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Transparency is Overrated: Communicating in a Coordination Game with Private Information

Abstract

We consider an experiment with a version of the Battle of the Sexes game with two-sided private information, allowing a possible round of either one-way or two-way cheap talk before the game is played. We compare different treatments to study truthful revelation of information and subsequent payoffs from the game. We find that the players are overall truthful about their types in the cheap-talk phase in both one-way or two-way talk. Furthermore, the unique symmetric cheap-talk equilibrium in the two-way cheap talk game is played when they players fully reveal their information; however, they achieve higher payoffs in the game when the talk is one-way as the truthful reports facilitate desired coordination.

JEL-Codes: C720, C920, D830.

Keywords: battle of the sexes, private information, cheap talk, coordination.

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1 INTRODUCTION

Organizations very often confront situations in which it is important that a common action is chosen by its members: selecting a candidate for a job opening, a programming language in a project, or a location for a new office building. Yet, the preferences about those actions are not, in general, common knowledge (who is the preferred job market candidate for each member of the organization: the search theorist, or the trade economist?). One possible solution in this context is to foster communication and "transparency" to achieve the desired coordination. Executives and managers are often recommended to improve communication (Smidts *et al*, 2001; Eisenberg and Witten, 1987), encouraged to perform 360 degree reviews (Yammarino and Atwater, 1997; Atwater and Waldman, 1998), and generally told to facilitate "making the views of all stakeholders heard" (Scholes and Clutterbuck, 1998; Morsing and Schultz, 2006).

The purpose of our research is to test the hypothesis that improved communication is always efficiency-enhancing within organizations. In order to do this, we design a simple strategic game of coordination with private information, and test in a laboratory experiment whether two-way communication is superior to one-way communication.

To be more specific, the participants in our experiment play a two-player game where each of them has two actions, that we call X and Y. It is common knowledge that taking different actions leads to the worst payoff, and that player 1 prefers the outcome achieved with the profile (X, X) and player 2 prefers that with (Y, Y). But the payoff for the player from her less profitable outcome is her private information, and can take one of two values $v \in \{A, B\}$, with $A < B$. Efficiency, or at least total surplus maximization, suggests that the partner should choose the profile with the lower loss for the "damaged" player. But choosing the efficient option is difficult because whether v_i is the low (A) or the high (B) value is private information of the player.

In our experiment, the X and Y actions are chosen only after some communication ensues. The participants can choose a message from A and B, before choosing actions. There are three treatments. In one of them, there is no communication, the participants just choose actions. The other two treatments have communication; in one of those treatments, only one (randomly chosen) player can send a message, while, in the other treatment with communication, both players choose a message simultaneously. After the player(s) send the message(s), both players choose actions.

There are at least two possible benchmarks against which we can compare our experimental results. First, we can compute the most informative symmetric Bayesian-Nash equilibrium with purely self-interested and consequentialist players, who care only about their own final payoffs and are Bayes-rational. We will call this the *standard prediction*. One potential alternative assumes that it is common knowledge that players always send truthful messages and otherwise they are standard Bayes-rational and self-interested. We will call this the *truthful prediction.*

Under two-way communication, these two predictions coincide (as proved in Ganguly and Ray, 2017). The most informative symmetric Bayesian-Nash equilibrium of the game posits that both players announce their types truthfully. If the two announced types do not coincide, the players then play the actions leading to the efficient outcome; when the two players announce the same type, the players use the symmetric (and thus mixed) equilibrium in the corresponding subform.

Under one-way communication, the two predictions diverge. The *truthful prediction* states that the player who sends the message announces her type truthfully. The players then play the actions corresponding to an equilibrium of the Bayesian game in which the type of the sender is common knowledge and that of the receiver is private information. The *standard prediction,* on the other hand, is that the players either *babble* at the communication stage, by sending the same (possibly mixed) uninformative message, or they choose the same action at the action stage. That is, in equilibrium, one of two things will happen. One is that the messages are independent of the players' types and then at the action stage, the players play the Bayesian-Nash equilibrium of the game without communication. The other is that the players' actions are independent of their messages, even if the messages are true reports.

The results of our experiment are, in essence, as follows. In the game with two-way communication, the common *standard* and *truthful prediction* hold remarkably well. Both players tell the truth a very large fraction of the time and, conditional on truth-telling, their subsequent behavior is also very much in line with the prediction. On the other hand, in the game with one-way communication, the observed play is statistically in line with the *truthful prediction.* By and large, senders tell the truth, and receivers act accordingly. Thus, the *standard prediction* is clearly rejected. Players do not use the same message, and they do not ignore the sender's message after communicating.

An important implication of our observations is that aggregate payoffs are significantly larger under one-way communication than those under two-way communication, and both of them are higher than those without communication. This is in stark contrast with the *standard prediction.*

Our result that payoffs are higher under one-way than two-way communication would seem superficially related to the previous experimental research on cheap-talk games under complete information, such as Cooper *et al.* (1989). But they are in fact quite different. In the corresponding games with complete information, as Cooper *et al* (1989) recognize, "the sender of the message simply chooses his preferred equilibrium and the receiver best responds." In our game, when the sender in one-way communication tells the truth, she in fact gets her worst outcome when she is of the High type; and this is why telling the truth is not an equilibrium. Yet, this is what we observe in our experiment, and this is the reason why one-way communication yields overall higher payoffs. It is indeed quite remarkable, because a straight application of the logic from the experiments with complete information would suggest that the sender should pretend that she is of Low type in order to achieve her preferred outcome.

Since reality is fraught with information asymmetries, our results are thus very significant because of its implications: a policy of unrestrained communication and transparency might not always be in the organization's best interest, although clearly some communication is necessary.

Note that our results are obtained in a one-shot game, where there is no chance of establishing a reputation for reliability and trustworthiness. We expect these results to be even stronger in the context of a long-lived organization where the actors have an incentive to establish themselves as trustworthy partners (Wilson and Sell, 1997).

1.1 Related literature

Many games of economic interest involve multiple (pure) Nash equilibria and it is therefore important to understand how, if at all, players coordinate to play a particular equilibrium outcome. This problem of equilibrium selection has been theoretically analyzed using different criteria, such as, payoff-dominance (Colman and Bacharach, 1997), or risk-dominance (see Harsanyi and Selten, 1988, and Straub, 1995, for experimental evidence).

The experimental literature shows that in coordination games with multiple equilibria, players often fail to coordinate (Van Huyck *et al*, 1991; Cooper and John, 1988; Straub, 1995) unless the game has special features, such as a very strong kind of risk-dominance (Cabrales *et al*, 2000). It is also well-known, since the work by Cooper *et al* (1989), that cheap-talk (Farrell, 1987) and in general, pre-play non-binding communication can significantly improve coordination in experiments with games like Battle of the Sexes (see Crawford, 1998; Costa-Gomes, 2002; Burton *et al*, 2005, for details and Ochs, 1995, for a survey). In contrast with the previous literature, we concentrate on games with private information. These games are very realistic in many contexts, and the coordination potential of communication is severely threatened in them because of the incentive problems of the players.

There is little evidence on coordination with incomplete information; most of it concentrates on the effect of adding public information about a common state (McKelvey and Page, 1990; Marimon and Sunder, 1993; McCabe *et al*, 2000; Heinemann *et al*, 2004; Cabrales *et al*, 2007; Cornand and Heinemann, 2008) in the spirit of global games (Carlsson and Van Damme, 1993; Morris and Shin, 1998, 2002) and on the effect of sunspots (Duffy and Fisher, 2005). Our experiment concentrates on the problem of coordination when the incomplete information is about private, not common, values. Some other literature has shown experimentally that communication and recommendations of play can serve to achieve correlated equilibria (Moreno and Wooders, 1998; Cason and Sharma, 2007; Duffy and Feltovich, 2010; Bone *et al*, 2013; Anbarci *et al*, 2017; Duffy *et al*, 2017; Georgalos *et al*, 2017) *a la* Aumann (1974, 1987).

A different strand of experimental literature concentrates on analyzing the sender-receiver games à la Crawford and Sobel (1982). In these games, coordinating actions is not a problem (unlike our case), since only the receiver takes an action, after the sender's message; however, there is still multiplicity of equilibria arising from the existence of equilibria where the messages are ignored ("babbling equilibria"). One main result in that literature (e.g., Dickhaut *et al*, 1995; Blume *et al*, 1998, 2001; Kawagoe and Takizawa, 1999) is that the players tend to behave as in the informative equilibrium when their interests are well-aligned. Duffy and Feltovich (2002) explain why cheap talk or observation is likely to be the more effective device for achieving good outcomes in some specific 2x2 games.

Our game is one where the players' interests do not coincide, and thus we are closer to another strand of the literature (Sánchez-Pagés and Vorsatz, 2007; Kawagoe and Takizawa, 2005; Cai and Wang, 2006; Wang *et al*, 2010) dealing with games where the players' interests do not coincide. They tend to find that in games where interests do not align well, the senders sometimes tell the truth even when this is not in equilibrium. This finding can be explained by a truth-telling norm. For example, Duffy and Feltovich (2006) observe that senders' signals tend to be truthful in games played repeatedly against changing opponents, while Capraro (2017) shows that even in an one-shot interaction, time pressure increases honest behavior. An exception to the above is Cabrales *et al* (2016), who also find some evidence of aversion to lying, but in addition a substantial amount of deception/misinformation even when lying does not increase the sender's payoff; this happens more often for the subjects who display non-pro-social or envious preferences, which they measure independently.

Gneezy (2005) explores deception for message-senders who could benefit materially from a deception, while harming the receiver, though, the experimenter does not inform the receivers of the payoffs of the sender, who is then unaware of the potential conflict of interest. In that case, many participants decide not to deceive the receiver. In contrast, in ultimatum games with private information, Kriss *et al* (2013) generally observe very high frequencies of dishonesty.

All these results are important for our paper, because in our context, there is also a tension between truth-telling norms and fairness preferences, which in our case seems to be resolved in favor of the truth-telling norm. This is likely because of repetition, since the participants are not always on the "losing" side of the coordination game.

2 MODEL

The subsections below present the theoretical concepts behind our experiment as discussed in the next section.

2.1 Game

We consider the following two-person Bayesian game in which each player has two pure strategies, namely, X and Y:

$1\backslash 2$	X	Y
X	$1, v_2$	$0, 0$
Y	$0, 0$	$v_1, 1$

Table 1: Battle of the Sexes with private information

where v_i's are independent random variables taking two values, $\{A, B\}$, with $A < B$ and p being the probability of B; v_i is private information for player i, $i = 1, 2$. Players get a positive payoff only when they coordinate their strategies either on X or Y.

We study an extended game in which the players are first allowed to have a round of simultaneous cheap talk, where they may reveal their private information about the value of v_i, before they play the above Battle of the Sexes (henceforth, BoS). The typical set-up is a three-stage game where, if the communication is two-way:

0 Nature tells players the value of v_i,

1 Players simultaneously report a value of v_i from the feasible set, $\{A, B\}$,

2 Players choose X or Y;

and if communication is one-way, the game is as above except that in stage 2 only one player reports her type.

At the end of the game, payoffs are realized according to Table 1, based on the realized values of v_i's.

In the communication stage of this game, an announcement strategy for player i is thus a function $a_i : \{A, B\} \to \Delta(\{A, B\})$, where $\Delta(\{A, B\})$ is the set of probability distributions over $\{A, B\}$. With some abuse of notation, one may write $a_i(B\,|v_i\,)$ for the probability that strategy $a_i(v_i)$ of player i with valuation v_i assigns to the announcement B.

For the two-way communication game, in the action stage, a strategy for player i is a function $\sigma_i : \{A, B\} \times \{A, B\} \times \{A, B\} \to \Delta(\{X, Y\})$, where $\Delta(\{X, Y\})$ is the set of probability distributions over $\{X, Y\}$. We write $\sigma_i(X\,|v_i; \tau_1, \tau_2\,)$ for the probability that strategy $\sigma_i(v_i; \tau_1, \tau_2)$ of player i with valuation v_i assigns to the action X when the communication stage announcements are (τ_1, τ_2). Similarly, for the one-way communication game, such a strategy of player i with valuation v_i will be $\sigma_i(v_i; \tau)$ that assigns probability to the action X when the communication stage announcement is τ.

2.2 Theoretical Benchmark

Ganguly and Ray (2017) showed that there exists a unique fully revealing symmetric perfect Bayesian equilibrium of this two-way communication game for a range of values of p. In that equilibrium, called $S_{separating}$, the players announce their types truthfully, that is, $a_i(B\,|B\,) = 1$ and $a_i(B\,|A\,) = 0$, for $i = 1, 2$. Then, in the action stage, when both players' types are identical, each player plays the mixed Nash equilibrium strategies of the complete information BoS (in which player 1 plays X with probability $1/\,(1 + v_2)$ and player 2 plays Y with probability $1/\,(1 + v_1)$); and when only player 1's value is B (A) they play the coordinated outcome (Y, Y) $((X, X))$. Theorem 1 in Ganguly and Ray (2017) confirms that $S_{separating}$ is the unique fully revealing symmetric perfect Bayesian equilibrium and it exists if and only if

$$\frac{A^2 + A^2B}{1 + A + A^2 + A^2B} \leq p \leq \frac{AB + AB^2}{1 + A + AB + AB^2}. \tag{1}$$

One may also be interested in knowing what happens in the corresponding game with one-way communication. In particular, we want to know whether any truthful equilibrium exists in this game or not. As the game is asymmetric in this case (as only one of the players is talking), we cannot resort to symmetry any further. It can be easily shown that there are multiple asymmetric equilibria.

In the game with one-way communication, players may babble at the cheap-talk stage, that is, they may report the same value (or distribution over values) regardless of the original value and then play any of the equilibria of the BoS. Also, in this case, truthfully revealed messages followed by actions that depend meaningfully on the messages are no longer equilibrium profiles. More formally, in the game with one-way cheap talk (say, by player 1), there does not exist an equilibrium in this game with a non-babbling strategy profile[1] where player 1 reports his type truthfully in the cheap talk stage

[1] An action profile is called non-babbling if at least one of the following conditions holds: (i) $\sigma_1(X\,|B; B\,) \neq \sigma_1(X\,|A; A\,)$, (ii) $\sigma_2(X\,|B; B\,) \neq \sigma_2(X\,|B; A\,)$, (iii) $\sigma_2(X\,|A; B\,) \neq \sigma_2(X\,|A; A\,)$, that is, if at least one type of one

(Theorem 4 in Ganguly and Ray, 2017).

2.3 Parameters

We now focus our attention on specific values of the parameters (the private values) in the BoS presented in Table 1, to be used in our experimental analysis. Since we would like to test for the validity of the fully revealing symmetric perfect Bayesian equilibrium, $S_{separating}$, in the two-way communication game, we choose values of A, B such that condition 1 is respected. In particular, a pair that works well is $A = 0.65$ and $B = 0.9$, with $p = 0.4$.

A remark is in order regarding our choice of values. These values of A and B are chosen because we want the low coordination payoff at state A to be sufficiently different from that at B so that the surplus difference is significant. Moreover, we know that the upper bound of p in 1 is such that $p < 0.5$. We would like the states (A, B) and (B, A) to happen sufficiently often because these are the states when there can be coordination in an outcome that does not maximize surplus. The combined probability of these states with our choice of $p = 0.4$ turns out to be $2p(1-p) = 0.48$, which we think is sufficiently large for our purposes.

In the rest of the paper, we call a player of High-type when $v_{i.} = 0.9$ and of Low-type when $v_{i.} = 0.65$. As a short-hand, four possible type profiles or four possible states will also be denoted by AA, AB, BA and BB, respectively. The game therefore can be presented in four different type-profiles as in Table 2 below.

Both Players: *High-types* (BB state)

	X	Y
X	$1, 0.9$	$0, 0$
Y	$0, 0$	$0.9, 1$

Player 1: *High-type*, Player 2: *Low-type* (BA)

	X	Y
X	$1, 0.65$	$0, 0$
Y	$0, 0$	$0.9, 1$

Player 1: *Low-type*, Player 2: *High-type* (AB)

	X	Y
X	$1, 0.9$	$0, 0$
Y	$0, 0$	$0.65, 1$

Both Players: *Low-types* (AA)

	X	Y
X	$1, 0.65$	$0, 0$
Y	$0, 0$	$0.65, 1$

Table 2: The Bayesian game with two types for each player

One may check that, for these parameter values, when the players follow the equilibrium strategy $S_{separating}$, they coordinate on (Y, Y) ((X, X)) when only player 1's value is B (A) and they play the mixed Nash equilibrium when both players' types are identical. This means that in the BB state, player

player chooses a different action.

1 plays X with probability 10/19 ($\simeq 0.53$) and by symmetry, player 2 plays Y with probability 10/19 ($\simeq 0.53$). In the AA state, player 1 plays X (and player 2 plays Y) with probability 20/33 ($\simeq 0.61$). Thus, $S_{separating}$ generates the following distribution (as shown in Table 3) over the outcomes, with the (expected) payoff for each player being 17598/26125 ($\simeq 0.67$).

	X	Y		X	Y		X	Y		X	Y
X	$\frac{90}{361} \simeq 0.25$	$\frac{100}{361} \simeq 0.28$	X	0	0	X	1	0	X	$\frac{260}{1089} \simeq 0.24$	$\frac{400}{1089} \simeq 0.37$
Y	$\frac{81}{361} \simeq 0.22$	$\frac{90}{361} \simeq 0.25$	Y	0	1	Y	0	0	Y	$\frac{169}{1089} \simeq 0.15$	$\frac{260}{1089} \simeq 0.24$
Types: BB			Types: BA			Types: AB			Types: AA		

Table 3: The two-way cheap-talk equilibrium distribution

Note that, as is evident from Table 3, this equilibrium, $S_{separating}$, generates a fair amount (about 50% in the BB state and 52% in the AA state) of miscoordination when the types are the same, as the players mix in these states.

One can also compare the cheap-talk equilibrium $S_{separating}$ with the unique symmetric Bayesian-Nash equilibrium of the BoS with no communication, given our parameter values, which can be computed easily (see Proposition 1 in Ganguly and Ray, 2017 for details).

Remark 1 *It is easy to verify, as* $A/(1+A)$ ($\simeq 0.39$) $\leq p$ ($= 0.4$) $\leq B/(1+B)$ ($\simeq 0.47$)*, that in the unique Bayesian-Nash equilibrium of the game without any communication, player* 1 *Low-type plays the pure strategy* X *and High-type plays* Y *(by symmetry, player* 2 *Low-type plays* Y *and High-type plays* X*). Thus, in this (pure) Bayesian-Nash equilibrium, the players fully coordinate when their types are different; however, they completely miscoordinate when their types are the same. The expected payoff for each player in this equilibrium therefore is* 0.456.

2.4 Reduced Games

The original Bayesian game, as in Table 2, can be reduced if we assume that only one of the players is communicating and thereby revealing the type truthfully. In such a case, we will have a reduced (Bayesian) game with one-sided private information, in which one of the players will have two types. For example, consider the case where player 1 truthfully reports to be of High-type; then the reduced game will have two types (High and Low) for player 2 only, as shown in Table 4 below.

Player 2: *High-type*			Player 2: *Low-type*		
	X	Y		X	Y
X	$1, 0.9$	$0, 0$	X	$1, 0.65$	$0, 0$
Y	$0, 0$	$0.9, 1$	Y	$0, 0$	$0.9, 1$

Table 4: The reduced Bayesian game with player 1 as High-type

For the above Bayesian game, one may easily find strategy profiles involving a strategy of player 1 and strategies of player 2 for different types that form a Bayesian-Nash equilibrium. Not surprisingly, this game has multiple equilibria. It is indeed easy to check that the profiles $(X; X, X)$ and $(Y; Y, Y)$ are both (pure) Bayesian-Nash equilibria. Moreover, one may prove that the mixed strategy profile given by $(\frac{20}{33}X; \frac{7}{57}X, X)$ in which player 1 plays X with probability $\frac{20}{33}$ (Y with $\frac{13}{33}$) and player 2 with Low-type plays X with probability $\frac{7}{57}$ (Y with $\frac{50}{57}$) while High-type plays the pure strategy X is also a Bayesian-Nash equilibrium of this game.

Similarly, when player 1 is of Low-type, then one may show that the set of equilibria for the corresponding reduced Bayesian game (with player 1 as Low-type and player 2 with two possible types, Low and High) consists of the pure profiles $(X; X, X)$ and $(Y; Y, Y)$ and the mixed profile given by $(\frac{10}{19}X; Y, \frac{65}{66}X)$, in which player 1 plays X with probability $\frac{10}{19}$ (Y with $\frac{9}{19}$) and player 2 with Low-type plays pure strategy Y while High-type plays the X with probability $\frac{65}{66}$ (Y with $\frac{1}{66}$).

By symmetry, using the above analysis, one can also easily find the corresponding sets of equilibrium profiles for two other reduced games in which player 2 is of a given specific type (High or Low) but player 1 has private information, with two types (High and Low).

We will use some of the above equilibria of these reduced games in our hypotheses and experimental analysis below.

3 EXPERIMENT

As explained in the Introduction, we mainly focus on the truthful equilibrium play in the two-way communication and the truthful play in the one-way communication. We are also interested in the differences, if any, in the payoffs obtained in the games, with and without communication, by the participants in our experiments. Our experimental design is guided by this agenda.

3.1 Design and Procedures

As already mentioned in the previous section, we use the version of 2 x 2 game of BoS with private information presented in Table 2.

We have a 3 x 2 experimental design. In total, we have six experimental treatments that can be divided into two categories: *direct* and *strategy* method. Within each category, there are three treatment subgroups. These treatments differ in the communication possibilities: two-way communication, one-way communication and no communication.

In our experiment, in the direct method treatments, the subjects were asked to choose what to announce in the communication stage and what to play in the game in the action stage, as described in the model above. In the strategy method treatments (following Mitzkewitz and Nagel, 1993; also see, Brandts and Charness, 2011, for a survey), they were asked to submit contingent decisions about their announcements and actions. Under the strategy method, in the communication stage (when it exists, i.e., for the two-way and the one-way communication treatments), subjects made announcement decisions conditional on their values; moreover, in the action stage, they chose X or Y in 2, 4 or 8 different situations defined by their types, their hypothetical announcements (if any) and the hypothetical announcements of their counterpart (if any) in the no-communication, one-way and two-way communication treatments respectively. Once both subjects in a matched pair made all the conditional decisions, the values of A and B were randomly and independently generated by the computer, with the probability of the low value (0.65) being 0.6; given the realized values of A and B, the participants' announcements (if any) and their corresponding action choices, one of the situations was identified to determine the payoffs.

Our experiment comprises 9 sessions involving a total of 216 subjects. For the direct method, in each of our treatments, we ran two sessions with 24 subjects; in total, 144 students participated in 6 sessions. For the strategy method, we ran one session with 24 subjects per treatment; hence, 72 subjects participated in these sessions.

We used a "between subjects" design, where each participant took part in only one session and thus only in one treatment. For each of the sessions, we used 3 matching groups, each comprising 8 subjects (i.e., 4 pairs) in order to increase the number of independent observations. Each of these matching groups represents an independent observation; hence, we have 6 and 3 independent observations per treatment for the direct method and the strategy method respectively.

The overview of the experimental design is summarized in Table 5 below. Note that in the strategy method, all subjects choose what they would do if they were of Low or High type; hence, the total number of elicited observations with both Low and High type is equal to 480, however the actual observed frequencies are lower.

Method	Treatment (Comm.)	#Subjects	#Ind. Obs.	#Periods	#Realized Obs. (Low Type)	#Realized Obs. (High Type)
Direct	Two-way	48	6	20	576	384
	One-way	48	6	20	576	384
	None	48	6	20	576	384
Strategy	Two-way	24	3	20	288	192
	One-way	24	3	20	288	192
	None	24	3	20	288	192

Table 5: Summary of the experimental design

Each treatment lasted for 20 rounds. We randomly re-matched the subjects in every round in order to create an environment as close as possible to a one-period interaction between subjects. Subjects were informed that they had been randomly paired with participants; however, they were not aware of the identity of the subjects they were matched with. The same matching protocol was used in all matching groups. In this paper, all our non-parametric tests are based on matching group averages of the relevant variables for each treatment.

All sessions used an identical protocol. At the beginning of a session, subjects were seated and then the instructions were read aloud by the experimenter to all the subjects. In addition, the subjects were given five minutes to review them (see Appendix 2). Then, they were given a few minutes to complete a brief comprehension test (see Appendix 2), to ensure that they had understood the instructions. When the subjects had done the test, we went around to them individually to make sure that they had all the correct answers. The experiment did not proceed until every subject had the correct answers to these questions. Subjects were not allowed to communicate with one another throughout the session, except via the decisions they made during the experiment.

At the beginning of a round, subjects were shown the payoff matrix corresponding to the game and the value of v_i (A or B). For any treatment, in all its sessions, we used the *same* random sequence of values to reduce across-subject variation. After the subjects decided which action to choose, they were provided with the feedback on their own announcement (depending on the treatment), own chosen action, counterpart's announcement (depending on the treatment), counterpart's chosen action, own payoff and counterpart's payoff, after each round. Subjects were not presented a history of the game, however they were given a record sheet in which they may be able to save their previous decisions as well as the decisions of their counterparts and their own payoffs (see Appendix 2 for details).

At the end of round 20, the experimental session ended. Subjects were asked to complete a brief on-screen questionnaire with some supplementary private (anonymous) information and then were privately paid according to their point earnings from all 20 rounds. We used an exchange rate of £1 per point, which allowed us to align the incentives of the subjects with the monetary gain in a clear manner. Sessions lasted, on average, for 45 minutes. The average payment over all treatments was about £11 (approximately $15) which is higher than student jobs in the UK that offer about £7.00 per hour.

The experiment was programmed and conducted with the software *z-Tree* (Fischbacher, 2007). All the sessions for the direct method were conducted at the laboratory of the Centre for Experimental Economics (EXEC) at the University of York while the sessions for the strategy method were conducted at the Economic Learning and Social Evolution (ELSE) at the University College London. The subjects were recruited, using the ORSEE software (Greiner, 2015), from various fields of studies, including, but certainly not confined to, Economics or other Social Sciences, of the University of York and University College London, respectively for the direct and the strategy method parts of the experiment.

3.2 Hypotheses

In this subsection, we formally present our theoretical hypotheses, following the discussion in the Introduction and the formal set-up in Section 2.

As noted earlier, we have chosen our parameters (prior probabilities and the payoffs in the game) so that the truthful equilibrium exists in two-way communication. We expect to observe the equilibrium in two-way communication. However, we believe that the individuals will report their values truthfully in the communication stage regardless of the treatment (one-way or two-way), even though it is not part of an equilibrium to report the type truthfully in the one-way communication game. Thus, our first null hypothesis is as below.

Hypothesis 1 *Individuals truthfully report their values in the communication stage in both the two-way and the one-way treatments.*

Hypothesis 1 also implies that we do not expect any difference in truth-telling between the two types of players within a given game and between the two (one-way and two-way) communication treatments.

Our main hypothesis regarding the players' behavior in the two-way communication treatment is straight-forward: we believe that the players do follow the equilibrium strategy $S_{separating}$ in the game with two-way communication.

Hypothesis 2 *Players follow the fully revealing symmetric perfect Bayesian equilibrium strategy, that is, they report their values truthfully and then choose the actions in $S_{separating}$ in the two-way communication treatment.*

Note that, under Hypothesis 2, the outcomes in the game are as in Table 3.

We now focus on one-way communication and hypothesize the expected outcome in this treatment. Given Hypothesis 1, the announcer's report in the communication stage can be treated as her true type. Therefore, the game is reduced to one in which only one player has private information, such as the one described in Table 4 (in which player 2 has two types). As explained earlier, such a game has multiple (Bayesian-Nash) equilibria. We hypothesize a natural selection from the set of equilibria in such a reduced game. First, we think that the selected equilibrium will be the one where there is coordination, which is desirable and thereby acceptable for both players. We further believe that coordination will occur in the favorite equilibrium of the announcer. That is, if the announcer is a row (column) player of Low-type, the choices will be (X, X) $((Y, Y))$ and when she is of High-type, the choices will be (Y, Y) $((X, X))$. We pose this as our next hypothesis formally.

Hypothesis 3 *In the one-way communication treatment, if the row (column) player truthfully announces the low value, 0.65, then the players coordinate on the equilibrium strategy profile* $(X; X, X)$ $((Y, Y; Y))$, *while the players coordinate on the equilibrium strategy profile* $(Y; Y, Y)$ $((X, X; X))$ *if the row (column) player truthfully announces the high value, 0.90, in the corresponding reduced Bayesian game in which only the column (row) player has private information with two types.*

Our hypothesis regarding the players' behavior in the no communication game is that the players follow the unique Bayesian-Nash equilibrium strategy of the game as described in Remark 1.

Hypothesis 4 *In the no communication treatment, the row (column) player plays the pure strategy* X (Y) *when the value* v_i *is 0.65 and the pure strategy* Y (X) *when the value* v_i *is 0.90.*

One may easily calculate the expected payoff of a player from the chosen equilibria in different treatments under our Hypotheses 2, 3 and 4. One may recall (from the previous section) that $S_{separating}$ generates an expected payoff of 0.67 (approximately) for each player, whereas the expected payoff for each player from the Bayesian-Nash equilibrium of the game (without communication) is 0.456.

Hypothesis 3 suggests that the players always get positive payoffs following the equilibrium selection using one-way communication. As an announcer (the probability of which is 0.5), a player gets either 1 (with probability 0.6) or 0.9 (with probability 0.4) while as a non-announcer, a player gets either 1 (with probability 0.4) or 0.65 (with joint probability 0.36) or 0.9 (with joint probability 0.24); hence, the expected payoff of a player in the game under Hypothesis 3 is 0.905.

This leads us to our final hypothesis regarding the level of coordination (measured by the sum of (X, X) and (Y, Y)) and the payoffs achieved by the players in the game. Note that under Hypothesis

3 (coupled with Hypothesis 1), the players fully coordinate on either (X, X) or (Y, Y) equilibrium in the game, for all type-profiles in the one-way treatment; however, in the two-way communication treatment, they do not fully coordinate when their types are the same under Hypothesis 2, following the equilibrium strategy $S_{separating}$. Also, the players completely miscoordinate in the no communication treatment when their types are the same, under Hypothesis 4, following the Bayesian-Nash equilibrium of the game. Therefore, we believe that the level of coordination and thus the payoffs are expected to be higher in the one-way treatment than those in the two-way treatment which in turn be higher than those in no-communication. We pose this as our final, and the most important, hypothesis.

Hypothesis 5 *Coordination on either (X, X) or (Y, Y) equilibrium and thus the individual payoffs in the game are the higher in the one-way communication than in the two-way communication treatment; these in turn are higher in two-way communication than the no communication treatment.*

Hypothesis 5 suggests that communication helps the players to achieve more coordination and payoffs; however, it's better to allow one-way communication.

We present our analysis of the experimental data and thereby test our hypotheses in the following section.

4 RESULTS

We divide our statistical analysis in different subsections below based on the hypotheses stated above. In each of these subsections, we discuss our findings and the results from the direct method only; a similar analysis for the strategy method is postponed to the Appendix (see Appendix 1).

4.1 Truthfulness

The first question that we are interested in is the truthfulness of the individuals while reporting their types in the communication treatments. The issue here is whether individuals truthfully reveal their types during the cheap talk phase. The short answer is yes. That is, individuals are indeed overall fairly truthful.

We do find that the proportion of truthful behavior is quite high. We can further split this answer into categories by types (Low and High) and by treatments (two-way and one-way communication). Table 6 provides the proportion of truthful reports by all individuals (of two different types, as both row and column players) in the two-way and the one-way communication treatments. For the one-way communication treatment, naturally we have considered only the individuals who are the announcers (as either row or column players).

	Individual Truthfulness					
	Two-way Communication			One-way Communication		
Type	Yes	No	Total	Yes	No	Total
Low	$\frac{459}{80\%}$	$\frac{117}{20\%}$	$\frac{576}{100\%}$	$\frac{240}{82\%}$	$\frac{54}{18\%}$	$\frac{294}{100\%}$
High	$\frac{290}{76\%}$	$\frac{94}{24\%}$	$\frac{384}{100\%}$	$\frac{147}{79\%}$	$\frac{39}{21\%}$	$\frac{186}{100\%}$
Total	$\frac{749}{78\%}$	$\frac{211}{22\%}$	$\frac{960}{100\%}$	$\frac{387}{81\%}$	$\frac{93}{19\%}$	$\frac{480}{100\%}$

Table 6: Truthfulness in all individual reports (by types and by treatments)

Table 6 shows that individuals are overall truthful (about 80% across types and communication treatments); it also indicates that there is hardly any difference between two types and between two different communication treatments.

One may look at the truthfulness within a pair in the two-way communication treatment. Using paired data, we find that in 61% of the pairs, both individuals are truthful while in another 34% of pairs, one of them is truthful.

We can also follow each individual over time and check how truthful she has been. First, in the two-way treatment, we find that 11 (out of 48 individuals) are completely (100%) truthful which is also the modal frequency in the corresponding frequency distribution of individual truthfulness. We also note that the "median" individual is 85% truthful (25 out of 48 individuals report their true types in at least 17 rounds, out of 20), as shown in the cumulative distribution in Figure 1.

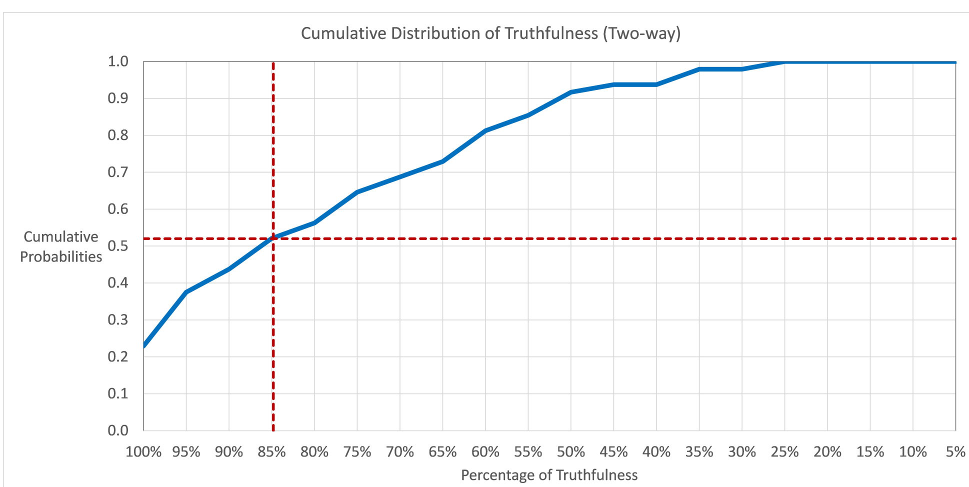


Figure 1: Truthfulness among individuals in two-way communication

We find a very similar distribution for the one-way treatment, as shown in Figure 2; in this case, 13 (out of 48 individuals) are completely (100%) truthful which also is the modal frequency and that the "median" individual is 83% truthful.

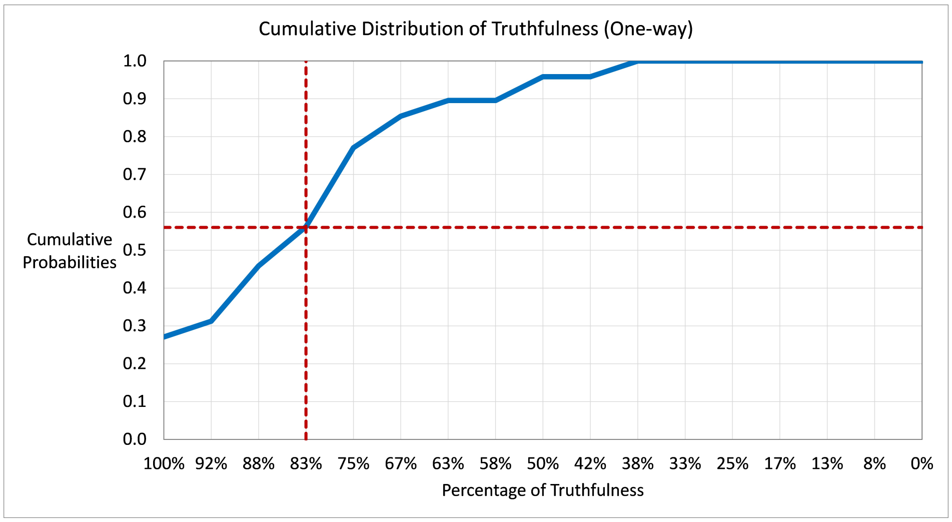


Figure 2: Truthfulness among individuals in one-way communication

To see if there is any time-trend in truth-telling, one may look at the data in five-period blocks. The frequencies (and the percentages) of reporting the true type, over 20 periods, divided into four equal five-period blocks for two types of individuals separately are presented in Table 7.1 (for the one-way treatment) and in Table 7.2 (for the two-way treatment). These frequencies indicate a time-trend that can be shown to be significant using an appropriate regression analysis (details of which are omitted here).

Type	Periods				Frequency
	1 – 5	6 – 10	11 – 15	16 – 20	Total
Low	46 out of 60 (77%)	61/78 (78%)	60/72 (83%)	73/84 (87%)	240/294 (82%)
High	49/60 (82%)	29/42 (69%)	37/48 (77%)	32/36 (89%)	147/186 (79%)
Total	95/120 (79%)	90/120 (75%)	97/120 (81%)	105/120 (88%)	387/480 (81%)

Table 7.1: Frequencies of truthfulness over period by types in one-way communication

Type	Periods				Frequency
	$1-5$	$6-10$	$11-15$	$16-20$	Total
Low	102 out of 138 (74%)	128/168 (76%)	112/132 (85%)	117/138 (85%)	459/576 (80%)
High	76/102 (75%)	53/72 (74%)	82/108 (76%)	79/102 (77%)	290/384 (76%)
Total	178/240 (74%)	181/240 (75%)	194/240 (81%)	196/240 (82%)	749/960 (78%)

Table 7.2: Frequencies of truthfulness over period by types in two-way communication

We may now summarize the main finding of this subsection below.

Result 1 *Individuals are overall truthful in reporting their types during the cheap talk phase, regardless of their private values, in both one-way and two-way communication treatments; truth-telling increases significantly over time.*

Based on Result 1 above we can say that Hypothesis 1 (that the individuals are truthful in the cheap talk phase) finds support in our data.

4.2 Equilibrium Play in Two-way Communication

In this subsection, we test our main equilibrium hypothesis (Hypothesis 2) for the two-way communication treatment. As noted already, given our parameters, the fully revealing separating cheap talk equilibrium of the game, $S_{separating}$, does exist and is unique. As explained earlier, under this equilibrium, having truthfully revealed their types, the players coordinate on the pure Nash equilibrium, (X, X) and (Y, Y), respectively, in the AB and BA states; the equilibrium strategy in the AA state is given by: X (Y) with probability $1/1.65 \simeq 0.61$ for the row (column) player, while for the BB state it is given by: X (Y) with probability $1/1.9 \simeq 0.53$ for the row (column) player.

We ask the question whether the individuals indeed played the equilibrium, $S_{separating}$, in our two-way communication treatment. We therefore look at what the individuals actually chose to play in the game after reporting their types. We present the data organized by individual truthfulness in this table as we have already seen that individuals are mostly truthful (Result 1). Table 8 shows the choices made by the individuals in the game for the two-way communication treatment, along with the theoretical prediction as in the equilibrium strategy profile $S_{separating}$, under truthfulness.

Truthful	Value	C'part Announce		Row Player			Column Player		
				X	Y	Total	X	Y	Total
Yes	A	A	Expt	$\frac{89}{62\%}$	$\frac{55}{38\%}$	144	$\frac{57}{44\%}$	$\frac{73}{56\%}$	130
			Theory	61%	39%		39%	61%	
	A	B	Expt	$\frac{86}{84\%}$	$\frac{16}{16\%}$	102	$\frac{6}{7\%}$	$\frac{77}{93\%}$	83
			Theory	100%	0%		0%	100%	
	B	A	Expt	$\frac{4}{5\%}$	$\frac{72}{95\%}$	76	$\frac{65}{79\%}$	$\frac{17}{21\%}$	82
			Theory	0%	100%		100%	0%	
	B	B	Expt	$\frac{24}{35\%}$	$\frac{44}{65\%}$	68	$\frac{27}{42\%}$	$\frac{37}{58\%}$	64
			Theory	53%	47%		47%	53%	
No	A	A		$\frac{10}{31\%}$	$\frac{22}{69\%}$	32	$\frac{31}{84\%}$	$\frac{6}{16\%}$	37
	A	B		$\frac{12}{55\%}$	$\frac{10}{45\%}$	22	$\frac{6}{23\%}$	$\frac{20}{77\%}$	26
	B	A		$\frac{9}{47\%}$	$\frac{10}{53\%}$	19	$\frac{19}{58\%}$	$\frac{14}{42\%}$	33
	B	B		$\frac{16}{94\%}$	$\frac{1}{6\%}$	17	$\frac{5}{20\%}$	$\frac{20}{80\%}$	25

Table 8: Choices made in the game by all individuals in two-way communication

Individuals appear to play the equilibrium strategy within $S_{separating}$ when they are truthful (from the top half of Table 8). For example, having truthfully reported their own types, individuals of High-type as the row player choose to play Y in 95% (72 out of 76) of the cases if the counterpart's reported type is Low (which may or may not be a true report); also, the truthful Low-type row player plays X in 62% cases if the counterpart's report is Low (compared to the theoretical equilibrium of 61%). These observations are highlighted in Figure 3 that presents the frequencies of the choices by the individuals having truthfully reported own type, compared to the corresponding equilibrium strategies.

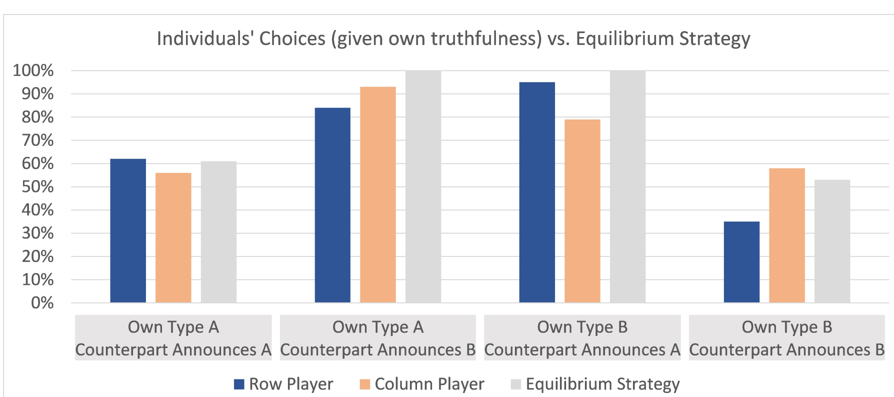


Figure 3: Individuals' choices following own truthful reports in two-way communication

As it is quite visible from the bar charts in Figure 3, truthful individuals seem to choose the equilibrium action, except perhaps the row players in the BB state. We have indeed formally checked if this experimental data statistically fits our equilibrium predictions by using an appropriate Chi-Square goodness of fit test. The test accepts the null hypothesis that our experimental data follows the experimental predictions, except for the case of row players in the BB state for which the data significantly differs from the corresponding equilibrium prediction.

To understand which factors affected the individuals' choices in the game, we run a Probit regression using 960 (48 x 20) individual observations from the 20 periods for the two-way communication treatment. Our dependent variable here is a binary variable called *Choice* that takes value 1 if Y is chosen in the game and 0 otherwise. We use the independent variables: *Player* (takes value 1 if the individual is a column player and 0 otherwise), *Period* (takes integer values from 1 to 20), *Value* (takes value 0 when the type for any individual is Low, that is, the private value in the game is 0.65 and 1 when it is 0.90) and *Truth* (takes value 1 when the reported type is the true type and 0 otherwise) and the variables *Player*Period*, *Player*Value* that are products of the two named variables. We can report that the marginal effects of the variables *Player, Value* and *Player*Value* are significant, indicating column players and High-types are more likely to choose Y and, more importantly perhaps, column players with High-type (only case when the variable *Player*Value* takes the value 1) are more likely to play X, something that is quite compatible with our Hypothesis 2. This result is even more pronounced if we perform the same regression within the truthful sub-sample (586 observations where both individuals are truthful) while dropping the independent variable *Truth*, as shown in Table 9.

Dependent Variable: *Choice* $= 1$ if Y; $= 0$ otherwise			
Number of Observations: 586; Pseudo $R^2 = 0.1241$			
Independent Variables	Marginal Effects	Robust Standard Errors	p-Values
Player	0.41***	0.09	0.000
Period	0.00	0.01	0.895
*Player*Period*	−0.00	0.01	0.701
Value	0.47***	0.05	0.000
*Player*Value*	−0.64***	0.04	0.000
Note: * denotes significance at 10% level, ** at 5% level and *** at 1% level.			

Table 9: Probit regression on choice in two-way communication for the truthful sub-sample

Another way of presenting the observation that the truthful individuals play to coordinate on (X, X) and (Y, Y), respectively in the AB and BA states is just to focus on the truthful subsample (when both players are truthful in a pair), as Figure 4 demonstrates.

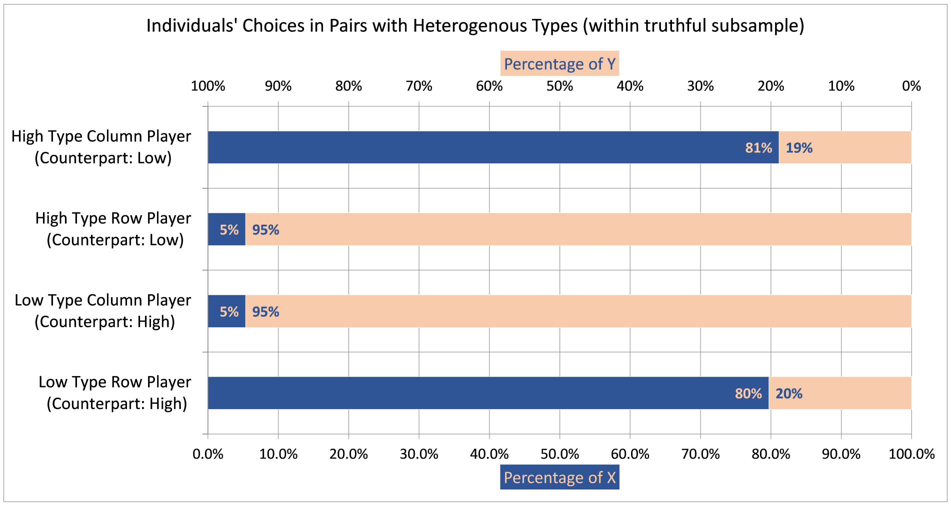


Figure 4: Individuals' play in two-way communication (within truthful pairs)

It is clear from Figure 4 that individuals play to coordinate on the desirable Nash outcome when their types are different. For example, the second bar from the top shows that the High-type row player plays Y in 95% cases when the counterpart is of Low-type.

We now test whether the observed distribution over the outcomes is the same as the theoretical equilibrium distribution for all possible type profiles (as described in Table 3 earlier). To test this equilibrium hypothesis (Hypothesis 2), we use a χ^2-test with the null hypothesis that the observed distribution is indeed same as the theoretical distribution. Table 10 reports the observed distributions under the truthful (where both individuals are truthful) and non-truthful sub-samples and the results of the corresponding χ^2-tests for hypothesis testing.[2]

[2]These tests are done by pooling all observations for all subjects and all periods.

Paired Types	Outcomes					χ^2	p-Values
	XX	XY	YX	YY	Total		
AA (Theoretical Equilibrium)	24%	37%	15%	24%	100%		
AA (Both Truthful)	$\frac{34}{29\%}$	$\frac{40}{34\%}$	$\frac{17}{14\%}$	$\frac{27}{23\%}$	$\frac{118}{100\%}$	$\frac{1.54}{3 \text{ d.f.}}$	0.674
AA (Not Truthful)***	$\frac{27}{40\%}$	$\frac{18}{26\%}$	$\frac{4}{6\%}$	$\frac{19}{28\%}$	$\frac{68}{100\%}$	$\frac{13.24}{3 \text{ d.f.}}$	0.004
AB (Theoretical Equilibrium)	100%	0%	0%	0%	100%		
AB (Both Truthful)*	$\frac{46}{67\%}$	$\frac{9}{13\%}$	$\frac{10}{14\%}$	$\frac{4}{6\%}$	$\frac{69}{100\%}$	$\frac{7.67}{3 \text{ d.f.}}$	0.053
AB (Not Truthful)***	$\frac{11}{24\%}$	$\frac{12}{28\%}$	$\frac{11}{24\%}$	$\frac{11}{24\%}$	$\frac{45}{100\%}$	$\frac{25.69}{3 \text{ d.f.}}$	0.000
BA (Theoretical Equilibrium)	0%	0%	0%	100%	100%		
BA (Both Truthful)	$\frac{0}{0\%}$	$\frac{3}{5\%}$	$\frac{3}{5\%}$	$\frac{50}{90\%}$	$\frac{56}{100\%}$	$\frac{0.64}{2 \text{ d.f.}}$	0.725
BA (Not Truthful)***	$\frac{7}{21\%}$	$\frac{7}{21\%}$	$\frac{8}{23\%}$	$\frac{12}{35\%}$	$\frac{34}{100\%}$	$\frac{14.24}{3 \text{ d.f.}}$	0.002
BB (Theoretical Equilibrium)	25%	28%	22%	25%	100%		
BB (Both Truthful)	$\frac{9}{18\%}$	$\frac{11}{22\%}$	$\frac{13}{26\%}$	$\frac{17}{34\%}$	$\frac{50}{100\%}$	$\frac{3.61}{3 \text{ d.f.}}$	0.307
BB (Not Truthful)*	$\frac{9}{22\%}$	$\frac{7}{18\%}$	$\frac{7}{18\%}$	$\frac{17}{42\%}$	$\frac{40}{100\%}$	$\frac{6.94}{3 \text{ d.f.}}$	0.074
Note: * denotes significance at 10% level, ** at 5% level and *** at 1% level.							

Table 10: Equilibrium predictions and experimental data for two-way communication

The statistical tests reported in Table 10 check whether our equilibrium predictions hold for the truthful and the non-truthful samples for different type profiles (AA, AB, BA and BB). Based on the p-values, we conclude that our experimental data significantly (at 1% level) differs from our equilibrium predictions in the non-truthful samples, whereas for the truthful samples, our experimental data does not differ significantly (at 5% level) from the equilibrium distributions.

We may now summarize the main finding of this subsection.

Result 2 *Individuals' choices in the two-way communication treatment are consistent with the equilibrium strategy, when they are truthful in the cheap talk phase; the unique symmetric fully separating equilibrium outcome is observed in this treatment within the sub-sample when both players are truthful in the cheap talk phase.*

Based on Result 2 above, we find support for our main equilibrium Hypothesis 2. The fully revealing separating cheap talk equilibrium is observed and the individuals play the equilibrium strategies in the game when they report truthfully their types.

4.3 Play in One-way Communication

We now present our results for the one-way communication treatment and thereby test our Hypothesis 3. To do so, we look at the choices made by the players in the game, split into two parts, one for the announcers and the other for the listeners. First, in Table 11, we present the frequencies of strategies played by the announcer in the one-way treatment, along with the theoretical prediction (under truthfulness) according to the equilibrium in the corresponding reduced games as mentioned in Hypothesis 3. Note that there is only one announcer in this treatment and thus the total number of data analyzed here is 480.

Truthful	Value		Row Player			Column Player		
			X	Y	Total	X	Y	Total
Yes	A	Expt	$\frac{133}{87\%}$	$\frac{20}{13\%}$	$\frac{153}{100\%}$	$\frac{10}{11\%}$	$\frac{77}{89\%}$	$\frac{87}{100\%}$
		Theory	100%	0%		0%	100%	
	B	Expt	$\frac{10}{13\%}$	$\frac{67}{87\%}$	$\frac{77}{100\%}$	$\frac{61}{87\%}$	$\frac{9}{13\%}$	$\frac{70}{100\%}$
		Theory	0%	100%		100%	0%	
No	A		$\frac{12}{36\%}$	$\frac{21}{64\%}$	$\frac{33}{100\%}$	$\frac{12}{57\%}$	$\frac{9}{43\%}$	$\frac{21}{100\%}$
	B		$\frac{21}{84\%}$	$\frac{4}{16\%}$	$\frac{25}{100\%}$	$\frac{2}{14\%}$	$\frac{12}{86\%}$	$\frac{14}{100\%}$

Table 11: Choices made in the game by the announcers in one-way communication

The top half of Table 11 shows the behavior of a truthful announcer (in 387 out of 480 cases as reported earlier in Table 6): as a row player, Low-type plays X (87%) and High-type plays Y (89%). Conversely, as a column player, Low-type plays Y (89%) and High-type plays X (87%) which fits well with our hypothesis of equilibrium selection for this treatment (as stated in Hypothesis 3).

One may now consider the listeners' choices to check the behavior as hypothesized in Hypothesis 3. Table 12 presents the listeners' choices (by type) following the announcements, along with the equilibrium predictions as in Hypothesis 3.

		Own (Listener's)				
Counterpart's (Announcer's)				Choice		
Role	Announcement	Value		X	Y	Total
Row	A	A	Expt	$\frac{79}{70\%}$	$\frac{34}{30\%}$	113
			Theory	100%	0%	
		B	Expt	$\frac{55}{85\%}$	$\frac{10}{15\%}$	65
			Theory	100%	0%	
	B	A	Expt	$\frac{3}{5\%}$	$\frac{52}{95\%}$	55
			Theory	0%	100%	
		B	Expt	$\frac{6}{11\%}$	$\frac{49}{89\%}$	55
			Theory	0%	100%	
Column	A	A	Expt	$\frac{24}{41\%}$	$\frac{35}{59\%}$	59
			Theory	0%	100%	
		B	Expt	$\frac{10}{24\%}$	$\frac{32}{76\%}$	42
			Theory	0%	100%	
	B	A	Expt	$\frac{48}{87\%}$	$\frac{7}{13\%}$	55
			Theory	100%	0%	
		B	Expt	$\frac{27}{75\%}$	$\frac{9}{25\%}$	36
			Theory	100%	0%	

Table 12: Choices made in the game by the listeners in one-way communication

Table 12 shows that the choices made by the listeners are broadly in the direction of our Hypothesis 3. For example, given that the row player announcement is A (taken as a true report), the listeners play X as a column player regardless of their own types (70% and 85%) and when this announcement is B, the listeners, play Y as a column player regardless of their own types (95% and 89%).

Tables 11 and 12 together indicate that following truthful announcements by the announcers, specific equilibrium profiles of the corresponding reduced games are played as indicated in Hypothesis 3; for example, having truthfully announced Low-type, a row player plays X and then the listener as a column player plays X regardless of own type, resulting in the equilibrium strategy profile $(X; X, X)$ in this reduced game.

We now present the actual outcomes of the game achieved in this treatment in Table 13.

Announcer's			Outcomes				
Role	Announcement	Observations	XX	XY	YX	YY	Total
Row	A	All	$\frac{98}{53\%}$	$\frac{47}{25\%}$	$\frac{18}{10\%}$	$\frac{23}{12\%}$	186
		Truthful	$\frac{96}{63\%}$	$\frac{37}{24\%}$	$\frac{18}{12\%}$	$\frac{2}{1\%}$	153
	B	All	$\frac{19}{18\%}$	$\frac{12}{12\%}$	$\frac{8}{8\%}$	$\frac{63}{62\%}$	102
		Truthful	$\frac{1}{1\%}$	$\frac{9}{12\%}$	$\frac{6}{8\%}$	$\frac{61}{79\%}$	77
Column	A	All	$\frac{14}{13\%}$	$\frac{32}{30\%}$	$\frac{8}{7\%}$	$\frac{54}{50\%}$	108
		Truthful	$\frac{4}{5\%}$	$\frac{27}{31\%}$	$\frac{6}{7\%}$	$\frac{50}{57\%}$	87
	B	All	$\frac{52}{62\%}$	$\frac{11}{13\%}$	$\frac{11}{13\%}$	$\frac{10}{12\%}$	84
		Truthful	$\frac{52}{74\%}$	$\frac{8}{12\%}$	$\frac{9}{13\%}$	$\frac{1}{1\%}$	70

Table 13: Outcomes in the game in one-way communication

Table 13 indicates that following the truthful announcements, players coordinate on the pure Nash equilibria ((X, X) and (Y, Y)) of the game as suggested by our Hypothesis 3. The message of this section therefore is that even though it's not an equilibrium to play the truthful fully revealing profile in the one-way communication treatment, players are indeed truthful and do play a Bayesian-Nash equilibrium of the corresponding reduced game with one-sided private information. We may now summarize the main finding of this subsection below.

Result 3 *In the one-way communication treatment, individuals play a particular Bayesian-Nash equilibrium in the reduced game with one-sided private information, if the announcer is truthful. When the row (column) player announces Low-type, the players play the strategy profile* (X, X) $((Y, Y))$, *while the players coordinate on* (Y, Y) $((X, X))$ *if the row (column) player announces the High-type.*

Based on Result 3 above we find evidence in favor of our Hypothesis 3 that players play a specific Bayesian-Nash strategy profile in the one-way communication game.

4.4 Play without Communication

We now present our results for the no communication treatment and thereby test our Hypothesis 4. We ask the question whether the individuals indeed played the unique Bayesian-Nash equilibrium of the game without communication. Table 14 shows the choices made by the individuals of different types in the game for the no communication treatment, along with the theoretical equilibrium .

Value		Row Player			Column Player		
		X	Y	Total	X	Y	Total
A	Expt	$\frac{213}{71\%}$	$\frac{87}{29\%}$	$\frac{300}{100\%}$	$\frac{107}{39\%}$	$\frac{169}{61\%}$	$\frac{276}{100\%}$
	Theory	100%	0%		0%	100%	
B	Expt	$\frac{89}{49\%}$	$\frac{91}{51\%}$	$\frac{180}{100\%}$	$\frac{146}{72\%}$	$\frac{58}{28\%}$	$\frac{204}{100\%}$
	Theory	0%	100%		100%	0%	

Table 14: Choices made in the game in no communication

Table 14 does indicate that the Bayesian-Nash strategies are very weakly followed; for example, row (column) players with Low (High) type play the pure strategy X in more than 71% cases which is in line with the equilibrium (pure) strategy, however in all other cases the frequencies do not really match with the corresponding equilibrium strategies.

We now test whether the observed distribution over the outcomes is the same as the theoretical equilibrium distribution for all possible type profiles. To test this equilibrium hypothesis (Hypothesis 4), we use a χ^2-test with the null hypothesis that the observed distribution is indeed same as the theoretical distribution. Table 15 reports the observed distributions and the results of the corresponding χ^2-tests for the hypothesis testing.

Paired Types	Outcomes					χ^2	p-Values
	XX	XY	YX	YY	Total		
AA (Theoretical Equilibrium)	0%	100%	0%	0%	100%		
AA (Observed)***	$\frac{56}{30\%}$	$\frac{73}{39\%}$	$\frac{19}{10\%}$	$\frac{38}{21\%}$	$\frac{186}{100\%}$	$\frac{68.65}{3 \text{ d.f.}}$	0.000
AB (Theoretical Equilibrium)	100%	0%	0%	0%	100%		
AB (Observed)***	$\frac{61}{53\%}$	$\frac{23}{20\%}$	$\frac{19}{17\%}$	$\frac{11}{10\%}$	$\frac{114}{100\%}$	$\frac{24.64}{3 \text{ d.f.}}$	0.000
BA (Theoretical Equilibrium)	0%	0%	0%	100%	100%		
BA (Observed)***	$\frac{17}{19\%}$	$\frac{33}{37\%}$	$\frac{15}{16\%}$	$\frac{25}{28\%}$	$\frac{90}{100\%}$	$\frac{46.94}{3 \text{ d.f.}}$	0.000
BB (Theoretical Equilibrium)	0%	0%	100%	0%	100%		
BB (Observed)***	$\frac{29}{32\%}$	$\frac{10}{11\%}$	$\frac{37}{41\%}$	$\frac{14}{16\%}$	$\frac{90}{100\%}$	$\frac{31.21}{3 \text{ d.f.}}$	0.000
Note: * denotes significance at 10% level, ** at 5% level and *** at 1% level.							

Table 15: Equilibrium predictions and experimental data for no communication

The statistical tests reported in Table 15 check whether our equilibrium outcome predictions hold for different type profiles (AA, AB, BA and BB). Based on the p-values, we conclude that our experimental data significantly (at 1% level) differs from the predicted outcome distribution for all states.

We may now summarize the main finding of this subsection below.

Result 4 *In the no communication treatment, the observed outcomes are different to those that would obtain under the unique Bayesian-Nash equilibrium of the game.*

Based on the analysis in this subsection and Result 4, we unfortunately do not find strong evidence to support our Hypothesis 4 that the players play the unique Bayesian-Nash equilibrium in the game without communication. However, in some cases (such as, row (column) players with Low (High) type), players do seem to play according to the equilibrium strategy.

Result 4 is in sharp contrast with the previous couple of results (Results 2 and 3) that suggest that the players follow the equilibrium in games with communication. The following subsection exploits this contrast even further.

4.5 Coordination and Payoffs

Having analyzed individuals' truthfulness and strategies played in the one-way and two-way communication games, we now focus on the payoffs in the game for different treatments, with and without communication. Obviously, payoffs are positively correlated with the level of coordination on the Nash equilibrium outcomes ((X, X) and (Y, Y)) in the game. Table 16 reports the frequencies of all outcomes chosen in the game. As we are interested in the cases where the individuals report their types truthfully, we also separately list the frequencies in the truthful sub-sample in the treatments with communication (truthfulness refers to the announcer being truthful in the one-way treatment, and both individuals being truthful for the two-way treatment).

TREATMENTS	All					Truthful				
	XX	XY	YX	YY	Total	XX	XY	YX	YY	Total
Two-way	$\frac{143}{30\%}$	$\frac{107}{22\%}$	$\frac{73}{15\%}$	$\frac{157}{33\%}$	$\frac{480}{100\%}$	$\frac{89}{30\%}$	$\frac{63}{22\%}$	$\frac{43}{15\%}$	$\frac{98}{33\%}$	$\frac{293}{100\%}$
One-way	$\frac{183}{38\%}$	$\frac{102}{22\%}$	$\frac{45}{9\%}$	$\frac{150}{31\%}$	$\frac{480}{100\%}$	$\frac{153}{40\%}$	$\frac{81}{21\%}$	$\frac{39}{10\%}$	$\frac{114}{29\%}$	$\frac{387}{100\%}$
No Communication	$\frac{163}{34\%}$	$\frac{139}{29\%}$	$\frac{90}{19\%}$	$\frac{88}{18\%}$	$\frac{480}{100\%}$	NA	NA	NA	NA	NA
Total	$\frac{489}{34\%}$	$\frac{348}{24\%}$	$\frac{208}{14\%}$	$\frac{395}{28\%}$	$\frac{1440}{100\%}$	$\frac{242}{36\%}$	$\frac{144}{21\%}$	$\frac{82}{12\%}$	$\frac{212}{31\%}$	$\frac{680}{100\%}$

Table 16: Outcomes in the game in different treatments

Table 16 suggests that there is hardly any difference between the whole dataset and the truthful sub-sample in terms of the frequencies of outcomes in the game. It also shows the level of coordination in the game, as measured by the proportion of Nash equilibrium outcomes ((X, X) and (Y, Y)). We can see that the percentage of coordination is highest in the one-way communication treatment (69%) followed by the two-way treatment (63%), while the the percentage of coordination in the no communication treatment is only 52%.

One may even look at the above frequencies split into five-period blocks. Figure 5 presents the percentages of coordination ((X, X) and (Y, Y)), over 20 periods, divided into four equal five-period blocks for three different treatments.

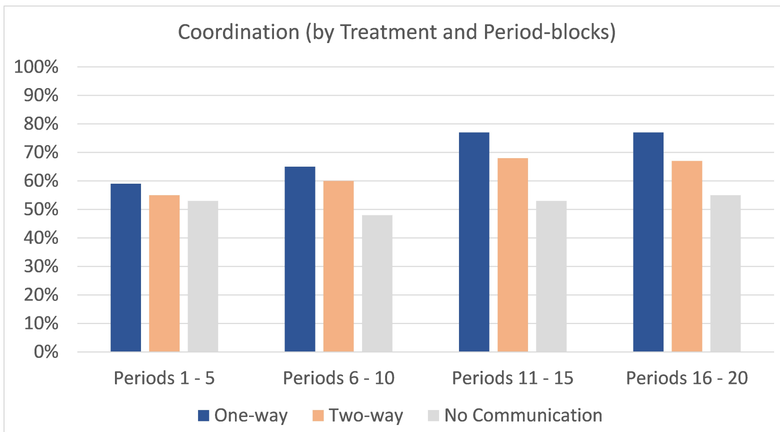


Figure 5: Frequencies (in percentages) of coordination over period blocks by treatments

We now present the actual payoffs in the game in a similar way. Figure 6 below mimics Figure 5 and shows the average payoffs for a pair (sum of payoffs for two players), over 20 periods, divided into four equal five-period blocks for three different treatments.

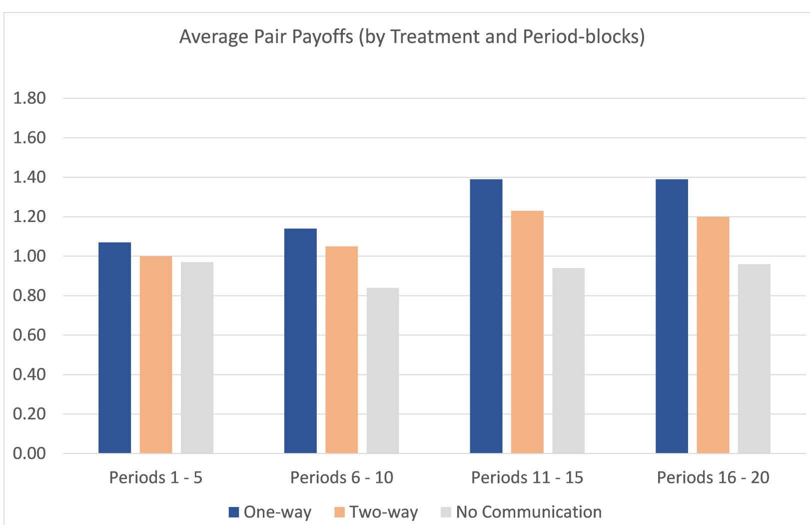


Figure 6: Average payoffs for a pair of players in the game over period blocks by treatments

The two figures above show that there are differences among the three treatments especially from periods 11 to 20. For the comparison of coordination levels (average percentages per treatment and block period are shown in Figure 5), the results of the Mann-Whitney test, using pooled data, show that the difference between one-way and no-communication treatments is significant at 1% level for periods 6 to 20 (with p-values being 0.0093, 0.0001 and 0.0004 for the block of periods 5-10, 11-15 and 16-20 respectively). Again, for periods 6 to 20, we find significant differences between two-way and no communication treatments at 5 to 10% level (with p-values being 0.0703, 0.0123 and 0.0647 for the block of periods 5-10, 11-15 and 16-20 respectively). Finally, we find that the difference between one-way and two-way communication is subtle and there is a significant difference between these two treatments for the last block of period (16-20) at 10% level (with p-value being 0.0863).

The differences between the treatments comparing pair payoffs (averages per treatment and per block period are shown in Figure 6) are more prominent. The results of the Mann-Whitney test, using pooled data, show that the differences between one-way and no-communication is again significant at 1% level for periods 6 to 20 (with p-values being 0.0003, 0.0000 and 0.0000 for the block of periods 5-10, 11-15 and 16-20 respectively). This time, we find significant differences between two-way and no communication treatments at 1 to 5% level (with p-values being 0.0145, 0.0004, and 0.0001 for the block of periods 5-10, 11-15 and 16-20 respectively). Finally, we find significant differences between one-way and two-way communication at 5 to 10% level for periods 11 to 20 (with p-values being 0.0737 and 0.0273 for the block of periods 11-15 and 16-20 respectively).

The charts in Figures 5 and 6 also suggest a time-trend for the two-way and the one-way treatments which can indeed be shown to be significant using a suitable regression analysis.

We now focus on the differences in payoffs among the treatments. A simple way of presenting the differences in payoffs among the treatments is to plot the payoff levels from a rank-sum test for different treatments as shown in Figure 7 below. Given the time-trend shown above, we focus here on periods $11 - 20$ only.

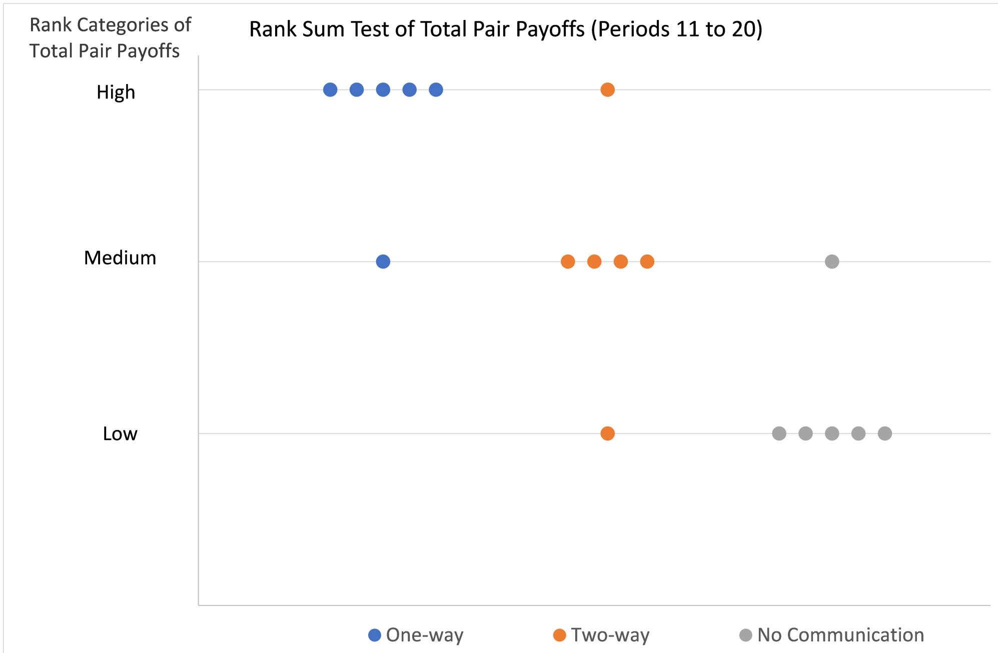


Figure 7: Comparisons of average payoffs for a pair of players in the game by treatments

Figure 7 shows that the payoffs are highest in the one-way treatment. Formally, we use a Kruskal-Wallis equality-of-populations rank test and find these three treatments are significantly different from each other (p-value = 0.0051). Using the similar test for each pair of treatments, we also find that each pair is indeed significantly different (at least at 10% level); the p-value for the comparison of no communication and one-way is 0.0039, the corresponding p-value for no communication and two-way is 0.0374 and the p-value for one-way and two-way is 0.0782. All these levels of significance are even stronger for periods $11-20$ only; for example, the $p-$value in this case (periods $11-20$ only) for comparing one-way and two-way is now 0.0374, indicating that the payoffs are higher in the one-way communication treatment than the two-way treatment.

We may now summarize the main finding of this subsection below.

Result 5 *By using cheap talk individuals coordinate more in the game and thus achieve higher payoffs. Coordination and payoffs increase over time and they are the highest in the one-way communication treatment.*

Based on Result 5 above, we accept our Hypothesis 5 that cheap talk helps the players to achieve more coordination and thereby higher payoffs in the game. We also show that one-way communication achieves the best results in this respect.

5 Conclusion

We performed an experiment using a version of the Battle of the Sexes game with two-sided private information. The main aim was to compare the outcomes when the game is played after either one-way or two-way cheap talk, as well as with no communication. We find that the players are overall truthful about their types in the cheap-talk phase in both one-way or two-way talk, something that is consistent with equilibrium behavior for the two-way treatment, but is not under one-way communication. We find that payoffs are the highest when the communication is one-way.

Clearly, this is an important result, as it suggests that maximum communication does not always enhance efficiency under private information. It would be interesting to know the extent to which this is maintained for other classes of games, for example, games where coordination is not the overarching driver of payoffs.

One important characteristic of our design is that the types of the participants in the experiment are not fixed; they are sometimes high, and sometimes low. This could be helpful for them to accept an implicit (non-equilibrium) truth-telling norm which leads to a socially desirable coordination. It sometimes goes against their self-interest, but over the course of play they end up better off if everyone abides by the norm of truth-telling. We suspect this would not be maintained if types were fixed and players were consistently on a "losing" side of the coordination.

6 APPENDIX 1: STRATEGY METHOD

As mentioned earlier, we ran three treatments (no communication, one-way communication and two-way communication) using the strategy method as well. We report below the observations in the strategy method, following the structure of the main paper on the direct method.

6.1 Truthfulness

Under the strategy method, in the two treatments with cheap talk (one-way and two-way), individuals report their strategies as complete plans; first, they submit a plan of reported types based on their true types and then they submit a plan of actions for the game. There are four possible plans of reporting, mapping from two possible true types to two possible reported types, which we will denote by AA (reporting A when the true type is Low and reporting A when the true type is High, that is, always reporting A regardless of the true type), AB (the truthful strategy of reporting A when the true type is Low and reporting B when the true type is High), BB (always reporting B regardless of the true type) and BA (reporting the opposite of the true value for both types). Table 17 provides all individuals' strategies in the two-way and one-way communication treatments using the strategy method.

Strategies (Maps)	AB (Truthful)	AA	BB	BA	Total
Two-way	$\frac{282}{59\%}$	$\frac{86}{18\%}$	$\frac{74}{15\%}$	$\frac{38}{8\%}$	$\frac{480}{100\%}$
One-way (Announcers only)	$\frac{129}{54\%}$	$\frac{53}{22\%}$	$\frac{42}{17\%}$	$\frac{16}{7\%}$	$\frac{240}{100\%}$

Table 17: Reporting strategies used by all individuals in the strategy method

We note from Table 17 that the truthful strategy has been used by majority of the individuals; however, the observed proportion of truthful reports (plans, in this case) is lower than that in the direct method (as shown in Table 6); also, we note that unlike the direct method (Table 6), individuals are slightly more truthful in the two-way treatment than one-way. We can also report that in the two-way communication, among all pairs, in only 33% (79 out of 240) pairs, both individuals used the truthful strategy (AB) which is way below the corresponding observation (61%) in the direct method; however, in another 52% pairs, one player is truthful.

To compare the individual truthfulness distribution with the corresponding distribution reported in Figure 1 for the direct method in the paper, we look at the individual data in the strategy method as well. We notice that a huge proportion of individuals used one of the non-truthful strategies at least once. Here, our data reveals that only 17% of the individuals used the truthful strategy (AB) in all the 20 periods in the two-way communication treatment while 21% did so (in all 20 periods) in the one-way communication treatment.

One can also do a Probit regression here to understand the effects of different factors behind truthful reporting; we find similar results as in the direct method.

6.2 Two-way Equilibrium

We first describe what the individuals have chosen in different hypothetical scenarios under the strategy method. Table 18 is for the two-way communication treatment under the strategy method where each individual makes conditional choices of X or Y for 8 possible situations as shown in Table 18. Here, the states refer to the situations based on the individual's type (value), own announcement and counterpart's announcement, respectively (see the instructions in Appendix 2). For example, the state AAA refer to the situation when the individual is of Low-type (value A), reports (truthfully) Low-type (value A) while the other player's reported value is also A.

Situations	States	Row Player			Column Player			Total
		X	Y	Total	X	Y	Total	
1	AAA	$\frac{52}{76\%}$	$\frac{16}{24\%}$	$\frac{68}{100\%}$	$\frac{42}{65\%}$	$\frac{23}{35\%}$	$\frac{65}{100\%}$	133
2	AAB	$\frac{38}{68\%}$	$\frac{18}{32\%}$	$\frac{56}{100\%}$	$\frac{7}{23\%}$	$\frac{23}{77\%}$	$\frac{30}{100\%}$	86
3	BBA	$\frac{6}{18\%}$	$\frac{27}{82\%}$	$\frac{33}{100\%}$	$\frac{19}{46\%}$	$\frac{22}{54\%}$	$\frac{41}{100\%}$	74
4	BBB	$\frac{21}{60\%}$	$\frac{14}{40\%}$	$\frac{35}{100\%}$	$\frac{16}{47\%}$	$\frac{18}{53\%}$	$\frac{34}{100\%}$	69
5	ABA	$\frac{10}{77\%}$	$\frac{3}{23\%}$	$\frac{13}{100\%}$	$\frac{9}{31\%}$	$\frac{20}{69\%}$	$\frac{29}{100\%}$	42
6	ABB	$\frac{11}{85\%}$	$\frac{2}{15\%}$	$\frac{13}{100\%}$	$\frac{9}{64\%}$	$\frac{5}{36\%}$	$\frac{14}{100\%}$	27
7	BAA	$\frac{4}{50\%}$	$\frac{4}{50\%}$	$\frac{8}{100\%}$	$\frac{5}{45\%}$	$\frac{6}{55\%}$	$\frac{11}{100\%}$	19
8	BAB	$\frac{11}{79\%}$	$\frac{3}{21\%}$	$\frac{14}{100\%}$	$\frac{10}{63\%}$	$\frac{6}{37\%}$	$\frac{16}{100\%}$	30
Total		153	87	240	117	123	240	480

Table 18: Choices of individuals in the two-way treatment under the strategy method

It is fairly straightforward to interpret the data reported in Table 18. We note, for example, row players who are truthful of their High-types (value B), having received a reported value A from the counterpart, plays Y in 82% of the cases, indicating the equilibrium behavior as mentioned in our Hypothesis 2, which is similar to the corresponding observations in Table 8 for the direct method.

We produce now the frequencies of the observed outcomes for the strategy method in Table 19 below, similar to those in Table 10.

Paired Types	Realized Outcomes				
	XX	XY	YX	YY	Total
AA (Theoretical Equilibrium)	24%	37%	15%	24%	100%
AA (Both Realized Truthful)	$\frac{32}{55\%}$	$\frac{11}{19\%}$	$\frac{6}{10\%}$	$\frac{9}{16\%}$	$\frac{58}{100\%}$
AA (Not Truthful)	$\frac{11}{31\%}$	$\frac{14}{40\%}$	$\frac{1}{3\%}$	$\frac{9}{26\%}$	$\frac{35}{100\%}$
AB (Theoretical Equilibrium)	100%	0%	0%	0%	100%
AB (Both Realized Truthful)	$\frac{13}{38\%}$	$\frac{9}{27\%}$	$\frac{1}{3\%}$	$\frac{11}{32\%}$	$\frac{34}{100\%}$
AB (Not Truthful)	$\frac{10}{43\%}$	$\frac{11}{48\%}$	$\frac{0}{0\%}$	$\frac{2}{9\%}$	$\frac{23}{100\%}$
BA (Theoretical Equilibrium)	0%	0%	0%	100%	100%
BA (Both Realized Truthful)	$\frac{1}{5\%}$	$\frac{4}{19\%}$	$\frac{3}{14\%}$	$\frac{13}{62\%}$	$\frac{21}{100\%}$
BA (Not Truthful)	$\frac{9}{37\%}$	$\frac{6}{25\%}$	$\frac{4}{17\%}$	$\frac{5}{21\%}$	$\frac{24}{100\%}$
BB (Theoretical Equilibrium)	25%	28%	22%	25%	100%
BB (Both Realized Truthful)	$\frac{8}{32\%}$	$\frac{7}{28\%}$	$\frac{4}{16\%}$	$\frac{6}{24\%}$	$\frac{25}{100\%}$
BB (Not Truthful)	$\frac{6}{30\%}$	$\frac{1}{5\%}$	$\frac{8}{40\%}$	$\frac{5}{25\%}$	$\frac{20}{100\%}$

Table 19: Equilibrium predictions and experimental data for two-way communication under the strategy method

6.3 One-way Play

We can report the data from the one-way treatment under the strategy method. Table 20 shows the choices of the announcers in 4 possible scenarios based on own types and announcements; for example, the situation AA refers to the state where the announcer is of Low-type (value A) and the announcement is A.

Situations	States	Row Player			Column Player			Total
		X	Y	Total	X	Y	Total	
1	AA	$\frac{115}{80\%}$	$\frac{29}{20\%}$	$\frac{144}{100\%}$	$\frac{51}{53\%}$	$\frac{45}{47\%}$	$\frac{96}{100\%}$	240
2	AB	$\frac{70}{49\%}$	$\frac{74}{51\%}$	$\frac{144}{100\%}$	$\frac{43}{45\%}$	$\frac{53}{55\%}$	$\frac{96}{100\%}$	240
3	BA	$\frac{87}{60\%}$	$\frac{57}{40\%}$	$\frac{144}{100\%}$	$\frac{58}{60\%}$	$\frac{38}{40\%}$	$\frac{96}{100\%}$	240
4	BB	$\frac{72}{50\%}$	$\frac{72}{50\%}$	$\frac{144}{100\%}$	$\frac{53}{55\%}$	$\frac{43}{45\%}$	$\frac{96}{100\%}$	240
Total		344	232		205	179		960

Table 20: Choices of the announcers in the one-way treatment under the strategy method

Table 21 shows the choices of the listeners in 4 possible scenarios based on own types and the announcements (of the announcers); for example, the situation AA refers to the state where the listener is of Low-type (value A) and the announcer's announcement is A.

Situations	States	Row Player			Column Player			Total
		X	Y	Total	X	Y	Total	
1	AA	$\frac{44}{46\%}$	$\frac{52}{54\%}$	$\frac{96}{100\%}$	$\frac{101}{70\%}$	$\frac{43}{30\%}$	$\frac{144}{100\%}$	240
2	AB	$\frac{61}{64\%}$	$\frac{35}{36\%}$	$\frac{96}{100\%}$	$\frac{41}{28\%}$	$\frac{103}{72\%}$	$\frac{144}{100\%}$	240
3	BA	$\frac{29}{30\%}$	$\frac{67}{70\%}$	$\frac{96}{100\%}$	$\frac{103}{72\%}$	$\frac{41}{28\%}$	$\frac{144}{100\%}$	240
4	BB	$\frac{60}{63\%}$	$\frac{36}{37\%}$	$\frac{96}{100\%}$	$\frac{67}{47\%}$	$\frac{77}{53\%}$	$\frac{144}{100\%}$	240
Total		194	190		312	264		960

Table 21: Choices of the listeners in the one-way treatment under the strategy method

6.4 No communication

We report the data from the no communication treatment under the strategy method. Table 22 shows the individual choices for each of the two situations they may be in (based on their values).

Situations	Values	Row Player			Column Player		
		X	Y	Total	X	Y	Total
1	0.65	$\frac{187}{78\%}$	$\frac{53}{22\%}$	$\frac{240}{100\%}$	$\frac{126}{53\%}$	$\frac{114}{47\%}$	$\frac{240}{100\%}$
2	0.90	$\frac{147}{61\%}$	$\frac{93}{39\%}$	$\frac{240}{100\%}$	$\frac{167}{70\%}$	$\frac{73}{30\%}$	$\frac{240}{100\%}$

Table 22: Choices in the no communication treatment under the strategy method

We also report the frequencies of the observed outcomes in this no communication treatment in Table 23, which compares with Table 15.

Paired Types	Outcomes				
	XX	XY	YX	YY	Total
AA (Observed)	$\frac{41}{44\%}$	$\frac{33}{35\%}$	$\frac{9}{10\%}$	$\frac{10}{11\%}$	$\frac{93}{100\%}$
AB (Observed)	$\frac{33}{58\%}$	$\frac{13}{23\%}$	$\frac{9}{16\%}$	$\frac{2}{3\%}$	$\frac{57}{100\%}$
BA (Observed)	$\frac{14}{31\%}$	$\frac{12}{27\%}$	$\frac{11}{24\%}$	$\frac{8}{18\%}$	$\frac{45}{100\%}$
BB (Observed)	$\frac{22}{49\%}$	$\frac{10}{22\%}$	$\frac{10}{22\%}$	$\frac{3}{7\%}$	$\frac{45}{100\%}$
Total	110	68	39	23	240

Table 23: Observed outcomes for the no communication treatment under the strategy method

6.5 Coordination

In the strategy method, individuals choose plans of reports and thereby what to play in the game in different hypothetical situations. We consider the actual outcomes, from the realizations of the plans, in the strategy method. Following Table 16 in the direct method, here as well we report the (realized) outcomes from all observations and also from the truthful sub-sample (truthful in actual realizations - both truthful in the two-way treatment) as shown in Table 24.

Treatments	All					Truthful				
	XX	XY	YX	YY	Total	XX	XY	YX	YY	Total
Two-way	$\frac{90}{38\%}$	$\frac{63}{26\%}$	$\frac{27}{11\%}$	$\frac{60}{25\%}$	$\frac{240}{100\%}$	$\frac{54}{39\%}$	$\frac{31}{23\%}$	$\frac{14}{10\%}$	$\frac{39}{28\%}$	$\frac{138}{100\%}$
One-way	$\frac{100}{42\%}$	$\frac{55}{23\%}$	$\frac{48}{20\%}$	$\frac{37}{15\%}$	$\frac{240}{100\%}$	$\frac{74}{42\%}$	$\frac{37}{21\%}$	$\frac{38}{22\%}$	$\frac{27}{15\%}$	$\frac{176}{100\%}$
No Communication	$\frac{110}{46\%}$	$\frac{68}{28\%}$	$\frac{39}{16\%}$	$\frac{23}{10\%}$	$\frac{240}{100\%}$	NA	NA	NA	NA	NA
Total	$\frac{300}{42\%}$	$\frac{186}{26\%}$	$\frac{114}{16\%}$	$\frac{120}{16\%}$	$\frac{720}{100\%}$	$\frac{128}{41\%}$	$\frac{68}{22\%}$	$\frac{52}{16\%}$	$\frac{66}{21\%}$	$\frac{314}{100\%}$

Table 24: Outcomes (realized) in the strategy method

As in the direct method, here as well we take the proportion of Nash equilibrium outcomes ((X, X) and (Y, Y)) as our measure of coordination. Table 25 below is derived from Table 24.

Treatments	All			Truthful		
	Coordination	No	Total	Coordination	No	Total
Two-way	$\frac{150}{63\%}$	$\frac{90}{37\%}$	$\frac{240}{100\%}$	$\frac{93}{67\%}$	$\frac{45}{33\%}$	$\frac{138}{100\%}$
One-way	$\frac{137}{57\%}$	$\frac{103}{43\%}$	$\frac{240}{100\%}$	$\frac{101}{57\%}$	$\frac{75}{43\%}$	$\frac{176}{100\%}$
No Communication	$\frac{133}{55\%}$	$\frac{107}{45\%}$	$\frac{240}{100\%}$	NA	NA	NA
Total	$\frac{420}{58\%}$	$\frac{300}{42\%}$	$\frac{720}{100\%}$	$\frac{194}{62\%}$	$\frac{120}{38\%}$	$\frac{314}{100\%}$

Table 25: Coordination per treatment in the strategy method

From Table 25, we note, contrary to the direct method, the percentage of coordination (in realized outcomes) is the highest in the two-way communication treatment followed by the one-way treatment.

7 APPENDIX 2: INSTRUCTION MATERIALS

We report below the full set of instructions, the test and the record sheet only for the two-way treatment of the direct method. The instructions (and the corresponding test and record sheet) for the one-way and no-way treatments differ in a natural way; thus, for obvious reasons, these have been omitted here. For the strategy method, we report just the instructions for the two-way treatment. The rest of the materials are available upon request.

7.1 Instructions (Two-way; Direct Method)

All participants in this session have the following identical instructions.

Welcome to this experiment, and thank you for participating. From now onwards please do not talk to any other participants until the experiment is finished.

You will be given five minutes to read these instructions. Then we will ask you to complete a brief test to ensure that you have understood them, before starting the experiment itself.

YOUR DECISION PROBLEM

In this experiment you are asked to make a simple choice, in each of 20 successive rounds. In each round you earn a number of points, as described below. The total number of points you accumulate over the 20 rounds determines your final money payment, at a conversion rate of 1 point = £1 (= 100 pence).

At the start of the first round, the computer randomly assigns you the role of either Player 1 or Player 2. You keep this same role throughout all 20 rounds.

But in each round you are randomly paired with another participant. So, if you are assigned the role of Player 1, then the Player 2 who is paired with you in each round will probably be a different participant from the Player 2 paired with you in earlier rounds. And likewise, if you are assigned the role of Player 2, then the Player 1 paired with you in each round will probably be a different participant from the Player 1 paired with you in earlier rounds.

In each round, Player 1 and Player 2 each have to choose one of two alternatives, X and Y. You do so independently of each other. So at the moment you make your own choice, you do not know the choice of the other player.

YOUR EARNINGS

The two players' choices together determine the points you each earn from that round, as described in the following table.

	Player 2's Choice	
Player 1's Choice	X	Y
X	$1, B$	$0, 0$
Y	$0, 0$	$A, 1$

The first number in each cell indicates the points earned by Player 1, and the second number indicates the points earned by Player 2.

In the above table, the number A is known to player 1 only; it is either 0.65 or 0.90. The probability of the low value (0.65) is 60% while the probably of the high value (0.90) is 40%. Similarly, the number B is known to player 2 only; it is either 0.65 or 0.90. Here as well, the probability of the low value (0.65) is 60% while the probably of the high value (0.90) is 40%.

At the start of each round, the values of A and B are generated randomly and independently by the computer.

The interpretation of the table is as follows:

If in some round, the choices made by the two players are different (XY or YX), then both players get 0.

If in some round, both players choose X, then from that round Player 1 will earn 1 point (£1) while Player 2 will earn either 0.65 (65p) or 0.90 (90p) which is known to Player 2 only.

If in some round both players choose Y, then from that round Player 2 will earn 1 point (£1) while Player 1 will earn either 0.65 (65p) or 0.90 (90p) which is known to Player 1 only.

In each round, you and your counterpart are each informed of the respective values. You are informed only of the value for you, and you don't know your counterpart's value, however, as mentioned, the chances for your counterpart's value being 0.65 (65p) or 0.90 (90p) are respectively 60% and 40%, regardless of your own value.

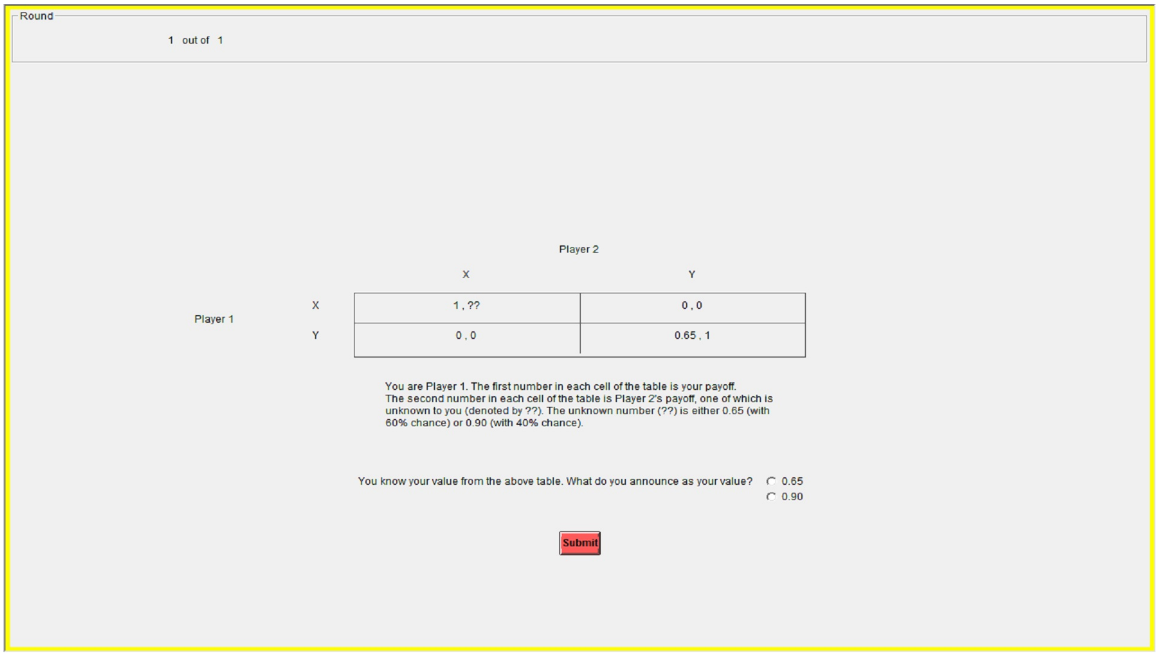
YOUR ANNOUNCEMENT

After learning the value (and before making a choice), you and your counterpart both will be asked to make an announcement regarding your respectively values. Each of you has two alternative values to announce: 0.65 or 0.90.

It is entirely up to you, in any round, whether or not to announce your true value for that round. The points that you will earn depend only on the choices made and the actual values, as described on the previous page, irrespective of the announcements.

THE COMPUTER SCREEN

The main screen for each round looks like this.

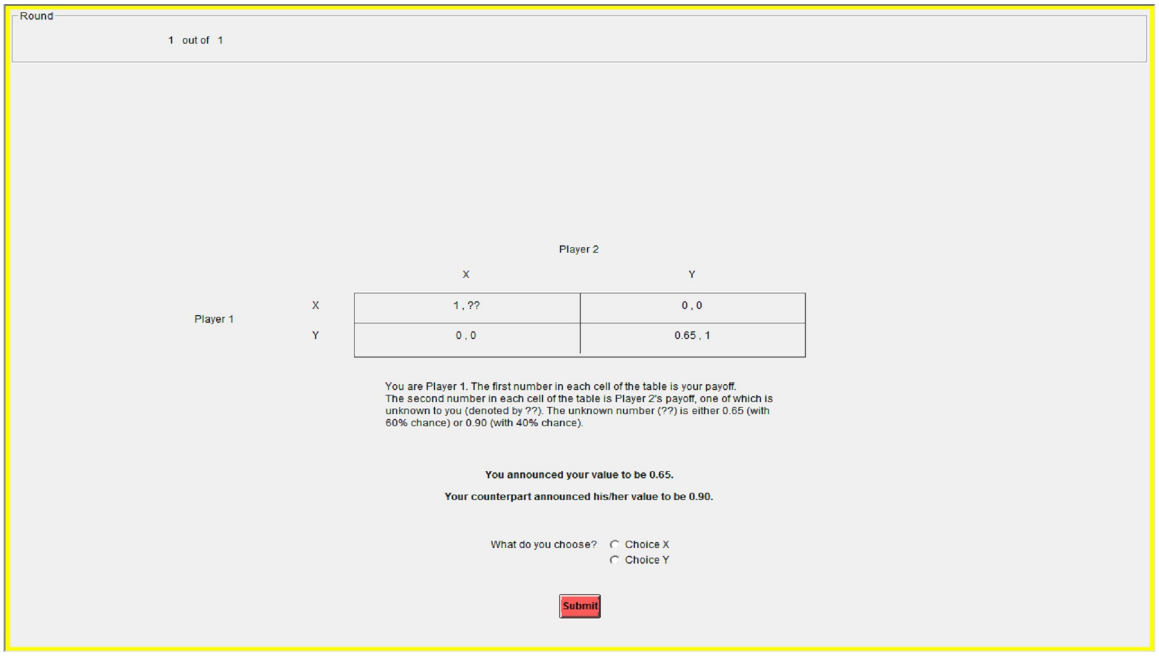


At the top of the screen there is a message which keeps count of the round, out of 20 (in this example, Round 1). In the centre of the screen is the table which appears on the first page of these instructions. Immediately below the table is a message informing you which role (Player 1 or 2) you have been assigned (in this example, Player 1). This is the same in each round.

You know your value from the table (in this example, the value of Player 1 is $A = 0.65$); however, the unknown value is indicated by “??” in the table (in this example, the value of Player 2, B, is unknown to player 1 and is indicated by “??”).

Having seen your value form the table, you may make your announcement of a value of 0.65 or 0.90 by selecting the appropriate button and then clicking on Submit.

You may then have to wait a few moments until all participants have made their announcements, after which will appear the next screen for you (in this example, Player 1) as shown below.

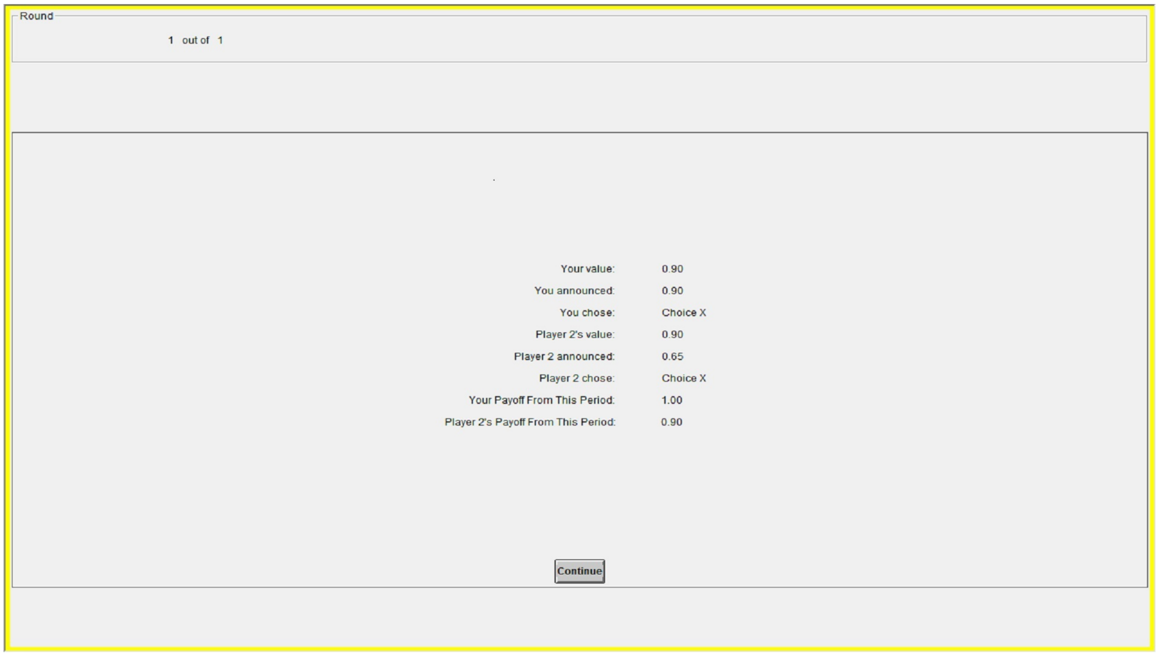


In this screen, you will be informed of your and your counterpart's announced values (these may not be the true values) below the description of the table and will be asked to make a choice. To make your choice of X or Y, select the appropriate button and then click on Submit.

You may then have to wait a few moments until all participants have made their choices, after which the results for you in that round will appear onscreen.

The result after each round includes information of the values for the both players, choices made by each of the two players, and the points earned by each player (as below for example).

On your desk there is a Record Sheet on which you can keep a note of these results, if you wish to.



After all the participants have read their results and clicked Continue, the main screen for the next round will appear again as shown earlier.

AT THE END OF THE EXPERIMENT

When all 20 rounds have been completed, you will be asked to complete a brief onscreen questionnaire, which provides useful supplementary (anonymous) information for us.

Having completed the questionnaire, you will see a final screen reporting your total points accumulated over the 20 rounds and the corresponding monetary payment (in £).

Please then wait for further instructions from the experimenter, who will pay you in cash before you leave. While waiting, please complete the receipt form which you will also find on your desk. We need these receipts for our own accounts.

The results from this experiment will be used solely for academic research. Participants will remain completely anonymous in any publications connected with this experiment.

Thank you for participating. We hope that you enjoy the experiment, and that you will be willing to participate again in our future experiments.

7.2 Test (Two-way; Direct Method)

After reading the instructions you will be asked to complete this brief test, to ensure you have understood them, before starting the experiment itself.

You may look again at the instructions while answering these questions.

For questions $1-4$, write the answers in the corresponding boxes.

1. If you choose Y and your counterpart chooses X, how many points do you earn in that round?

2. Suppose your value is 0.90; if you announce 0.65 and choose X and your counterpart announces 0.65 and chooses Y, how many points do you earn in that round?

3. Suppose you are Player 1 and your value is 0.65; if you announce 0.90 and choose Y and your counterpart also chooses Y, how many points do you earn in that round?

4. If over the 20 rounds you accumulate a total of 10.65 points, what is your final cash payment (in £) for the experiment?

For questions $5-8$, circle either True or False.

5. Your counterpart is the same person in each round. True / False

6. If the value for you is 0.65, then your counterpart's value must be 0.65. True / False

7. Suppose you are Player 1; whatever the true and announced values are, you always get more points when both of you choose the same than different. True / False

8. In any publications arising from this experiment the participants will be completely anonymous. True / False

Thank you for completing this test. Please leave this completed sheet face up on your desk.

The experimenter will come round to check that you have the correct answers. If any of your answers are incorrect then the experimenter will give you some explanatory feedback.

7.3 Record Sheet (Two-way; Direct Method)

Use of this sheet is optional. It is provided so that you can keep a record of the results in each round, as reported on your computer screen at the end of the round. This may be useful to you in considering your decisions in subsequent rounds.

You have been assigned the role of the Player (circle one): 1 2

In each cell in the table below, simply circle the correct value as appropriate, while the information is still on your screen at the end of that round, before clicking Continue.

Round	My Value	Announce	Choice	C'part's Value	Announce	Choice	My Point
1	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
2	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
3	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
4	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
5	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
6	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
7	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
8	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
9	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
10	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
11	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
12	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
13	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
14	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
15	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
16	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
17	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
18	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
19	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	
20	0.65 0.90	0.65 0.90	X Y	0.65 0.90	0.65 0.90	X Y	

7.4 Instructions (Two-way; Strategy Method)

All participants in this session have the following identical instructions.

Welcome to this experiment, and thank you for participating. Please read the instructions carefully. If you have any questions or concerns, please raise your hand and the experimenter will come to answer your question in private. From now onwards please do not talk to any other participants until the experiment is finished. After you read these instructions we will start our experiment but before you take your actual decisions we will ask you to complete a brief test in the computer screen.

YOUR DECISION PROBLEM

In this experiment you are asked to make choices in 20 successive rounds. In each round, you earn a number of points as described later. The total number of points you accumulate over the 20 rounds determines your final monetary payment, at a conversion rate of 1 point = £1 (= 100 pence); additionally, you will earn £5 as a fixed show-up fee. The amount you make will be paid to you in cash at the end of the experiment.

At the start of the first round, the computer randomly assigns you the role of either Player 1 or Player 2. You keep this same role throughout all 20 rounds. At the beginning of each round you are randomly paired with another participant (of different role) and neither of you will know the identity of your counterpart throughout the experiment.

In each round, you and your counterpart (the person are paired with) will be asked to make announcement decisions in two situations and will face 8 different situations in each of which you have to choose one of two alternatives, X or Y. Please note that you and your counterpart will make your decisions independently of each other. So at the moment you make your own choice, you do not know the choice of the other player.

YOUR POINTS

The two players' choices together determine the points you each earn from that round, as described in the following table.

		Player 2's Choice	
		X	Y
Player 1's Choice	X	$1, B$	$0, 0$
	Y	$0, 0$	$A, 1$

The first number in each cell indicates the points earned by Player 1, and the second number indicates the points earned by Player 2. Number A represents Player 1's value, similarly number B represents Player 2's value. Both the values A and B are either 0.65 or 0.90. The probability of the low value (0.65) is 60% while the probably of the high value (0.90) is 40%, and the probabilities for A and B are generated randomly and independently. In other words, the probability of A being 0.65 or 0.90 does not influence the probability of B being equal to 0.65 or 0.90 and vice versa.

The interpretation of the table is as follows:

If in some round, the choices made by the two players are different (XY or YX), then both players get 0.

If in some round, both players choose X, from that round Player 1 will earn 1 point (£1) while Player 2 will earn the value of B; that is, either 0.65 (65p) or 0.90 (90p).

If in some round both players choose Y, from that round Player 2 will earn 1 point (£1) while Player 1 will earn the value of A; that is, either 0.65 (65p) or 0.90 (90p).

YOUR DECISIONS

PART 1: YOUR CONDITIONAL ANNOUNCEMENTS

In each round, both you and your counterpart will be asked to make conditional announcements regarding your respective values of A and B. Each of you has two alternative values to announce (0.65 or 0.90) for the two possible situations shown in Table 1 below.

Table 1

Situation	Your value	What do you announce?
1	0.65	0.65 or 0.90
2	0.90	0.65 or 0.90

For example, if you are assigned the role of Player 1, in situation 1 you are informed that $A = 0.65$, and you decide what to announce (0.65 or 0.90), whereas in situation 2, you are informed that $A = 0.90$, and again decide your announcement. On the other hand, if you are assigned the role of Player 2, in situation 1 you are informed that $B = 0.65$, and you decide what to announce (0.65 or 0.90), whereas in situation 2, you are informed that $B = 0.90$, and decide your announcement.

It is entirely up to you, in any round, whether or not to announce your true value in either situation. Your and your counterpart's conditional announcement decisions in this part will determine a situation in Table 2 in Part 2. The points that you will earn depend only on the choices made and your value for that situation, as described in the previous page, irrespective of the announcements.

PART 2: YOUR CONDITIONAL CHOICES

In each round, you and your counterpart will be asked to make conditional choices for 8 situations as shown in Table 2 below. In Table 2, column 1 represents the number of the situation. Column 2 shows your value (that is, the value of A if you are assigned to be Player 1, and the value of B if you are Player 2). Columns 3 and 4 show respectively, your and your counterpart's announcements. Finally, column 5 is where you choose X or Y for each situation.

Table 2

Situation	Your value	Your announcement	C'part's announcement	What do you choose?
1	0.65	0.65	0.65	X or Y
2	0.65	0.65	0.90	X or Y
3	0.65	0.90	0.65	X or Y
4	0.65	0.90	0.90	X or Y
5	0.90	0.65	0.65	X or Y
6	0.90	0.65	0.90	X or Y
7	0.90	0.90	0.65	X or Y
8	0.90	0.90	0.90	X or Y

For example, for situation 1, you will have to choose X or Y given that your value (A for Player 1 and B for Player 2) is equal to 0.65, you announced your value to be 0.65, and you received an announcement that your counterpart's value is also 0.65.

On the other hand, for situation 5, you have to choose X or Y given that your value (A for Player 1 and B for Player 2) is 0.90 but you announced your value to be 0.65 and you received an announcement of 0.65 from your counterpart.

YOUR EARNINGS

In each round, once you and your counterpart have made all the conditional decisions in parts 1 and 2, the values of A and B are randomly and independently generated by the computer, with the probability of the low value (0.65) being 60% and the probability of the high value (0.90) being 40%.

Given the realized values of A and B, and your and your counterpart's announcements from Table 1, one of the 8 situations in Table 2 is identified. Your and your counterpart's choices of X and Y in the corresponding situation will then determine your points.

AT THE END OF THE EXPERIMENT

When all 20 rounds have been completed, you will be asked to complete a brief onscreen questionnaire, which provides useful supplementary (anonymous) information for us.

Having completed the questionnaire, you will see a final screen reporting your total points accumulated over the 20 rounds and the corresponding monetary payment including your show-up fee (in £).

Please then wait for further instructions from the experimenter, who will pay you in cash before you leave. While waiting, please complete the receipt form provided in your computer screens. We need these receipts for our own accounts.

The results from this experiment will be used solely for academic research. Participants will remain completely anonymous in any publications connected with this experiment.

Thank you for participating. We hope that you enjoyed the experiment, and that you will be willing to participate again in our future experiments.

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