoff matrix with ACTUAL value of x substituted in
4. cell with relevant payoffs, determined by the choices made by RED and BLUE

Then you will proceed to the next round which will be identical to the round you just finished, except that at the beginning of the new round a new value of x will be chosen.

Payment

The number of tokens you earn in this experiment will be converted to US dollars using the following conversion rates: If you are acting as player RED, the conversion rate is 7 tokens = \$1. If you are acting as player BLUE, the conversion rate is 15 tokens = \$1. If you are acting as player GREEN, the conversion rate is 22 tokens = \$1.

To summarize:

- Each round starts with the computer randomly choosing x between 0 and 9
- Player GREEN observes the actual value of x chosen by the computer
- Player GREEN makes an announcement describing the value of x
- Both RED and BLUE see the announcement, as well as the payoff matrix with announced x substituted in; then they have to choose between option A and B.
- After both RED and BLUE have made their choices, everyone gets to observe the actual value of x chosen by the computer, the announced value of x made by GREEN, the payoff matrix with the actual value of x substituted in and the relevant payoff cell determined by the choices made by RED and BLUE.
- The final payoffs of the subjects are determined by the payoff table described above. The payoffs of RED are indicated by the red color and the payoffs of BLUE are indicated by the color blue in the payoff matrix. The payoff of GREEN is equal to the sum of the payoffs of RED and BLUE.

Appendix B - NOT FOR PUBLICATION

Instructions for Experiment 3

This is an experiment in decision-making. If you follow the instructions and make good decisions, you can earn a substantial amount of money, which will be paid to you at the end of the session. The experiment in total consists of 4 parts, with 20 identical decision rounds in each part. Before the start of each part you will be given the instructions for the following 20 decision rounds of the experiment.

The currency in this experiment is called tokens. All payoffs are denominated in this currency. Your payment in the experiment will consist of several parts: you will earn tokens for each part of the experiment, the total amount of which will be converted into US dollars using the rate 29 tokens = \$1. Payments for each part of the experiment are independent of each other and will be described to you in detail in the instructions. You will receive all the payments at the end of the experiment.

At the beginning of each part of the experiment you will be randomly matched with one other person participating in the experiment. One person in your pair will be assigned to be subject 1 and the other subject 2. You will stay paired with this subject for the 20 rounds of this part of the experiment. The identity of the subject you are paired with will never be revealed to you and the subject you are paired with will never know your identity.

At the top of the screen you will be told whether you are acting as subject 1 or subject 2. If you were assigned to be subject 1 at the beginning of one part of the experiment you will remain subject 1 for the whole part of 20 rounds. After the part is over you will be re-matched randomly with another subject participating in the experiment. Again, one of the subjects in the pair will be assigned to be subject 1 and the other subject 2, and so on.

Instructions for the first part of the experiment.

Your decision in each round.

At the beginning of each round the computer will choose a number between 0.2 and 6.2 at random with equal probability. This means that the probability that 1.5 is chosen is equal to the probability that 4.25 is chosen, which is equal to the probability that 2.7 is chosen, etc... We will call the random number chosen x .

Your task in each round is to choose an option labeled A or B. The subject you are paired with also chooses between option A and option B. Each subject in the pair will make his/her choice without knowing what the other subject chooses.

Payoffs.

The payoff of each subject in a particular round depends on the number x chosen by the computer, and the options chosen by you and your opponent. The table below summarizes the payoffs of both subjects:

| | | subject 2 choice | |
|------------------|----------|------------------|--------------------------|
| | | option A | option B |
| subject 1 choice | option A | $2x + 3, x + 3$ | $2x + 8, 3$ |
| | option B | $x + 6, 1.5x$ | $1.75x + 8.75, 6 - 0.5x$ |

Here is how to read this payoff table. The table has four cells or boxes each determined by the choices made by subjects 1 and 2. For example, if Subject 1 and Subject 2 both choose option A, then the payoffs for each subject are given by the cell in the upper left hand corner of the table. In this cell there are two payoffs, one on the left and one on the right. The first payoff, $(2 \times x + 3)$, is the payoff to Subject 1 while the second payoff, $(x + 3)$, is the payoff to Subject 2. If Subject 1 chose option A and Subject 2 chose B, the relevant cell would be the upper right hand corner cell with payoffs to Subject 1 of $2 \times x + 8$ and payoffs to Subject 2 of 3.

Note that your payoff depends on the x that was chosen by the computer. For example, say you were assigned to be Subject 1 and chose option A. Say, also, that the subject you are paired with chose option B and the computer randomly chose $x = 3$. Then you will get the payoff in the upper right hand corner of the matrix, $2 \times 3 + 8 = 14$ tokens, while your pair member would get 3 tokens. If, on the other hand, you were to choose option B, while the subject you are paired with chose option A and the computer picked $x = 1$, then you would get $1 + 6 = 7$ tokens and your pair member would get $1.5 \times 1 = 1.5$ tokens.

Before you and the person you are paired with make the choice, you will both observe the number x that was picked by the computer. Also you will be shown the relevant payoff table with number x being substituted in the original payoff matrix described above. Then you will choose one of two options: A or B. You will finalize your choice by clicking the “Submit” button.

Information Feedback

After both you and the subject you are paired with have made your choices you will get to observe the actions taken by you and your pair member, and both of your payoffs. You will then proceed to the next round which will be identical to the round you just finished except that at the beginning of the new round a new value of x will be chosen and the associated payoff table shown to you. The x chosen for any given round will be independent of that chosen in any previous round. In other words, it will again be a number drawn with equal likelihood from the interval 0.2 to 6.2.

Payment for the first part of the experiment

To determine your payment for the first part of the experiment we will sum up the number of tokens you earned in each of 20 rounds. This number of tokens will become part of the total number of tokens you will earn in the experiment which will be converted into US dollars and paid to you at the end of the experiment.

To summarize:

- each round starts with the computer randomly choosing a number x between 0.2 and 6.2, and both you and the subject you are paired with will observe the value of x as well as the payoff matrix with number x being substituted in it;
- each subject in the pair, after observing the value of x and its associated payoff table, then chooses between option A or B
- the final payoffs of the subjects are determined by the payoff table described above (you will see the payoff table on the screen all the time)

Instructions for the second part of the experiment.

At the beginning of this part of the experiment you will be randomly re-matched with one other participant in the experiment. One of the subjects in the pair will be assigned to be subject 1, the other subject 2. You will stay paired with this subject for the 20 rounds of this part of the experiment. The identity of the subject you are paired with will never be revealed to you and the subject you are paired with will never know your identity.

Your decision in each round

In this part of the experiment everything stays the same as in part 1 except for one thing: the situation you are in is made more complex by the fact that you will not know the exact value of x before you get to choose between option A and B. Instead, you and the subject you are paired with will hear the announcement describing x .

This announcement will be made as follows: before the start of this part of the experiment, the computer will divide the interval, $[0.2, 6.2]$ from which number x is picked into 2 pieces or sub-intervals. The computer will attach a word to each piece which will be announced to both subjects before you are asked to make your choice of option. For example, say that the interval of possible values of x was divided in the following way: all numbers from 0.2 to 3.3 are in the group called “low”, whereas all numbers from 3.3 to 6.2 are in the group called “high”. (In this example let us call 3.3 the “cutoff value” for x). Hence, given this partition, if at the beginning of the round, the computer randomly picks number x which is smaller than 3.3 (say 0.9 or 2.4), the computer

will announce that x is “low”. If, on the other hand, x is greater than 3.3 (say 5.7 or 3.9) the computer will announce that x is “high”. Both you and your pair member will get to observe that announcement before making your choices, but you will not be told the cutoff value.

Note that with this example, if x was announced to be low, then x can be any number between 0.2 and 3.3 with equal chance. That is, $x = 1.3$ and $x = 3$ are equally likely when the announcement is “ x is low”. The same is true for the announcement “ x is high”: any number between 3.3 and 6.2 has the exact same chance of being the actual value of x .

The actual cutoff value used will not necessarily be 3.3; that value was just used for exposition. In the experiment the computer has been programmed to choose its cutoff value in a manner to maximize the sum of the payoffs of the players.

Information Feedback

After the announcement is made and both subjects have made their choices about option A or B, the value of x picked by the computer will be shown to you and your pair member as well as the options the two of you have chosen. This will allow you to determine your payoff which will also be shown to you on your screen. So, at the end of each round you will get to observe the value of x , the word used to describe it, the actions taken by you and your pair member, and both of your payoffs. When a round is over you will then proceed to the next round which will be identical to the round you just finished except that at the beginning of the new round a new value of x will be chosen and a new announcement about its value will be made. The cutoff value used will be the same for all 20 rounds in this part.

Finally, after every 5 rounds we are going to ask you 2 questions:

- what you think the cutoff value of the computer is, and
- what you think your pair member thinks the cutoff value used by the computer is.

This will be done as follows. On the separate screen that will appear after every 5 rounds you will be asked to choose where you think the cutoff point of the computer is. Say, you think that the computer announces “ x is low” whenever x is smaller than 3, otherwise (x is bigger than 3) the computer announces “ x is high”. Then you should choose number 3 as a cutoff value of the computer. Simply enter this number on the screen that will appear, press “Enter” and click the “Ok” button. Then you will observe the picture of the interval from 0.2 to 6.2 divided into 2 sub-intervals according to the cutoff point you just chose: the red colored interval will indicate the region for which you think the computer announces “ x is low”, and the blue colored region will indicate the region for which you think the computer announces “ x is high”. If you want to change your decision, you can change the cutoff value by clicking “Enter” and then click “Ok” again. Once you are happy with the partition you’ve chosen please click the “Submit” button.

The second question (what you think your pair member thinks the cutoff value used by the computer is) is done exactly in the same way: you need to choose the cutoff value you think your pair member chose. Note that you will not get to observe the partition chosen by other subjects and no other subject participating in the experiment will observe your choice of partition.

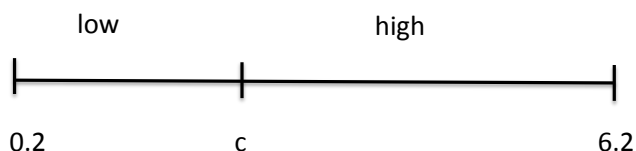
Payment for the second part of the experiment

The number of tokens you can earn in the second part of the experiment will consist of two parts: first, we will sum up the number of tokens you earned in each of 20 rounds. In addition, you will earn tokens for answering the two questions described above every five rounds. This will be done in the following way: say, you are answering the first question stated above which is “what cutoff value do you think the computer is using?” In other words, the question is asking you to state what you think the value of x is such that for any x below that value the computer will announce low and above which it will announce high. You will be prompted to answer this question. After you do we will compare your partition of the interval 0.2 to 6.2 to that actually used by the computer and pay you according to how close your partition, determined by your cutoff value, is to the partition used by the computer, determined by its cutoff value. We will do this according to the following formula:

$$\text{Payoff} = 12 - 0.33 \times (\text{your cutoff} - \text{computer's true cutoff})^2.$$

Note what this means. We will pay you a constant of 12 tokens but subtract from it the extent to which your cutoff value differed from that of the computer (the distance between them) squared times 0.33. So, if you guessed the computer's cutoff value correctly you will get 12 tokens (we will subtract nothing from you), but if you were completely wrong, i.e. if you said 6.2 while the computer was using a cutoff of 0.2 (or said 0.2 when the computer was using 6.2), you would receive 0 tokens.

Put differently, we are asking you to state a cutoff, call it the value c , which separates the region the computer (or the subject you are paired with) has associated with the word “low” and the word “high” as follows:



We have devised this scheme so that if you wanted to make the most amount of money in this part of the experiment, your best decision would be to state your truthful cutoff value, i.e. the one you truly believe the computer is using.

The exact same procedure will be used to elicit an answer from you to question 2, although here we will compare your answer not to the cutoff value used by the computer but rather to that used by your pair member when describing the cutoff point he thinks the computer is using. If you guessed this cutoff point correctly, then you will get 12 tokens, whereas if you were completely wrong you will get only 0 token. Again, given the payoff your best decision would be to state your truthful cutoff value, i.e. the one you truly believe the other subject is using.

You will repeat this procedure every five rounds.

The total number of tokens you receive in the second part of the experiment will be equal to the sum of your token payoffs in each round plus the sum of the tokens you received every five rounds when you tried to guess both the computer's and the other subject's cutoffs. This number of tokens will become part of the total number of tokens earned in the experiment which will be converted into US dollars and paid to you at the end of the experiment.

To summarize:

- each round starts with the computer randomly choosing a number x between 0.2 and 6.2 and, given the cutoff value used by the computer for the 20 rounds and the interval this number falls in, one of the two announcements, “ x is low” or “ x is high”, is made and observed by both subjects in the pair
- each subject in the pair, after hearing the announcement about x but without observing the actual number x picked by the computer, then chooses between option A or B
- the final payoffs of the subjects are determined by the payoff table described above (you will see the payoff table on the screen all the time) and the actual value of x chosen in that round
- both subjects then observe the actual value of x and the payoffs for this round
- after every 5 rounds you will be asked to state what you think the cutoff value of the computer is, and what you think your pair member thinks the cutoff value used by the computer is

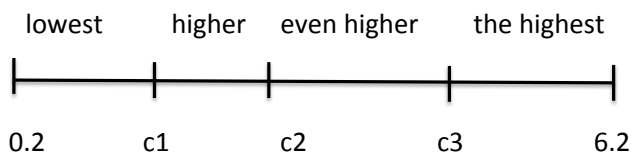
Instructions for the third part of the experiment.

At the beginning of this part of the experiment you will be randomly re-matched with one other participant in the experiment. One of the subjects in the pair will be assigned to be subject 1, the other subject 2. You will stay paired with this subject for the 20 rounds of this part of the experiment. The identity of the subject you are paired with will never be revealed to you and the subject you are paired with will never know your identity.

In this part of the experiment everything stays the same as in part 2 except for one feature. Before the start of this part of the experiment, the computer will divide the interval, $[0.2, 6.2]$ from which number x is picked into 4 (instead of 2) sub-intervals. To each of those sub-intervals a word describing this region will be attached and will stay the same for all 20 rounds of the third part. So, in each round you and the subject you are paired with will hear one of the following announcements: “ x is lowest”, “ x is higher”, “ x is even higher” or “ x is the highest”. Everything else stays the same.

To summarize:

- each round starts with the computer randomly choosing a number x between 0.2 and 6.2 and, depending on the cutoff value used by the computer and the interval this number falls in, one of the four announcements, “ x is lowest”, “ x is higher”, “ x is even higher” or “ x is the highest”, is made and observed by both subjects in the pair
- each subject in the pair, after hearing the announcement about x but without observing the actual number x picked by the computer, then chooses between option A or B
- the final payoffs of the subject are determined by the payoff table described above (you will see the payoff table on the screen all the time)
- both subjects then observe the actual value of x and the payoffs for this round
- after every 5 rounds you will be asked to state what you think the partition the computer uses is, and what you think your pair member thinks the partition the computer uses is. Your payoffs here will be identical to those described in part two of the experiment except that instead of stating one cutoff you will need to state three: one cutoff separating the “lowest” region from the “higher” region, one separating the “higher” region from the “even higher” region, and one separating the “even higher” region from the “highest” region. In other words, we are asking you to choose three numbers c_1, c_2, c_3 such that the following is true:



As in the previous part of the experiment, we will pay you for your guess as follows: let c_1^*, c_2^*, c_3^* be the cutoffs of the computer (or your pair member’s guess of the computer’s cutoff) and let c_1, c_2, c_3 be your guess. Then your payoff from guessing will be determined in an identical manner as we did in part two except for the fact that in this part you will have three cutoff values instead of

one. More precisely, your payoff will be determined as follows:

$$\text{Payoff} = 18 - 0.16 \times (c_1^* - c_1)^2 - 0.16 \times (c_2^* - c_2)^2 - 0.16 \times (c_3^* - c_3)^2.$$

Again, we have devised this scheme so that if you wanted to make the most amount of money in this part of the experiment your best decision would be to state your truthful cutoff value, i.e. the one you truly believe the computer is using.

Your payment for this part of the experiment will consist of 2 parts as in the second part of the experiment: the number of tokens you received in each round will be summed up and in addition you will be rewarded for stating partitions (the same way it was done before).

Instructions for the fourth part of the experiment.

At the beginning of this part of the experiment you will be randomly re-matched with one other participant in the experiment. One of the subjects in the pair will be assigned to be subject 1, the other subject 2. You will stay paired with this subject for the 20 rounds of this part of the experiment. The identity of the subject you are paired with will never be revealed to you and the subject you are paired with will never know your identity.

In this part of the experiment everything stays the same as in part 3 except for one feature. Before the start of this part of the experiment, the computer will divide the interval, $[0.2, 6.2]$ into, again, 2 sub-intervals: $[0.2, 5]$ and $[5, 6.2]$. But instead of announcing the word associated with each sub-interval, you will observe the interval itself. That is, if x is below 5 then you will observe the announcement " x is between 0.2 and 5" and if x is above 5 you will observe the announcement " x is between 5 and 6.2". Both you and your pair member will get to observe that announcement before making your choices.

Note that if x was announced to be in the interval $[0.2, 5]$ then x can be any number between 0.2 and 5 with equal chance. That is, $x = 1.3$ and $x = 3$, etc., are equally likely when the announcement is " x is between 0.2 and 5". The same is true for the announcement " x is between 5 and 6.2": any number between 5 and 6.2 has the exact same chance of being the actual value of x . Everything else stays the same.

To summarize:

- each round starts with the computer randomly choosing a number x between 0.2 and 6.2 and the computer announcing the interval that x falls in depending on the cutoff value chosen by the computer at the beginning of this part. This announcement is observed by both subjects in the pair

- each subject in the pair, after hearing the announcement about x but without observing the actual number x picked by the computer, then chooses between option A or B
- the final payoffs of the subjects are determined by the payoff table described above (you will see the payoff table on the screen all the time)
- both subjects then observe the actual value of x and the payoffs for this round

Your payment for this part of the experiment will consist of the sum of the payoffs you receive in each of the 20 rounds in part 4.

Total payoffs in the Entire Experiment.

Your final payoffs from participating in all four parts of the experiment will be the sum of your token payoffs in each part converted to dollars at the rate of 29 tokens = \$1.