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Ignorance Is Bliss: An Experimental Study of the Use of Ambiguity and Vagueness in the Coordination Games with Asymmetric Payoffs†

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We consider a game where one player, the Announcer, has to communicate the value of a payoff relevant state of the world to a set of players who play a coordination game with multiple equilibria. While the Announcer and the players agree that coordination is desirable, since the payoffs of the players at the equilibria are unequal, they disagree as to which equilibrium is best. We demonstrate experimentally that in such coordination games, in order to mask the asymmetry of equilibrium payoffs, it may be advantageous for a utilitarian benevolent Announcer to communicate in an ambiguous or vague manner. (*JEL* C71, D81, D83)

In this paper, we consider a game where one player, the Announcer, has to communicate the value of a payoff relevant state of the world to a set of other players who play a coordination game with multiple equilibria. While everyone, the Announcer and the players, agree that coordination is desirable, the payoffs of the players at the various equilibria are unequal, and thus players disagree as to which equilibrium they should coordinate on.

What we argue in this paper is that in such coordination games with multiple equilibria in which payoffs are asymmetric, it may be advantageous for a utilitarian benevolent Announcer to communicate in a coarse manner to the players when informing them of the value of payoff relevant states of the world. This can be beneficial because such coarse communication may be able to mask the existing payoff asymmetry and thereby facilitate coordination if people find it hard to coordinate in games with asymmetric (unequal) equilibrium payoffs (see Crawford, Gneezy, and Rottenstreich 2008).[1] As a result, our paper offers an additional reason for coarse communication beyond that offered by Crawford and Sobel (1982) since, in our game, the Announcer is communicating to a set of agents (rather than a single agent)

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[1] Even if Players get equal payoffs, the Announcer might find it beneficial to conceal the information regarding additional coordination opportunities if one is presently prominent. Introducing additional coordination opportunities might interfere with coordination and lead to a decrease in efficiency.

TABLE 1—COORDINATION GAMES FROM CRAWFORD, GNEEZY, AND ROTTENSTREICH (2008)

	Game 1			Game 2	
	Sears Tower	AT&T building		Sears Tower	AT&T building
Sears Tower	5 , 5 (81%)	0 , 0 (9%)	Sears Tower (36%)	5.1 , 5 (24%)	0 , 0
AT&T building	0 , 0 (9%)	5 , 5 (1%)	AT&T building	0 , 0 (24%)	5 , 5.1 (16%)

who interact strategically once they have received a message from the Announcer. In our setting, then, coarse communication is needed for both strategic and inequality aversion reasons.

To illustrate the problem, consider the two simple coordination games in Table 1, taken from Crawford, Gneezy, and Rottenstreich (2008). The numbers in parentheses report the fraction of time each cell was chosen.

Note two features of these games. First, the labels associated with the strategies are not neutral. For example, if the game is interpreted as having two tourists choose which location to meet at if separated in Chicago (i.e., Schelling 1960), then it is clear that the (Sears, Sears) equilibrium is a more salient location to meet at since that is a well-known landmark, while the AT&T building is not. Second, note that the games differ only in the fact that while all equilibrium payoffs are symmetric and equal in Game 1, in Game 2 the equilibrium payoffs have the typical Battle-of-the-Sexes payoff configuration, in which there is asymmetry (albeit extremely small) at the equilibrium for the players.

The interesting thing demonstrated by Crawford, Gneezy, and Rottenstreich (2008) is that, while in the absence of unequal payoffs in Game 1, players are successful in their ability to coordinate on the salient equilibrium (they do so 81 percent of the time and 82 percent overall), even small amounts of asymmetry (as in Game 2) dramatically diminish the power of saliency to help their subjects coordinate (the coordination rate on the salient equilibrium drops to only 36 percent and to 52 percent overall). In other words, the saliency of the strategy label is not strong enough to overcome the equilibrium payoff differences, even though they are quite small. Even slight payoff asymmetry is enough to overcome the usefulness of the focal equilibrium points that Schelling (1960) relied on to solve such coordination problems.

While Crawford, Gneezy, and Rottenstreich (2008) use a level-k analysis to explain these results, the question we ask here is what can be done to help our agents coordinate their actions and restore the power of the saliency to the labels employed? To answer this question we modify the typical sender-receiver cheap-talk game to include three players: an Announcer who observes a payoff relevant state of the world and announces it, and two Players who, upon hearing this announcement, play a coordination game with each other. The Announcer is able to choose the precision with which he communicates by using a more or less coarse information partition. Using a coarse information partition can mask the asymmetry of payoffs and make subjects believe that, on average, they are playing the game with equal payoffs. By doing this, people can go back to using the focal point to improve coordination as they do when the actual payoffs are equal.

In our experiments, we are interested in two related questions. The first focuses on the behavior of our Players and asks how they respond to Announcers using different types of announcement strategies. To answer this question, in some of our treatments (Treatments 1, 2, 3, and 6) we replace the Announcer with a computer who is instructed to use one of two different announcement strategies which vary according to their coarseness. What we demonstrate is that coarseness allows the Announcer to mask the equity concerns in the problem and allows the salient location to reemerge as the focal equilibrium.

In our computerized Announcer treatments, we investigate two types of coarse communication strategies: ambiguous intervals and vague words (natural language).[2] We compare their performance with a third communication strategy that fully reveals the payoffs of the game being played (truthful values). Ambiguous intervals achieve significantly higher coordination rates than the truthful values thereby determining that even when everyone, the Announcer and the players, agree that coordination is desirable, it may still be beneficial to make communication ambiguous. While the benefits of being vague are never as high as those associated with being ambiguous, our results do indicate that we lose relatively little by communicating in a vague manner (once subjects converge on the meaning of the words used). This is significant because it may indicate that our daily use of natural language is not necessarily efficiency decreasing.

After establishing the power of using coarse information we study its limitations. Our results indicate that the symmetry in expected payoffs triggers the use of focal points when coarse strategies are used. If, however, ambiguous or vague strategies leave even a minute amount of expected payoff asymmetry, then words (intervals) lose their beneficial aspects and we are right back where we started.

Our second question shifts our focus from the Players to the Announcers and, in a separate set of treatments, we replace the computerized Announcer with real human subjects. Here we ask whether ordinary subjects are capable of discovering how to optimally manipulate vagueness to their advantage and whether the substitution of real Announcers decreases the welfare achieved by the subjects.[3] What we find is that real human subjects are impressively creative in devising announcement strategies both when they are left free to do so (Treatment 5) and when they are restricted in the vocabulary they can use (Treatment 4). Overall, we find that a significant proportion of the subjects acting as senders (40 percent in Treatment 4 and 58 percent in Treatment 5) recognize the benefits of being vague and transmit the private information available to them in a coarse (vague) manner.

Our paper contributes to the growing experimental literature that investigates Schelling's (1960) idea of focal points in the context of pure coordination games. The first experimental study on this topic is Mehta, Starmer, and Sugden (1994a, 1994b), in which the authors show that labeling strategies using words or pictures can generate a much higher coordination rate than random play would suggest. In

[2] We use Fine (1975) to define the notion of ambiguous and vague statements. According to Fine (1975), ambiguous statements are the ones that have multiple meanings, while vague statements may be deficient in meaning unless one knows exactly where the boundaries between words lie.

[3] See also Agranov and Schotter (2011) for a discussion of communication strategies used by human Announcers in a different Announcement Game.

other words, players make beneficial use of the familiar labels of strategies. Blume and Gneezy (2000) examine the role of endogenous focal points in pure coordination games that lack a common description. Bosch-Domènech and Vriend (2008) show that a focal point that is itself not a Nash equilibrium and is Pareto dominated by all Nash equilibria, may still attract the players' choices. Dugar and Shahriar (2009) analyze the effectiveness of label-based focal points in Pareto-ranked coordination games. Bardsley et al. (2010) design an experiment to distinguish between two alternative explanations (cognitive hierarchy theory and the theory of team reasoning) of how players use focal points to select equilibria in one-shot coordination games. Bacharach and Bernasconi (1997) test experimentally the variable frame theory, according to which different subjects perceive objects of choice differently. In their experiment, objects vary in characteristics such as shape, color, and size, and while differences in some characteristics are easy to spot right away, others require subjects to "notice" them, which is more a matter of psychological perception than mathematical logic. The recent paper by Blume and Gneezy (2010) studies coordination games in which sophisticated players can arrive at the unique choice by using logical inferences. Authors carefully control for nonpayoff-related symmetries and find that players play differently against themselves than against other player.[4]

Our paper is also related to the literature that explores the ways to improve coordination in the Battle-of-the-Sexes games. The experimental literature has suggested several methods that can increase coordination rates in such games, for example: pre-play communication, the order of play and the presence of an outside option. Cooper et al. (1989) report that the coordination rate increases from 48 percent without communication to 95 percent with one-way pre-play communication and to 55 percent with two-way communication (see also Costa-Gomez 2002 for the interpretation of the experimental results of Cooper et al. 1989). Muller and Sadanand (2003) investigate the effects of order-of-play in the Battle-of-the-Sexes games and find that knowledge of the order of play affects the strategies chosen by participants and outcomes.[5] Cooper et al. (1993) study the game in which one of the two players has a choice between playing a Battle-of-the-Sexes game or instead receiving a predetermined payoff. They find limited support for the forward induction argument, according to which choosing to play the game is a signal about intended action.

Finally, our paper also relates to the literature that studies vagueness property of language. Lipman (2009) argues that one needs a model of bounded rationality to explain the use of vague terms in natural language. Blume and Board (2009) and De Jaegher (2003) show that communication with a vague language may mitigate conflict and thus increase welfare. Finally, Serra-Garcia, van Damme, and Potters (2011) experimentally study communication between leaders and followers in sequential public good games. They find that in some states of the world the leader

[4] The game we study in this paper differs from the ones studied by Bacharach and Bernasconi (1997) and by Blume and Gneezy (2010) in that there is no ambiguity about the focal point: Empire State Building is an obvious focal point in our coordination game.

[5] In Muller and Sadanand (2003), in the treatment in which a second-mover is not informed about the choice of the first-mover, subjects play the equilibrium in which the first-mover gets a higher payoff about 70 percent of the time. In the treatment in which the second-mover observes the choice of the first-mover they do that 87.5 percent of the time. These fractions represent a significant improvement in coordination rates compared to the cases where play is simultaneous (47 percent).

has an incentive to lie to the follower about the state of the world. Using vague messages however, allows the leader to avoid lying. The authors document that when leaders are forced to be precise they lie in an optimal manner. When vague messages are allowed, leaders fail to optimally use them.

In this paper we will proceed as follows. In Section I we will describe the setup of the game. In Section II we describe the design of our experiments. In Section III we state our hypotheses and in Section IV we present the results. Section V offers some conclusions.

I. Setup

Consider the following "Announcement Game" (see Agranov and Schotter 2011) played by three players: an Announcer (A) and two Players P_1 and P_2. In this game the first move is made by nature who randomly picks the value of a payoff relevant random variable, x—the State of Nature—from a known set of integers using a commonly known prior distribution $F[\cdot]$ which, for our purposes here, will be assumed to be uniform. After x is realized, the Announcer privately observes its value and makes a public announcement, m, which is commonly heard by the two Players in the game. Once an announcement about x is made, the Players are engaged in the finite simultaneous-move 2×2 game, $\Gamma(x)$, whose payoffs depend on the true value of x. The payoff of the Announcer is equal to the sum of the Players' payoffs; that is, the Announcer represents a benevolent planner in this game whose interests are to foster coordination.

In the experiment that follows, the game is phrased as a coordination game where the goal is to meet one's partner in either one of two places in New York City: the Empire State Building (ES) or the AXA building (AXA). They choose one of their two actions and payoffs are then determined. The game they play, $\Gamma(x)$, appears in Table 2.

Moreover, as we stated in the Introduction, in some treatments the announcer is a computer while in others it is a human subject. That is, in the computerized announcer treatment, after the value of x is drawn from the specified distribution, the computer makes an announcement describing the value of x according to one of the three communication strategies programmed by the software. We will discuss later which communication strategies were used by the computerized and real Announcers and what information was given to the subjects in each treatment.

Note that in the game $\Gamma(x)$ the payoffs depend on the value of x realized. As x varies over the set $\{1, 2, 3, 4\}$ we see $\Gamma(x)$ vary over the following four games in Table 3.

When x takes on the value of 1, 2, or 3 the game defined has the structure of a Battle-of-the-Sexes game while when $x = 4$ there is a unique Pareto optimal equilibrium. We included the $\Gamma(4)$ game only for technical purposes and hence will not spend much time discussing it.[6] Our main interest is in games $\Gamma(1) - \Gamma(3)$. In these games

[6] The reason we included $\Gamma(4)$ in the design was the following. Imagine the game described above where x takes on only values 1, 2, or 3 with equal chances. In that game, the Announcer who is aware of the coordination problem in games with asymmetric payoffs (see Crawford, Gneezy, and Rottenstreich 2008) would not announce anything upon learning the state of the world, because making any informative announcement will lead to inefficient miscoordination due to asymmetry in payoffs. Hence in such setting there is no place to distinguish between ambiguity

Table 2—The Game $\Gamma(x)$

	ES	AXA
ES	$4x + 1, x + 7$	0, 0
AXA	0, 0 if $x < 4$ 25, 25 if $x = 4$	$x + 7, 4x + 1$

Table 3—The Games $\Gamma(1)$, $\Gamma(2)$, $\Gamma(3)$, and $\Gamma(4)$

	The Game $\Gamma(1)$ ES	AXA		The Game $\Gamma(2)$ ES	AXA
ES	5, 8	0, 0	ES	9, 9	0, 0
AXA	0, 0	8, 5	AXA	0, 0	9, 9
	The Game $\Gamma(3)$ ES	**AXA**		**The Game $\Gamma(4)$ ES**	**AXA**
ES	13, 10	0, 0	ES	17, 11	0, 0
AXA	0, 0	10, 13	AXA	25, 25	11, 17

notice that only in the middle game, where $x = 2$, are the equilibrium payoffs equal so if the players knew that $x = 2$, while the players still face a game with two equilibria, the payoffs at those equilibria would be the same so no equity issues exist. Moreover, the strategies are labeled in a particular way so that one meeting place is focal, the Empire State Building, while the other is not, the AXA building. We do this because as Crawford, Gneezy, and Rottenstreich (2008) have demonstrated, when there are no payoffs asymmetry (equity concerns), players are easily able to coordinate around the focal equilibrium and choose Empire State. However, as we have seen above, they also demonstrate that even the slightest introduction of payoff asymmetry leads people to ignore the salience of the focal equilibrium and have trouble coordinating. When $x = 1$ or $x = 3$, the asymmetry issue raises its head and a tension arises as to which equilibrium strategy to choose. Such tensions have been shown to inhibit equilibrium coordination as we have seen in the Crawford, Gneezy, and Rottenstreich (2008) results above and Cooper et al. (1993).

A. *How Coarse Information Can Enhance Coordination*

We start by demonstrating that transmitting the value of x using a coarse partition allows the Announcer to mask the payoff asymmetry in the Announcement game described above and allows the salient location to reemerge as the focal equilibrium. The idea is to make the Players think that *on average* they are playing the game with symmetric payoffs, in which case they can go back to using the focal point to improve coordination as they do when the actual payoffs are symmetric.

and vagueness. The existence of $x = 4$ makes the game more interesting and the role of the Announcer relevant, as he/she is faced with the question of how to partially transmit the information about x in order to separate between games with multiple ($x < 4$) and unique ($x = 4$) equilibria and also to avoid mis-coordination due to the asymmetric payoffs when $x < 4$.

Consider the following communication strategy of the Announcer, which we will call an Intervals strategy. According to this strategy the Announcer would announce "x is 1, 2, or 3" if in fact $x \in \{1, 2, 3\}$, or "x is 4" if $x = 4$. Note that when the former announcement is made, the expected value of x is 2 and so, on average, the Players can expect to be playing $\Gamma(2)$ whose equilibria yield a payoff of 9 to each Player. Playing $\Gamma(2)$ does not solve the coordination problem for the subjects since there are still two equilibria, but it does give them a common interest in coordinating since there are no equity concerns raised by the asymmetry in payoffs. We would therefore expect the Players to coordinate on the Empire State Building since it is focal.

The Intervals strategy described here is not the only coarse communication strategy that can mask the payoffs asymmetry. Consider, for example, the following Words strategy: "x is low" is announced when $x \in \{1, 2, 3\}$ and "x is high" is announced when $x = 4$. This Words strategy is similar to the Intervals strategy except instead of announcing a sub-interval into which x falls, the Announcer uses words (natural language) from a pre-selected vocabulary. The difference between using words (i.e., "x is low" and "x is high") instead of intervals (i.e., "x is 1, 2, or 3" and "x is 4") is the difference between an attempt to be vague instead of ambiguous. According to Fine (1975) a statement is vague if it is deficient in meaning while it is ambiguous if it lacks a unique interpretation. In our case, a statement "x is 1, 2, or 3" is ambiguous because it does not have a unique meaning, i.e., x could be one of three values, while a statement that "x is low" has no meaning at all because we have no idea of where the boundary between one potential word used starts and another ends. For example, if a two word vocabulary, "low" and "high" is used, stating that x was "low" tells us nothing unless we know where the dividing line is between "low" and "high."

Of course once subjects reach a common understanding of the cutoff point between the words "low" and "high," the words become identical to the ambiguous intervals, due to Fine's (1975) definition.

In the computerized Announcer treatments that follow, we will compare the performance of the three types of communication strategies used by the computerized Announcer:

- the **Values** strategy according to which the computer truthfully reports the true value of x drawn at the beginning of the game;
- the **Intervals** strategy according to which the computer announces "x is 1, 2, or 3" when $x \in \{1, 2, 3\}$ and "x is 4" when $x = 4$; and
- the **Words** strategy according to which the computer announces "x is low" when $x \in \{1, 2, 3\}$ and "x is high" when $x = 4$.

If we can demonstrate that our three person society achieves higher payoffs when coarse communication strategies (such as intervals or words) are used than when true values are used, and if we link the poor performance in the true Values treatment to the payoffs asymmetry, then we think we have demonstrated a rationale for using coarse information even when everyone, the Announcer and the players, agree that coordination is desirable.

B. *Real Announcers*

Our computerized treatments focus on the behavior of the Players and their ability to coordinate given pre-determined (and optimal) computerized (word and interval) announcement strategies. The idea behind the computerized treatments is that in the real world Announcers are likely to be sophisticated institutional agents who should be capable of employing the optimal degree of vagueness or ambiguity. The obvious question is whether "normal people" functioning as Announcers would be capable of figuring out how to communicate in a sophisticated manner. To investigate this question we run two treatments with real announcers where they are limited in the vocabulary we allow them to use. In one treatment (Treatment 4) our laboratory announcers are only able to announce values to describe the values of x they observe. In other words, they are allowed to make statements such as "x is 2" or "x is 4." In Treatment 5, on the other hand, they are capable of announcing that x is one of any combination of values. For example, in Treatment 5 an announcer can announce "x is 1 or 2" or "x is 1, 2, or 3," etc.

Note that while the vocabulary in Treatment 4 appears to be restrictive, it is actually at least as flexible as the word strategy used by our computerized Announcers since a strategy of announcing say "x is 1" whenever x is 1, 2, or 3, and "x is 4" when x is 4 is equivalent to an optimal Words strategy where "x is 1" replaces "x is low" and "x is 4" replaces "x is high." Likewise our vocabulary in Treatment 5 can easily replicate an interval strategy as described before.

As a result, the vocabularies available to our subjects permit a considerable amount of strategic flexibility and our goal in running Treatment 4 and 5 is to see how creative subjects are in discovering the optimal way to use them.

C. *Limitations of Coarse Information*

After establishing the power of using coarse information we study its limitations. We will address the following questions: What is the necessary condition for coarse information to facilitate coordination? What property of coarse information triggers the use of the focal points?

There are two possible explanations for why the Intervals or the Words strategies discussed in the previous section may help coordination. The first explanation suggests that it is the uncertainty about the game being played that triggers the use of focal points. In other words, when the Players observe message "x is 1, 2, or 3" or "x is low," they know that they are playing one of three possible games, but they don't know which one. One might hypothesize that in this circumstance, Players resort to playing the focal equilibrium as it is the only common feature in all three games, each of which is a candidate for the actual game being played. The second explanation attributes the use of the focal strategies to the equity of the expected payoffs that the Players face when the Announcer reports "x is 1, 2, or 3" or "x is low." Indeed, when "x is 1, 2, or 3" or "x is low" is reported, the Players may correctly anticipate that *on average* they are playing the game with symmetric payoffs. In other words, the labels of the strategies become prominent only when actual or expected payoffs of both Players in both equilibria are symmetric.

Table 4—The Game $\Gamma(11/6)$

	ES	AXA
ES	$50/6$, $53/6$	0, 0
AXA	0, 0	$53/6$, $50/6$

To distinguish the two proposed mechanisms, we study a modification of the Announcement Game described above, in which everything is the same except x takes values $\{1, 3/2, 3, 4\}$ with equal probabilities instead of $\{1, 2, 3, 4\}$. In this modified game, when the computerized Announcer reports "x is 1, 3/2, or 3" the Players can expect to play the game shown in Table 4.

In other words, using a coarse partition to report the value of x does not eliminate asymmetry in expected terms: the Players are still faced with the multiple-equilibria game in which they get unequal expected payoffs at the various equilibria. If the uncertainty about the game being played is what triggers the use of the focal point, then we should observe similar coordination rates on the (ES, ES) equilibrium when "x is low" is reported in both the Words and the $\text{Words}_{\text{modified}}$ treatments. If, however, focal points are triggered only when Players face a game with symmetric expected payoffs, then after the announcement "x is low," the (ES, ES) equilibrium will be played less often in the $\text{Words}_{\text{modified}}$ treatment compared with the Words treatment.

II. Experimental Procedures and Design

All of the treatments were run at the laboratory of the Center for Experimental Social Science (CESS) at New York University. In total 279 subjects participated, drawn from the general undergraduate population in the university by e-mail solicitations. Each treatment lasted approximately 1 hour and average payoffs were $25.

In all treatments, subjects arrived at the lab and were divided into groups of two or three depending on whether the Announcer was real or computerized in the treatment they performed. Those subjects designated as Players were assigned to be either Player 1 or Player 2. The role of the Announcer was performed either by a computer (Treatments 1–3 and 6) or by a third subject (Treatments 4–5). If the Announcer was computerized the computer would transmit the value of x in either a vague, ambiguous, or precise manner. The identity of the subjects they were paired with was not known to the subjects. Each session was performed with a set of different subjects.

Let us concentrate on the computerized treatments first. In all these treatments, a strangers protocol was used so after each round of the 40 round experiment subjects were randomly allocated a new pair member.[7] All four treatments with computerized Announcers consisted of two parts. In the Values-Intervals experiment the subjects first engaged in the $\Gamma(x)$ game for 20 rounds during which time the computerized

[7] Subjects were paid based on the total amount of tokens earned on all rounds of the experiment, which was converted into US dollars using the rate 20 tokens = $1. In addition, subjects received $5 participation fee for completing the experiment.

Announcer announced the true value of x before each round.[8] This was done to allow us to see how well people were able to coordinate when they saw the actual game they were playing complete with its inequitable equilibria (at least when $x \neq 2$). After playing this game 20 times, the subjects then played $\Gamma(x)$ but this time the Announcer used an interval strategy to communicate. In this strategy the Announcer would either announce "x is 1, 2, or 3" if in fact $x \in \{1,2,3\}$, or $x = 4$ otherwise. This strategy of the Announcer was common knowledge amongst the subjects and at the end of each round subjects learned the actual value of x.[9]

In the Intervals-Values experiment everything was the same as in the Values-Interval experiment except for the order of the announcement strategies used by the computerized Announcer. Subjects first played the game in which the Announcer used the interval strategy described above for 20 rounds they played the game in which the true value of x was announced before each round for 20 rounds. This treatment was done to investigate whether there is an order effect for treatments.

The Values-Words experiment was identical to the Values-Intervals experiment except for the fact that instead of using interval strategies in the second 20 rounds, the computerized Announcer used words as a communication device. Here the announcement strategy was to announce "x is low" if $x \in \{1,2,3\}$ and "x is high" if $x = 4$. This strategy was not known to the subjects so they had to figure out the vocabulary of the Announcer, but they did know that he was using a fixed language which did not vary during the treatment. As before, at the end of each round subjects learned the actual value of x.

Our two Human-Announcer treatments were identical to our computerized ones except for the fact that the computerized Announcer was replaced with a real human subject whose task was to announce the value of x to two other Players after observing it. Subjects that participated in this treatment were randomly divided into groups of three. One of the subjects in each group was assigned to be an Announcer and the other two subjects were assigned to be Players 1 and 2. Subjects stayed in the same groups and kept the same roles for the whole duration of the treatment. At the beginning of each round, the Announcer observed the value of x drawn by the computer from the set $\{1,2,3,4\}$ and chose what announcement to make to Players 1 and 2 as described above. In Treatment 4 the strategy space of the Announcer was restricted in that the Announcer could report a single value of x to the other Players. Hence, an announcement "x is 3" or "x is 2" could be made but not more complicated statements such as "x is 2 or 3" or "x is 1, 2, or 3." After hearing the announcement the Players played the game $\Gamma(x)$. At the end of each round, all subjects learned the true value of x, the announced value of x, as well as their payoffs. While this strategy space appears to be restrictive, as we will see later, it actually allowed for a wide variety of strategies on the part of the Announcer allowing him, to replicate the word strategies used by the computerized Announcers discussed above.

In Treatment 5 we allowed our human announcers a larger vocabulary by allowing them to make compound statements where they could use any combination of

[8] The value of x was drawn independently in each session, in each round and for each pair.

[9] The complete instructions for the Values-Intervals experiment are presented in online Appendix A.

values in their announcements such as "x is 2 or 3" or "x is 1, 2, or 3" etc. We ran these treatments to study whether we can expect human Announcers to opt for the coarse communication strategy anticipating that this strategy could enhance coordination by masking payoff asymmetries. We ran Treatment 5 to see if allowing greater strategic freedom on the part of the Announcer could enhance the welfare of our subjects.

The reason we used fixed matching in the human Announcers treatments is that subjects have to establish the convention of what the announcements mean in order to have a shot at reaching coordination when hearing those announcements. If one constantly changes players and announcers, it becomes extremely hard to interpret and learn the meaning of the announcements made. Moreover, as we see in our data, different Announcers used different announcement strategies, the performance of which would be hard to assess if we were to implement a random matching design. While repeated game behavior is a legitimate concern when fixed matching is used, in our results we do not see that such behavior played any significant role.

To test the limits of course communication, we also run the Values-Words modified experiment, which was identical to the Values-Words experiment except that x—the State of Nature—took values $\{1, 3/2, 3, 4\}$ with equal probability instead of $\{1, 2, 3, 4\}$. In the first 20 rounds of this treatment the true value of x was announced before each round and in the last 20 rounds the following Words strategy was used to communicate value of x: "x is low" if $x \in \{1, 3/2, 3\}$ and "x is high" if $x = 4$.[10]

Our experimental design is summarized in Table 5.

For the analysis of the experimental data, we will often refer to the six treatments: Values, Intervals, Words, $\text{Words}_{\text{modified}}$, Restricted, and Unrestricted Human Announcers treatments.

III. Hypotheses

Given our discussion above we can define a set of hypotheses that can be tested using the data generated by our experiment. We will first state the hypotheses related to our Computerized-Announcer treatments (Treatments 1–3) and then our Human-Announcer treatments (Treatments 4 and 5). Hypothesis 7 returns to the Computerized-Announcer treatment (Treatment 6) to investigate the impact of asymmetric payments in the "modified game."

Computerized-Announcers Hypotheses: We use the Values treatment to replicate the results of Crawford, Gneezy, and Rottenstreich (2008). In their paper they demonstrate that when no equity concerns exist and some strategy is made focal by labeling (as in our Empire State Building strategy) then subjects are capable of using the focal strategy as a coordination device. In our experiment this implies that when $x = 2$ we should see far more successful coordination on the (ES, ES)

[10] In the Values-Words modified treatment, as well as in any other treatment, subjects were not told the expected value of x and had no access to calculators or computational aids. There was a technical problem with one of the sessions in this treatment. This is why we have only 18 rounds in the values part of one of the sessions as opposed to 20 rounds.

Table 5—Experimental Design

Treatment (# of sessions)	State of nature	Sequence	Announcer	# of subjects
Treatment 1 Values-Intervals (3 sessions)	$x \in \{1,2,3,4\}$	20 rounds–value of x announced 20 rounds–intervals strategy "x is 1, 2, or 3" if $x \in \{1,2,3\}$ "x is 4" if $x = 4$	Computer	50
Treatment 2 Intervals-Values (2 sessions)	$x \in \{1,2,3,4\}$	20 rounds–intervals strategy "x is 1, 2, or 3" if $x \in \{1,2,3\}$ "x is 4" if $x = 4$ 20 rounds–value of x announced	Computer	32
Treatment 3 Values-Words (2 sessions)	$x \in \{1,2,3,4\}$	20 rounds–value of x announced 20 rounds–words strategy "x is low" if $x \in \{1,2,3\}$ "x is high" if $x = 4$	Computer	44
Treatment 4 Real announcers values only (3 sessions)	$x \in \{1,2,3,4\}$	20 rounds	Real subjects	48
Treatment 5 Real announcers unrestricted (4 sessions)	$x \in \{1,2,3,4\}$	20 rounds	Real subjects	63
Treatment 6 Values-Words modified (2 sessions)	$x \in \{1,3/2,3,4\}$	20 rounds–value of x announced 20 rounds–words strategy "x is low" if $x \in \{1,3/2,3\}$ "x is high" if $x = 4$	Computer	42

equilibrium than when $x = 1$ or $x = 3$. This conjecture is summarized by the following hypothesis.

HYPOTHESIS 1: *"Coordination Failure with Asymmetric Payoffs." In the Values treatment, subjects play the (ES, ES) equilibrium more often when $x = 2$ is announced than when $x = 1$ or $x = 3$ is announced.*

The trick of using partial information is then to make subjects think that, on average, they are playing $\Gamma(2)$ and hence increase coordination. This, of course, relies on them playing the same way when x is known to be equal to 2 as when they only expect to be playing $\Gamma(2)$ due to the ambiguous announcement made. This yields the second hypothesis.

HYPOTHESIS 2: *"Coarse Information Increases Efficiency." Subjects play the (ES, ES) equilibrium equally often when $x = 2$ is reported in the Values treatment and when "x is 1, 2, or 3" is reported in the Intervals treatment.*

As Hypothesis 2 states, we expect intervals to perform well because not only does it mask the asymmetric payoffs (inequity problem) but also, while ambiguous, it is still precise about the range of values that x can take in any round. Because words are vague, they require that the Players reach an understanding about what those words mean. This is potentially harder, so we would expect that before such a common understanding is reached, words should perform worse than intervals. However, after our subjects come to a common understanding of what the words mean, i.e., where the cutoff is between "low" and "high," there should be no difference between the performance of the intervals and the words. This leads us to the third hypothesis.

HYPOTHESIS 3: *"Vagueness versus Ambiguity." The Words strategy performs worse than the Interval strategy at the beginning of the experiment, however, the performance of the Words and the Interval strategies is comparable by the end of the experiment.*

Human Announcers Hypotheses: As we indicated in our Introduction, we introduced the Human Announcer treatment in order to get an insight into whether human subjects would be adept at using the strategic freedom we give them to mask the states of nature they observe in a welfare enhancing manner. This leads us to three hypotheses.

HYPOTHESIS 4: *"Announcement Strategies." When human announcers are free to announce either any values of x (as in Treatment 4) or any combination of values of x that they wish (as in Treatment 5), they opt for nontruth telling strategies by using strategies that are noninvertible.*

HYPOTHESIS 5: *"Invertible vs Noninvertible Strategies." Announcers that used invertible announcement strategies achieved lower welfare than those that used noninvertible strategies to mask inequality in payoffs.*

HYPOTHESIS 6: *"Strategic Freedom vs Restrictions." The efficiency of Announcers is no greater in Treatment 4 where they are restricted by having to announce values than in Treatment 5 where they have more strategic freedom.*

For our final hypothesis we return to our Computerized announcement treatment and investigate the impact of payoff asymmetries on behavior. As we will be shown the frequency of (ES, ES) equilibrium play is the same in the last five rounds of the Words and the Intervals treatments when "x is low" or "x is 1, 2, or 3" are announced. This suggests that when vagueness or ambiguity is used to mask the true state of the world and when the expected payoffs implied by this camouflage are symmetric, both words and intervals are equivalent. However, we expect that a small change of the underlying distribution of the State of Nature (as in the Values-Words modified treatment) may significantly change the coordination rates. If this is true, then it would imply that what triggers the use of the focal points is not the uncertainty about the game being played, but rather the symmetry of the expected payoffs.

HYPOTHESIS 7: *"Equality in Expectations." Subjects play the (ES, ES) equilibrium more often in the Words than in the $Words_{\text{modified}}$ treatment when "x is low" is announced.*

IV. Results

In this section we will describe the results by investigating each of our seven hypotheses in sequence.

Table 6—Distribution of Outcomes in the Values Treatment

	Values: $x = 1$ (307 obs)			Values: $x = 2$ (328 obs)			Values: $x = 3$ (301 obs)	
	ES	AXA		ES	AXA		ES	AXA
ES	33%	24%	ES	81%	9%	ES	41%	21%
AXA	32%	11%	AXA	9%	1%	AXA	25%	13%

HYPOTHESIS 1: *"Coordination Failure with Asymmetric Payoffs."*

Hypothesis 1 asks whether in the Values treatment, where the true value of x was announced, the incidence of coordination on the (ES, ES) equilibrium is less when $x = 1$ or $x = 3$ is reported than when $x = 2$ is reported. Table 6 reports the distribution of outcomes in the Values treatment for different announcements. To construct Table 6, and all other relevant tables, we pooled observations from the first 20 rounds of the Values-Words and the Values-Intervals experiments as well as the last 20 rounds of the Intervals-Values experiments. The same qualitative results can be obtained by looking separately at the experiments in which the Values treatment was performed before and after the Intervals treatment. In other words, we find no order of treatments effect by comparing the data from the Values-Intervals and the Intervals-Values experiments. In both the Values-Intervals and the Intervals-Values experiments the incidence of coordination on the (ES, ES) equilibrium was significantly higher when $x = 2$ was reported than when $x = 1$ or $x = 3$ was reported. Kolmogorov-Smirnov test cannot reject the null that the distribution of outcomes played in the Values-Intervals experiment was the same as the one in the Intervals-Values experiment for every value of x reported ($p > 0.1$ in all cases).

As we see in Table 6, when $x = 1$ ($x = 3$) was announced subjects coordinated on the (ES, ES) equilibrium 33 percent (41 percent) of times, while the same coordination rate was 81 percent when $x = 2$ was announced.[11] It is important to point out that this result is a function of two things, the equity of the payoffs when $x = 2$ and the labeling of the strategies.

To perform statistical analysis we will construct the measure that indicates how often each subject chose focal strategy Empire State when various announcements were made by the computerized Announcer (one observation per subject). Figure 1 below depicts the histograms of this measure for $x = 1$, $x = 2$, and $x = 3$ (there are 126 observations in each histogram).

Remarkably, when $x = 2$ was announced, 80 percent of subjects *always* played the focal strategy ES, while there is a disperse distribution for $x = 1$ or $x = 3$ announcements. The Wilcoxon matched-pairs signed-ranks test confirms what we see in Figure 1: the null that these samples come from the same population is rejected for $x = 1$ and $x = 2$ ($p < 0.01$) as well as for $x = 3$ and $x = 2$ ($p < 0.01$).

[11] For the reasons described above, our main interest is in games $\Gamma(1) - \Gamma(3)$ and not in game $\Gamma(4)$ which has unique Nash equilibrium (AXA, ES). However, one can use the frequency of equilibrium play in $\Gamma(4)$ to calibrate an underlying error or the fraction of players that behave in a nonrational way. When $x = 4$ was reported in Values treatment, subjects played the equilibrium of the game 80 percent of the times in all 20 rounds and 100 percent of the times in the last five rounds, which suggests that players have no problem of coordinating on a unique equilibrium when there is no conflict of interests.

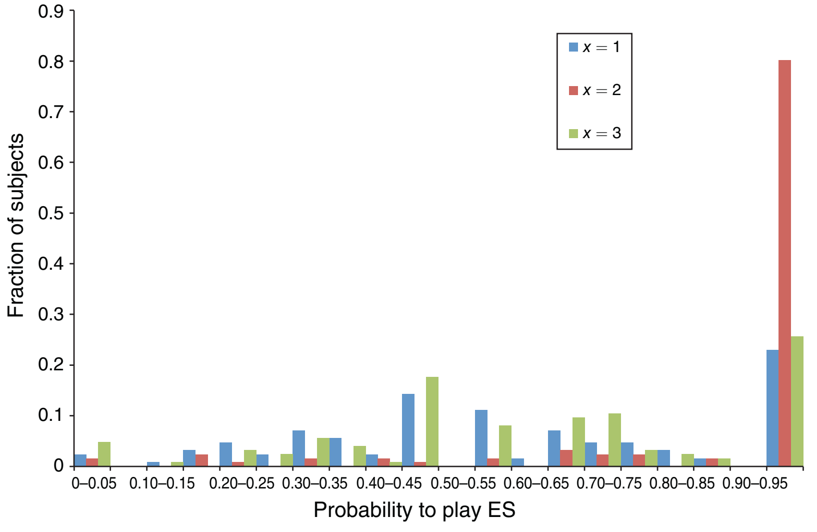

Figure 1. How Often Subjects Play ES in the Values Treatment

Table 7—Distribution of Outcomes in the Values Treatment When $x = 2$ and in the Intervals Treatment When "x is 1, 2, or 3" Is Announced

Values: $x = 2$ All rounds (328 obs)			Intervals: "x is 1, 2, or 3" All rounds (605 obs)			Intervals: "x is 1, 2, or 3" Last 5 rounds (152 obs)		
	ES	AXA		ES	AXA		ES	AXA
ES	81%	9%	ES	69%	15%	ES	78%	13%
AXA	9%	1%	AXA	13%	3%	AXA	7%	2%

Our results are consistent with those of Crawford, Gneezy, and Rottenstreich (2008) since they indicate that even a slight deviation from equity can lead to a decrease in the rate of coordination even when one strategy is made focal.

HYPOTHESIS 2: *"Coarse Information Increases Efficiency."*

Hypothesis 2 is the main hypothesis of this paper since it aims to show that when we alter our announcement strategy away from true values and towards ambiguous intervals we are capable of achieving higher efficiencies. Table 7 presents the distribution of outcomes across the Values and Intervals treatments where in the former case an announcement that "x is 2" is made while in the later case an announcement of "x is 1, 2, or 3" is made.[12]

As we can see from Table 7, the performance of our subjects when they heard an ambiguous announcement "x is 1, 2, or 3" was comparable to the one when they knew for sure that x was equal to 2 in the last five rounds of the game. For example, in the last five rounds, subjects played (ES, ES) 78 percent of the time when intervals were

[12] Again, we pooled together the observations from the Values-Intervals and the Intervals-Values experiments because we observe no significant difference in the behavior of subjects when the Intervals strategy is played before or after the Values strategy.

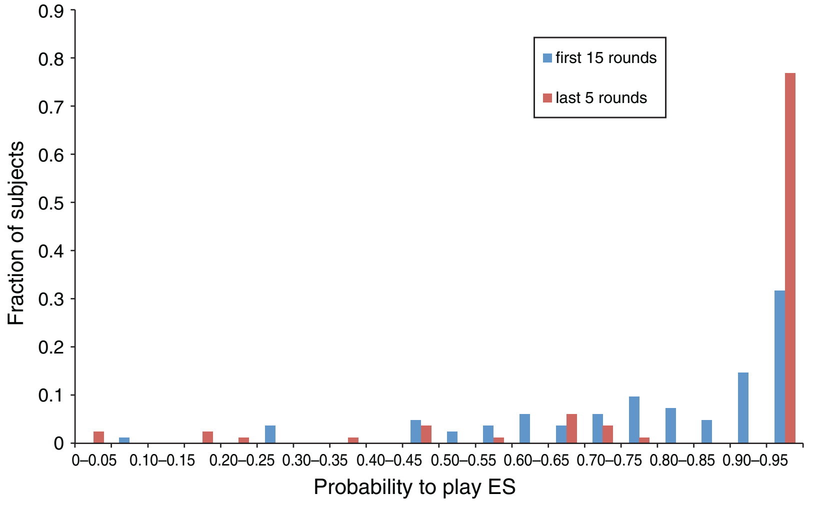

Figure 2. How Often Subjects Play ES in the Intervals Treatment When $x < 4$

used while when values were used they did so 81 percent of the time. The fraction of times subjects played the (ES, ES) equilibrium in the Values treatment in the last five rounds is not much different when we consider all rounds. In the last five rounds (ES, ES) was played 80 percent of the time compared with 81 percent in all rounds.

In the experimental literature, it is a common observation that subjects take time to get used to a game and understand its mechanism. Our experiment is not an exception. Figure 2 shows the distribution of how often each subject played their ES strategy in the first 15 and in the last 5 rounds of the Intervals treatment.[13]

Comparing the distributions in Figure 2 to the one when $x = 2$ was announced in the Values treatment (see Figure 1) we observe that 78 percent of subjects *always* play the ES strategy when they hear announcement "x is 1, 2, or 3" in the last five rounds of the Interval treatment, which is very similar to the behavior observed in the Values treatment when $x = 2$ in which 80 percent of subjects always played the ES strategy when they heard "$x = 2$." This proportion is, however, smaller in the first 15 rounds of the Intervals treatment, in which only 32 percent of subjects always play the ES strategy when they observe "x is 1, 2, or 3." According to the Wilcoxon matched-pairs sign-ranks test, we reject the null that the sample of observations when $x = 2$ was announced in the Values treatment and "x is 1, 2, or 3" in the first 15 rounds of the Interval treatment come from the same population ($p < 0.01$) and we cannot reject the same null for $x = 2$ in the Values treatment and "x is 1, 2, or 3" in the last five rounds of the Interval treatment ($p = 0.1871$).

To sum up, the use of the ambiguous announcement strategy has helped our agents to overcome the coordination problems endemic in situations where asymmetry is a problem and to obtain higher payoffs.

[13] There are 82 observations in both histograms—one observation per Player.

Table 8—Distribution of Outcomes in the Words Treatment when $x < 4$

	Words: "*x* is low" first 15 rounds (249 obs)			Words: "*x* is low" last 5 rounds (85 obs)	
	ES	AXA		ES	AXA
ES	57%	17%	ES	74%	9%
AXA	20%	6%	AXA	13%	4%

HYPOTHESIS 3: *"Vagueness versus Ambiguity."*

In Hypothesis 2 we have confirmed the idea that coarse information in the form of ambiguous intervals can improve coordination rates over transmitting true values of x. However, intervals are not the only possible coarse communication strategy that one might use. Another way to hide the asymmetry in payoffs is to use the same partition as before ($x < 4$ and $x = 4$) but instead of announcing the sub-interval in which x falls, attach a word to each sub-interval and report this word.

Table 8 presents the distribution of outcomes when $x < 4$ in the first 15 and last five rounds of the Words treatment.

In the first 15 rounds of the Words treatment, after observing the "x is low" announcement, subjects coordinated on the Empire State equilibrium 57 percent of the time, while they did so 74 percent of the time in the last five rounds when words were no longer vague. That is, once the meaning of the words was commonly understood, the Words strategy achieved coordination rates similar to those of the Intervals strategy (see Table 7). This is confirmed by the Wilcoxon rank-sum test: the null that the sample of individual plays of the ES strategy in the Words and in the Intervals treatments come from the same population is rejected in the first 15 rounds ($p < 0.05$) and cannot be rejected in the last five rounds ($p = 0.5974$).

We will now compare the performance of the Words and Intervals strategies with that of the Values strategy. Table 9 reports the LOGIT regression with dummy variables for the Words and the Intervals treatments, while the Values treatment serves as the base group.

As we can see from Table 9, in the first 15 rounds of the experiment subjects coordinated on the focal equilibrium (ES, ES) more often when the Intervals strategy was used than when the Words or the Values strategies were used. The picture becomes different when subjects had enough time to learn the cutoff between "low" and "high" and converge to the common interpretation of words. At this point (the last five rounds), words are no more vague and both words and intervals outperform values.

To summarize, at first when subjects are still learning the meaning of the words, the Words strategy achieves similar coordination rates as the Values strategy, while the Intervals strategy outperforms the Values strategy. However, once the vocabulary becomes common knowledge, there is no difference between words and intervals and both outperform the truthful values.

Human Announcers Hypotheses:

Having confirmed (through the use of computerized announcers) our hypothesis that coarse information can enhance coordination by masking payoffs asymmetry we now ask whether human Announcers can figure this out by themselves. Put

Table 9—LOGIT Regression when $x < 4$ (*Clustering by Session*)

	First 15 rounds	Last 5 rounds
Words	0.09	1.06*
	(0.26)	(0.65)
Intervals	0.30**	1.18**
	(0.13)	(0.35)
Constant	0.45**	0.18
	(0.09)	(0.17)
Observations	1,396	479
log likelihood	−913.02	−289.79

Note: Dependent variable is 1 if (ES, ES) was played and 0 otherwise, base group is the Values treatment and robust standard errors are in the brackets.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

differently, can we expect human Announcers to understand that they might benefit both themselves and society by being vague?

To address this question we focus on our Human Announcers treatments. As you may recall, in Treatment 4, Announcers observed the actual value of x at the beginning of each round and could announce any value to the two other Players, i.e., "x is 1," "x is 2," "x is 3," or "x is 4." In this treatment the Announcer's "vocabulary" was restricted to including only one of these four possible announcements. In Treatment 5, however, Announcers were not limited in their announcement strategy and could announce any set of states after observing the actual state x, i.e., "x is 1, 2, or 3," "x is 3 or 4," "x is 2," etc.

The main strategic consideration for subject Announcers in both experiments is whether to be strategic or truthful about the states they observe. This is equivalent to asking whether they will choose an invertible or noninvertible announcement strategy. An invertible strategy is one where, for any given announcement, the state is uniquely defined. For example, the "truthful Values strategy" is invertible. A vague noninvertible strategy is one where there is not a one-to-one mapping from states to announcements as in the strategy of saying "x is 2" when x takes a value of 1, 2, or 3, and reporting "x is 4" when x is equal to 4.

We call the later strategy the word strategy since it requires that the Players reach a common understanding that the announcement "x is 2" (or "x is 1," or "x is 3") is made when x takes values 1, 2, or 3.[14] This Word strategy incorporates the idea that the Players may find it hard to coordinate on an equilibrium when they face asymmetric payoffs, and one way to avoid this problem is to disguise values of x for which the situation of asymmetry occurs. Because the strategy set was larger for Announcers in Treatment 5, the strategies used were more varied and complex than those discussed above. However, they still can be divided into those that were invertible and those that were not. In our analysis below we will look at the announcement strategies used by Announcers in both Treatments 4 and 5, categorize them, and

[14] Even though this announcement strategy does not use actual words to describe value of x, it has all the features of the Words strategy, since Players need to infer the actual value of x from the announcement just like they do when words are used to describe x. This is why we will call it the Words strategy.

TABLE 10—ANNOUNCEMENT STRATEGIES USED BY HUMAN ANNOUNCERS IN TREATMENTS 4 AND 5

	Treatment 4 observations	Treatment 5 observations	Both fraction
Panel A. Invertible announcement strategies			
Strategy A1 (Truthful) "x is 1" when $x = 1$ "x is 2" when $x = 2$ "x is 3" when $x = 3$ "x is 4" when $x = 4$	9	7	47%
Strategy A2 (Invertible Complex) "x is 1 or 2" when $x = 1$ "x is 2" when $x = 2$ "x is 2 or 3" when $x = 3$ "x is 4" when $x = 4$		1	3%
Panel B. Noninvertible announcement strategies			
Strategy B1 (Words) "x is 2" when $x < 4$ "x is 4" when $x = 4$	6	3	26%
Strategy B2 (Words) "x is 1" when $x < 4$ "x is 4" when $x = 4$		1	3%
Strategy B3 (Words) "x is 2 or 3" when $x < 4$ "x is 4" when $x = 4$		1	3%
Strategy B4 (Words) "x is 1, 2, or 3" when $x < 4$ "x is 4" when $x = 4$		2	6%
Strategy B5 (Words) "x is 1, 2, or 3" when $x < 4$ "x is 1, 2, 3, or 4" when $x = 4$		1	3%
Strategy B6 (Words/Values) "x is 1 or 3" when $x \in \{1,3\}$ "x is 2" when $x = 2$ "x is 4" when $x = 4$		3	9%
	15	19	100%

compare their efficiencies both within and across treatments to see if the extra strategic flexibility accorded to Announcers in Treatment 5 led to greater efficiencies.

HYPOTHESIS 4: *"Announcement Strategies."*

We start by categorizing the types of announcement strategies that human Announcers used in Treatments 4 and 5. In order to classify subject Announcers according to the announcement strategy they used, we look at the behavior of each Announcer over the 20 rounds of the experiment and, for each strategy, ask how many observations would have to be removed from the dataset in order to fit the strategy exactly. A subject will be classified as belonging to a strategy if that strategy best describes his or her behavior, that is, minimizes the number of removed observations.[15] Table 10 presents all the strategies used by human Announcers in both treatments.

[15] The set of all announcement strategies that we considered includes all possible partitions of the state space and all possible announcements for each partition.

In both treatments, the strategies we selected for each Announcer fit their behavior remarkably well in that on average only 1.25 observations in Treatment 4 and 1.4 observations in Treatment 5 needed to be removed before a perfect fit was achieved. In addition, the strategy we select as the best fitting strategy for the Announcer performed significantly better than the second best amongst all possible announcement strategies according to our metric. For example, in order to make the second best strategy fit the data as well as our first best, one needs to remove, on average, an additional 8.5 out of 20 observations in Treatment 4 and 10.25 out of 20 observations in Treatment 5.[16]

In Treatment 4, we observe a significant proportion of Announcers using both invertible truthful and noninvertible Words strategies: out of 15 Announcers, 9 (60 percent) used the truth-telling strategy and the remaining 6 (40 percent) used the Words strategy.

Despite the strategic freedom offered Announcers in Treatment 5, 42 percent of them (8 out of 19) persisted in using invertible strategies. While this percentage is down from the 60 percent of subjects using such strategies in Treatment 4, it is still considerable. The most popular such strategy was the truthful strategy, in which the Announcer simply reported the value of x he or she saw in each period (Strategy A1): 87.5 percent of all Announcers that used invertible strategies in Treatment 5 used the truthful strategy. The remaining 58 percent of Announcers used noninvertible strategies of various kinds. One popular group of noninvertible strategies is similar to the Words strategy observed in Treatment 4, in which the Announcer sends the same message to the Players when x takes values of 1, 2, and 3 and another message when x is 4. The difference between strategies B1–B5 is the messages used to report x when the later is below 4 and the message used to report that x is 4. Notice that strategies B1–B5 use the same partition of the state space and they all require that the Players reach a common understanding of the message sent when x takes values 1, 2, or 3 and when x takes value of 4. The most popular strategy amongst the ones that use $x < 4$ and $x = 4$ partition is strategy B1, which reports "x is 2" when $x < 4$ and " x is 4" when $x = 4$ (27 percent of Announcers that use noninvertible strategies use this one). Another popular strategy that was used by 27 percent of all Announcers who employed noninvertible strategies is strategy B6 which disguises the value of x only when inequality problems may interfere with coordination ($x = 1$ and $x = 3$) and reveals x truthfully when this is not an issue ($x = 2$ and $x = 4$).

Overall, combining data from both treatments we see that half of human Announcers (17 out of 34) used invertible announcement strategies and another half used noninvertible strategies that hide the value of x when the inequality problem was present.

We will now compare the performance of these two groups of strategies in terms of efficiency.

[16] There were also three Announcers (one in Treatment 4 and two in Treatment 5) who used strategies which were hard to classify. One would have to remove at least 9 out of 20 observations in order to classify these subjects into one of the strategies. We, therefore, exclude these Announcers from the analysis.

Table 11—Profits of Announcers, by Type of Announcement Strategy

	Mean profits	Median profits
Invertible strategies Strategies A1 and A2	375 tokens	388 tokens
Noninvertible strategies Strategies B1–B6	449 tokens	471 tokens

HYPOTHESIS 5: *"Invertible vs Noninvertible Strategies."*

Given the results obtained in the Computerized-Announcers treatments, we would expect that the invertible announcement strategies would be less efficient than the noninvertible strategies since the later disguise the inequality of payoffs when this inequality may interfere with coordination. Table 11 presents the average and median total profits of Announcers grouped by the type of announcement strategy used (summed over all 20 rounds). Since the Announcers' payoff is the sum of Players' earnings, the profits of Announcers is a perfect indicator of the welfare captured by all subjects in a group.

As we see, the profits of the Announcers were higher when they disguised the actual value of x than when they revealed it to the Players (both means and medians preserve the same order). A Wilcoxon rank-sum test rejects the hypotheses that the distributions of Announcers' profits came from the same population ($z = 2.067$ and $p = 0.0388$).[17]

Now that we established that noninvertible strategies performed better than the invertible ones, we will explore why this is the case. We will show that it is the inequality problem that stands in the way of achieving high coordination rates when the true value of x is revealed to the Players.

We first look at the invertible strategies and show that subjects play the (ES, ES) equilibrium more often when $x = 2$ than when $x = 1$ or $x = 3$ (see Table 12).

As we see, the incidence of coordination on the (ES, ES) equilibrium was significantly higher when $x = 2$ was reported than when $x = 1$ or $x = 3$ was reported. When $x = 1$ ($x = 3$) was announced subjects coordinated on the (ES, ES) equilibrium 33 percent (39 percent) of times in the first 15 rounds and 22 percent (45 percent) of the time in the last 5 rounds, while the same coordination rate was 71 percent when $x = 2$ was announced in the first 15 rounds and 77 percent in the last 5 rounds.

Disguising the value of x when $x = 1$ and $x = 3$ can mitigate the inequality problem and help subjects coordinate on the focal equilibrium (ES, ES). This can be seen by looking at the distribution of outcomes when x took values 1, 2, and 3, and noninvertible strategies B1–B6 were used (see Table 13).

To perform a statistical analysis we use the same measure as the one in the Computerized-Announcer treatments: this measure indicates how often each subject chose the focal Empire State strategy when various announcements were made by the human Announcers (one observation per subject). The Wilcoxon rank-sum test

[17] To perform the test, we used one observation per Announcer, which is the sum of the profits of the Announcer in all 20 rounds.

TABLE 12—DISTRIBUTION OF OUTCOMES WHEN INVERTIBLE STRATEGIES (A1 AND A2) ARE USED

$x = 1$ first 15 rounds (70 observations)	ES	AXA	$x = 2$ first 15 rounds (55 observations)	ES	AXA	$x = 3$ first 5 rounds (70 observations)	ES	AXA
ES	33%	16%	ES	71%	9%	ES	39%	41%
AXA	43%	9%	AXA	5%	15%	AXA	13%	7%
$x = 1$ last 5 rounds (23 observations)	ES	AXA	$x = 2$ last 5 rounds (22 observations)	ES	AXA	$x = 3$ last 5 rounds (22 observations)	ES	AXA
ES	22%	4%	ES	77%	9%	ES	45%	41%
AXA	57%	17%	AXA	0%	14%	AXA	5%	9%

TABLE 13—DISTRIBUTION OF OUTCOMES WHEN NONINVERTIBLE STRATEGIES (B1–B6) ARE USED

$x < 4$ first 15 rounds (187 obs)	ES	AXA	$x < 4$ last 5 rounds (60 obs)	ES	AXA
ES	64%	15%	ES	83%	0%
AXA	12%	9%	AXA	12%	5%

cannot reject the hypothesis that the probability to the play focal strategy ES comes from the same distribution when an invertible strategies A1 and A2 are used and $x = 2$ is announced as when a noninvertible strategy B1–B6 is used and x below 4 is announced ($z = 1.517$ and $p = 0.1294$).[18] In other words, when the value of x is disguised from the Players, they play the ES strategy as often as they do when there is no inequality problem, i.e., x is known to equal 2. On the contrary, when invertible strategies are used and $x = 1$ or $x = 3$, subjects play the ES strategy far less often than when $x = 2$. The Wilcoxon matched-pairs signed-ranks test rejects the null that these samples come from the same population ($z = 2.745$ and $p = 0.0061$ for $x = 1$ versus $x = 2$ and $z = 2.291$ and $p = 0.0219$ for $x = 3$ versus $x = 2$).

Finally, we ask whether the strategic flexibility awarded Announcers in Treatment 5 leads to greater efficiencies.

HYPOTHESIS 6: *"Strategic Freedom vs Restrictions."*

Table 14 presents the average and the median total profits of the Announcers (summed over all 20 rounds), in Treatments 4 and 5.

As can be seen the mean and the median sum-of-player payoffs is actually higher in Treatment 4 where there is less strategic freedom. However, a Wilcoxon Rank-sum test shows that there is no statistical difference between Treatment 4 and Treatment 5 profits ($z = 0.451$ and $p = 0.6520$). This fact is interesting since it

[18] Notice that here we compare the performance of invertible strategies when $x = 2$ with the performance of the noninvertible strategies when $x < 4$. This is different from the exercise performed in Table 9, in which we are concerned with overall performance of invertible (Values) and noninvertible (Words and Intervals) strategies when x takes values below 4.

Table 14—Payoffs of the Announcers, by Treatment

	Mean profits	Median profits
Treatment 4	421 tokens	441 tokens
Treatment 5	404 tokens	384 tokens

indicates that the vocabulary used by Announcers in Treatment 4, while restricted, was sufficient to yield an efficiency comparable to that in Treatment 5.

We conclude the analysis of the Human Announcers treatments by noting that a significant proportion of subject Announcers changed their strategy in the course of the experiment. Nine out of 17 Announcers (53 percent) that used noninvertible strategies started the experiment by truthfully announcing the value of x. However, after a few rounds they changed their strategy. Why did those Announcers change their strategy and others did not?

To answer this question we will look at the performance of the Players in the first rounds of the experiments. It turns out that those Announcers that changed their strategy experienced low coordination rates when x took values of 1 and 3 and they announced the truth. The typical example of what happened can be illustrated by an Announcer in Treatment 5, Session 2, Group 1. The first two times that x took values 1 and 3, this Announcer truthfully reported x to the Players. However, both these times, Players failed to coordinate on which equilibrium to play and ended up with zero payoffs. After those two failures, the Announcer switched to announcing "x is 1, 2, or 3" when $x < 4$.

The example above is not an exception. Those Announcers that switched from the truthful to the noninvertible announcement strategy experienced low coordination rates when x was equal to 1 and 3 and they reported the true value of x: in only 2 out of 14 instances (14 percent) did the Players managed to play the equilibrium when $x = 1$ or $x = 3$ was announced.[19] On the contrary, the Announcers that decided to stick with the truth-telling strategy experienced higher coordination rate of 47 percent the first time they announced the true value of x when x took values of 1 or 3 and 53 percent the second time they did so. In other words, the decision to change the announcement strategy was triggered by the ability of the Players to coordinate on one of the equilibria when Players faced the game with unequal payoffs.

Reporting the true value of x is the natural starting point for an inexperienced Announcer since his interests coincide with the equilibrium of the game $\Gamma(x)$ for every value of x and he might not realize immediately the problem of payoffs asymmetry.[20] However, after observing several coordination failures when payoffs are unequal, we might expect sophisticated Announcers to adjust their behavior and find a way to overcome this problem (by using the attraction of the focal point). This is precisely what happened in the experiment: those Announcers that experienced the

[19] Three Announcers announced the true value of x when $x = 1$ and $x = 3$ twice and got miscoordination both times, then changed their strategy. Four Announcers announced the true value of x once when $x = 1$ and $x = 3$, got miscoordination and changed their strategy. Finally, two Announcers reported $x = 1$ and $x = 3$ two times and got one miscoordination and then changed the strategy.

[20] Moreover, a recent experimental work of Gneezy (2005) and Hurkens and Kartik (2009) documents that people have an intrinsic aversion to lying and, thus, telling the truth might be a natural first thought.

Battle-of-the-Sexes mis-coordination type of problem switched to transmitting the value of x in a coarse manner, while the remaining Announcers kept using the truth-telling strategy which performed relatively well. In addition to 9 Announcers who changed their strategy in the course of the experiment, we observe that a large fraction of Announcers, 6 out of 17 (35 percent), are sophisticated enough to foresee the asymmetry problem in advance and implement the strategy that corrects for it from the beginning of the experiment. The remaining 2 Announcers (12 percent) used the first couple of rounds to try out different nontruthful announcements and then converged to using their noninvertible strategy.

Finally, we note that when x takes values of 1 or 3, the Announcer that masks the value of x and reports "x is 2" or "x is 1, 2, or 3" or "x is 1 or 3" cannot achieve lower coordination rates (and thus lower payoff) than the one that reveals the actual value of x by reporting $x = 1$ or $x = 3$.[21] In other words, we expect that any of the Words strategies used by our subject Announcers performs at least as well as the truth-telling strategy. Table 15 reports the coordination rates and the fraction of times Players played the (ES, ES) equilibrium when the true value of x was 1 or 3 and different announcements were made.

As we can see from Table 15, our expectations were borne out. The Announcers that masked payoff asymmetry by using Strategies B1, B4, B5, or B6 achieved strictly higher coordination rates and, thus, higher total welfare than those that used Strategy A1 and truthfully reported $x = 1$ or $x = 3$. Moreover, the most effective way of disguising payoff asymmetry was to announce that "x is 1, 2, or 3" when x was smaller than four. Announcers that used this type of Words strategy achieved coordination rate of 91 percent in all rounds and 100 percent in the last five rounds, with the majority of the coordination occurring on the (ES, ES) equilibrium (70 percent in all rounds and 100 percent in the last five rounds). On the contrary, if Players were told that "x is 1" or "x is 3" when truth-telling strategy A1 was used, they coordinated on one of the equilibria only 42 percent of the times in all 20 and 41 percent in the last 5 rounds.

We conclude this section by noting that our subject Announcers exhibited an amazing degree of sophistication. Most human Announcers started by using the truthful strategy. However, depending on the performance of the Players, a significant fraction of subject Announcers switched to using vague communication strategies that masks payoff asymmetry and facilitated coordination through the use of the focal points. In other words, human Announcers are capable of identifying the asymmetry problem and finding a way to correct for it by using coarse announcement strategies.

HYPOTHESIS 7: *"Equality in Expectations."*

Finally, we are interested in understanding what triggers the use of the focal point when coarse information is used: is it the uncertainty about the game being played? or is it the symmetry of the expected payoffs? To distinguish between the two possible explanations, we go back to the Computerized-Announcer treatment and look

[21] In this exercise, we concentrate on the announcement strategies that were used by more than one Announcer, and thus abstract from strategies A2, B2, and B3.

Table 15—Coordination Rates when x Takes Values 1 and 3
(*Total number of observations in each case is reported in the parentheses*)

Announcements	Coordination rates: All rounds	Coordination rates: Last 5 rounds	(ES, ES) play: All rounds	(ES, ES) play: Last 5 rounds
Strategy B1: "x is 2"	81% (70 observations)	90% (20 observations)	80% (70 observations)	90% (20 observations)
Strategies B4 and B5: "x is 1, 2, or 3"	91% (23 observations)	100% (7 observations)	70% (23 observations)	100% (7 observations)
Strategy B6: "x is 1 or 3"	75% (24 observations)	83% (6 observations)	75% (24 observations)	83% (6 observations)
Strategy A1: "x is 1" or "x is 3"	42% (158 observations)	41% (37 observations)	31% (158 observations)	24% (37 observations)

Table 16—Distribution of Outcomes in the $\text{Words}_{\text{modified}}$ Treatment

	$\text{Words}_{\text{modified}}$: "$x$ is low" first 15 rounds (245 obs) ES	AXA		$\text{Words}_{\text{modified}}$: "$x$ is low" last 5 rounds (79 obs) ES	AXA
ES	41%	27%	ES	49%	23%
AXA	20%	11%	AXA	20%	8%

at the performance of subjects in the $\text{Words}_{\text{modified}}$ treatment (Treatment 6). Hence, when "x is low" is announced, the Players expect to be playing $\Gamma(11/6)$ which has unequal payoffs (8.33 to one player and 8.83 to another one).

As Table 16 shows, even in the last 5 rounds of the $\text{Words}_{\text{modified}}$ treatment when words are no more vague, subjects played the (ES, ES) equilibrium only 49 percent of the time after announcement "x is low" (41 percent in the first 15 rounds). These coordination rates can be compared to the ones reported in Table 8, which presents the distribution of outcomes in the Words treatment when "x is low" is announced and the Players expect to be playing $\Gamma(2)$ with symmetric payoffs. Here subjects play the (ES, ES) equilibrium much more often: 57 percent in the first 15 rounds and 74 percent in the last 5 rounds in the Words treatment. Put differently, the slight asymmetry in expected payoffs in the $\text{Words}_{\text{modified}}$ treatment is enough to destroy the power of salient equilibrium and interfere with coordination.

Figure 3 presents the distribution of the individual behavior of subjects after the announcement "x is low" in the last five rounds of the Words and the $\text{Words}_{\text{modified}}$ treatments.[22]

As Figure 3 shows, when "x is low" is announced only 38 percent of subjects always play the focal Empire State strategy in the $\text{Words}_{\text{modified}}$ treatment, while this fraction is much higher in the Words treatment (about 73 percent). The null that these samples come from the same population is rejected by the Wilcoxon rank-sum test ($p = 0.0041$). This result suggests that what triggers the use of the focal strategies is not the uncertainty about the game being played but the symmetry in the expected payoffs of the Players.

[22] There are 44 observations in the histogram on the left (Words treatment) and 42 observations in the histogram on the right ($\text{Words}_{\text{modified}}$ treatment).

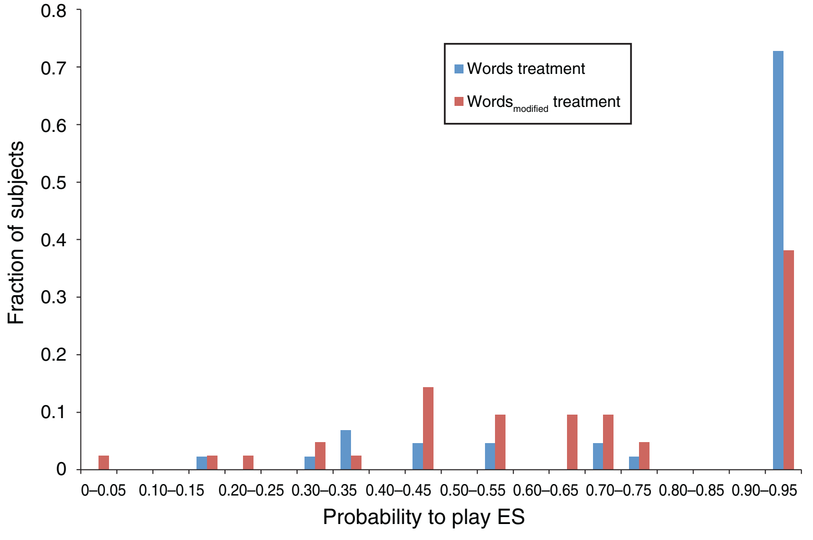

Figure 3. How Often Subjects Played ES when "x is low" was Announced in the Words and $\text{Words}_{\text{modified}}$ Treatments in the Last Five Rounds

To conclude, our results indicate that a vague strategy enhances coordination by increasing the use of salient strategies only if it totally masks payoff asymmetry as it does in the Words treatment. Merely reducing asymmetry, as it does in the $\text{Words}_{\text{modified}}$ treatment, is not enough to restore the power of focal points and increase coordination.

V. Conclusions

In this paper we have attempted to make one simple point which is that even when there are no strategic tensions between a sender and receiver in a communication game, it still may be beneficial for the sender to communicate in a imprecise manner. The reason for this is that in situations where payoff asymmetry is likely to interfere with coordination (as in the Battle-of-the-Sexes game), being ambiguous or vague about the game being played and its payoffs may help to mask this underlying inequality and allow players to focus on those aspects of the problem that aid coordination such as the saliency of the strategy labels. While the benefits of being vague are never as high as those associated with being ambiguous, our results do indicate that we lose relatively little by the vagueness of our language and that human announcers gain an appreciation of the fact that payoff inequality is best disguised and attempt to do so.

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