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Abstract

We present a theoretical and experimental study of three Cheap Talk games, each having two senders and one receiver. The communication of senders is simultaneous in the first game, sequential in the second game and determined by the receiver in the third game (the Choice Game). We find that the overcommunication phenomenon observed in similar settings with only one sender becomes insignificant in our two-sender model regardless of the mode of communication. Despite similar theoretical predictions for these games, we observe systematic differences in experiments. In particular, while non-conflicting messages are observed less frequently under sequential communication due to the tendency of the second sender to revert the message of the first sender, the frequency of the second sender being truthful when the first sender lies is considerably higher in the Sequential Game in comparison to the truth-telling level in the Simultaneous Game. Moreover, in the Choice Game receiver prefers simultaneous mode of communication slightly more often than the sequential one. We explain the observed behavior of the players, estimating a logit quantal response equilibrium model and additionally running some logistic regressions. We find that the mode of communication is critical in design problems where a second opinion is available.

Keywords: Strategic information transmission; truth-telling; trust; sender-receiver game.

JEL Classification Numbers: C72; C90; D83.

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1 Introduction

A recent experimental literature analyzes information transmission in a class of sender-receiver games in which the only equilibrium is a 'babbling equilibrium' where communication is not informative. In this class of games, a sender privately observes Nature's realization of a conflicting payoff table that could be of two equally likely types. The sender then transmits a message involving the type of the payoff table to the receiver, whose action will in turn determine an outcome in the payoff table chosen by Nature. The possible strategies are telling the truth and lying about the payoff table from the viewpoint of the sender whereas trusting and distrusting from the viewpoint of the receiver. For this class of games, it is known since the seminal work of Crawford and Sobel (1982) that the sender will optimally not transmit any information in any sequential equilibrium. While the comparative statics predictions of this theory was experimentally confirmed by Dickhaut et al. (1995), a number of experiments conducted recently offer conflicting evidence. The main experimental findings of this recent literature (which we present in detail in Section 1.1) are the existence and the robustness of overcommunication and overtrust phenomenon i.e. higher truth-telling and trust levels than the theory predicts.

In this paper, we extend the baseline cheap talk model of Sánchez-Pagés and Vorsatz (2007) in a direction to allow for two senders under different modes of communication (simultaneous vs sequential) to identify whether the overcommunication and overtrust persists and which mode could potentially bring more benefit to an uninformed receiver. As the mode of communication could be relevant on the level of information transmitted in various settings (such as getting advice from two experts, doctors, lawyers, managers etc.), extending a one sender and one receiver model to a multi-sender setup to identify the effects of different modes of communication could be instrumental in mechanism design.

In that regard, we consider three different sender-receiver games played by two senders and one receiver, namely the Simultaneous, Sequential, and Choice Game. The informational setup in each game is similar to that in the single sender -receiver game studied by Sánchez-Pagés and Vorsatz (2007). The receiver only knows the possible payoff tables, whereas the two senders also know the actual payoff table. Each game is a constant-sum; so the receiver and the two senders as a whole have opposing interests. Additionally, we assume that the two senders' payoffs are always equal in order to isolate the effect of the order of play in the sequential communication of the senders with the receiver. In the Simultaneous Game, the two senders simultaneously transmit a payoff-relevant message (the type of the actual payoff table) to the receiver. In the Sequential Game, the two senders are named by sender 1 and sender 2 with respect to a given order, and then sender 1 transmits a payoff-relevant message that is received by both sender 2 and the receiver. Next, sender 2 transmits a payoff-relevant message to the receiver. Finally, in the Choice Game, the receiver first decides whether the Simultaneous or Sequential Game will be played, and then the chosen game is played accordingly. In each of these three games, the receiver takes an action after observing the message of the senders, and consequently the payoffs of the three players are determined by the actual payoff table chosen by Nature and the action taken by the receiver. Since preferences of the senders and the receiver are not aligned, the theory predicts that rational and self-interested senders will optimally not transmit any information under any mode of communication; and consequently the choice of the game will be immaterial for a rational receiver.

Our experiments yield the following results.

- While the excessive truth-telling phenomenon –which has been observed in sender-receiver games that involve a single sender but otherwise have similar structures– is still somewhat persistent, it becomes insignificant with the addition of a second sender regardless of the mode of communication of the senders.

- In particular, senders exhibit excessive truth-telling by sending truthful messages with a frequency of 54% in the Simultaneous Game and 53.3% in the Sequential Game, which are higher than the theoretical prediction of the one half, but with p-values that are higher than 0.05.

- Interestingly, the frequency that sender 1 is truthful is 50% in the Sequential Game, whereas the frequency that sender 2 is truthful given that sender 1 is truthful is 54% and it becomes as high as 58.9% when sender 1 lies in the Sequential Game. Thus, the main contribution to the excessive truth-telling comes from senders playing the second move in the Sequential Game.

- Senders send non-conflicting messages 51.4% of the time in Simultaneous Game and 46.4% in the Sequential Game. While non-conflicting messages in the Sequential Game are more likely to be truthful than not with a frequency of 54.5%, this figure is remarkably higher in the Simultaneous Game with 58.2%.

- Excessive trust the receiver is found to exhibit in cheap talk games with a single sender is not affected by the presence of a second sender under any type of communication. The trust frequencies are 56.5% for the Simultaneous Game and 59.6% for the Sequential Game, but only the latter figure is significantly different than the theoretical prediction of 0.5.

- The expected utility of the receiver is higher in the Simultaneous Game compared to the Sequential Game.

- In the Choice Game receivers prefer simultaneous messages slightly more often than sequential messages, however it is not significantly different than the theoretical prediction.

In order to explain the observed differences in behavior of senders and receiver in simultaneous and sequential plays, we use a logit agent quantal response equilibrium (logit-AQRE) model, following Peeters et al. (2013) and Gurdal et al. (2014).[1] In this behavioral model, where players could be boundedly rational, each sender is associated with a parameter representing non-monetary cost of lying. The Maximum Likelihood Estimations of the model show that the subjects in our experiments are indeed boundedly rational, while the magnitude of their irrationality is found to be independent of the type of the game they play. However, while the senders in the Simultaneous Game and sender 2 in the Sequential Game who moves after sender 1 has lied are found to face a nonzero cost of lying; this is not the case for sender 1 or for sender 2 when sender 1 is truthful in the Sequential Game.

Our findings also reveal that in terms of the induced expected utilities the Sequential Game is the superior game for each of the two senders and consequently the inferior game for the receiver. Additionally, in both of the Simultaneous and Sequential Games the receiver becomes better off when senders submit nonconflicting messages, which are observed more frequently in Simultaneous Game. These results suggest that the choice of how players communicate may be essential for principal-agent problems with multiple agents.

To investigate the determinants of the observed receiver behavior in the Choice Game we run logistic regressions. Among various results, we show that the receiver is more likely to select simultaneous play if the previous play was simultaneous and the receiver earned the high payoff and much more likely to select simultaneous play if the messages were nonconflicting additionally. Whether the messages are conflicting in a sequential play does not statistically significantly affect the probability of choosing simultaneous play the next period. The receiver is statistically significantly the least likely to select simultaneous play if the receiver earned the high payoff in a sequential play in the last period. Also, we find that high ratio of nonconflicting messages in both the Simultaneous and the Sequential Game increases the likelihood of simultaneous choice in the Choice Game, while the estimated impact is much larger in the Simultaneous Game than in the Sequential Game.

The rest of the paper is organized as follows: Section 1.1 presents the related literature. Section 2 introduces two senders and one receiver games played in the experiments and presents some theoretical predictions. Section 3 presents the experimental design and procedures, while Section 4 reports experimental results. Section 5 estimates logit quantal response equilibrium (logit-AQRE) models for the Simultaneous and the Sequential Game and Section 6 contains several logistic regressions to estimate the receiver behavior in the Choice Game. Finally, Section 7 contains some discussion and concluding remarks. (The instructions corresponding to the experi-

[1] The logit-AQRE model was introduced by McKelvey and Palfrey (1995, 1998). Due to the bounded rationality of players in this model, the best response correspondences are continuous as in laboratory experiments.

mental games are presented in Appendix A, and the proofs of all the propositions are relegated to Appendix B.)

1.1 Related Literature

The theoretical literature has studied the multi-sender cheap talk games quite well. For example, Gilligan and Krehbiel (1989), Krishna and Morgan (2001), Gick (2008), and Li (2008) among others extend the basic one sender and one receiver model in Crawford and Sobel (1982) by allowing two perfectly informed senders. Austen-Smith (1990a, 1990b, 1993b) consider the case with two imperfectly informed senders while Austen-Smith (1990b, 1993b) also analyze the effects of alternative communication modes, namely simultaneous and sequential transmission of information. A common feature of these extensions is that the policy space is unidimensional, while Milgrom and Roberts (1986), Austen-Smith (1993a), Battaglini (2002, 2004), Ambrus and Takashi (2008) and Lai et al. (2011) consider multidimensional models of cheap talk. Very recently, a number of models in this rapidly growing literature were also tested by game-theoretic laboratory experiments (see, for example, Minozzi and Woon (2018); Vespa and Wilson (2012a, 2012b) among others). The main focus of this literature has been to study the effect of different institutions on information transmission or to find conditions which ensure that a fully-revealing equilibrium exists. To the best of our knowledge, this literature is currently missing multi-sender extensions of one sender and one receiver models with an essentially unique and babbling equilibrium under different modes of communication.

The basic models of cheap talk with essentially unique babbling equilibria have drawn attention in the experimental literature as these models enables one to clearly distinguish between the experimental observations and theoretical predictions. For the basic sender-receiver game, Gneezy (2005) shows that when preferences are conflictive but only the sender knows the structure in the possible payoff tables, the sender is more likely to lie when her gain from lying is higher or the loss for the receiver is lower. Hurkens and Kartik (2009) control for preferences in Gneezy's (2005) experiment and show that the behavior of some subjects can be rationalized with the propensity to lie. Similar results to those in Gneezy (2005) are also obtained by Sutter (2009), using a broader definition of deception according to which the sender can be truthful under the expectation that the receiver will not trust him. Cai and Wang (2006) find that the truth-telling of senders and the trust of receivers are higher than predicted by theory. In another strand of the same experimental literature, Sánchez- Pagés and Vorsatz (2007) show that when conflicting preferences in a baseline game of the described class are zero-sum but not too unequal, the subjects in the role of a sender transmit a correct message significantly more frequently than theoretically expected. To study the behavioral basis of the observed overcommunication, Sánchez-Pagés and Vorsatz (2007) also consider a punishment game in which the receiver can costly punish the sender after observing the outcome of the baseline game. This extension shows that subjects who, in the role of the sender, tell the truth excessively are those who, in the role of the receiver, punish the sender frequently after any game history where they were deceived by trusting the message of the sender. This result is more recently supported by Peeters et al (2012), where a baseline sender-receiver game is played both under a sanction-free institution and under a sanctioning institution, where the receiver has the option to reduce the payoffs of both players to zero after observing the outcome of the baseline game. An alternative behavioral explanation for excessive truth-telling is provided by Sánchez-Pagés and Vorsatz (2009). Using the baseline and punishment games in Sánchez-Pagés and Vorsatz (2007) with a modification that the sender in the baseline game additionally has a costly option of remaining silent, they show that overcommunication in the baseline game can be attributed to lying aversion and not to a preference for truth-telling.

Recently, a number of papers have studied the robustness of overcommunication phenomenon to several extensions of the basic sender-receiver model. For example, Peeters et al. (2008) considered, in addition to a baseline sender-receiver game, a reward game permitting the receiver to give a fixed reward to the sender after observing the outcome of the baseline game. They show that overcommunication of the sender disappears in the presence of rewards, whereas the trust by the receiver increases significantly. Their findings also involve that subjects that choose to reward frequently tell the truth and trust more often than the whole population. More recently, Gurdal et al (2014) analyzed the robustness of excessive truth-telling and excessive trust to the intervention of a regulator, or equivalently to the presence of non-strategic sender types. In this regulatory setup, a strategic sender is allowed to transmit messages only with some fixed probability less than one. The experimental findings of Gurdal et al (2014) show that excessive truth-telling and excessive trust are higher under intervention than under the absence of intervention. In addition, receivers earn significantly more than senders under intervention; but not so in the absence of intervention.

In a more recent paper, Minozzi and Woon (2018) analyze the effect of having a second sender in a sequential cheap talk game taking into account differences in alignment of preferences of the senders and receiver and test the predictions of Krishna and Morgan (2001). They compare the amount of information transmitted in a two-sender sequential model and a single-sender model. They show that the receiver gets the same amount of information –which is higher that the theoretical prediction– with the addition of the second sender regardless of the alignment or competition between the senders. Our model investigates a case with two-senders under different modes of communication where essentially unique equilibria is a babbling one to experimentally identify the effects of different modes of communication on the truth-telling of the senders and the trust of the receiver.

2 The Model and the Theoretical Predictions

We extend the sender-receiver game studied by Sánches-Pagés and Vorsatz (2007) by adding a second sender to the environment. We denote sender 1, sender 2 and receiver by S_1, S_2 and R, respectively. At the beginning of the game, Nature chooses a payoff table A or B (see Table 1) with equal probability that determines the final payoffs (in TL) of the three players.

Table 1. Payoff Tables

Table A	Sender 1	Sender 2	Receiver
Action U	4.5	4.5	1
Action D	0.5	0.5	9

Table B	Sender 1	Sender 2	Receiver
Action U	0.5	0.5	9
Action D	4.5	4.5	1

The senders are privately informed about the realized payoff table. Depending on the information observed, S_1 and S_2 respectively choose possibly mixed actions p and q from the set of messages $M = \{A, B\}$. Here, p and q denote the probabilities that the message A is submitted by S_1 and S_2, respectively. After observing the messages submitted by the two senders, the receiver chooses a possibly mixed action r from the set of actions $\{U, D\}$, showing the probability that U is played by the receiver. We analyze two games that differ with respect to the mode of communication of the senders with the receiver, namely the Simultaneous and the Sequential Game. In the Simultaneous Game, the two senders simultaneously transmit a message to the receiver after observing the actual state. Then, the receiver takes an action knowing that the senders have not observed each others' messages. In the Sequential Game, first moves sender 1, transmitting a message. Then, after observing the message of sender 1, sender 2 transmits a message. Knowing that sender 2 has observed the message transmitted by sender 1, the receiver takes an action that determines the payoffs of all three players. The third game we consider is the Choice Game, where the receiver moves first and chooses whether the Simultaneous or the Sequential Game is going to be played, and then the chosen game is played accordingly.

2.1 The Simultaneous Game

In the Simultaneous Game, both senders have two information sets corresponding to the events that the actual payoff table is A or B. When the actual state is A, the strategies of S_1 and S_2 are p_A and q_A, respectively denoting the probabilities that sender 1 and sender 2 choose message A when the actual state is A. Similarly, when the actual state is B, the strategies of S_1 and S_2 are p_B and q_B, respectively denoting the probabilities that sender 1 and sender 2 choose message A when the actual state is B. The receiver, on the other hand, has four information sets corresponding to four possible message pairs that can be submitted by the two senders. Here, r_{AA}, r_{AB}, r_{BA} and r_{BB} denote the probabilities that action U is played corresponding to the observed messages of S_1 and S_2 (which are denoted in the subscripts of r in order). The receiver forms the beliefs $\mu_{AA}, \mu_{AB}, \mu_{BA}$, and μ_{BB}, each denoting the belief that the actual state is A after observing the corresponding set of messages by S_1 and S_2 specified in the subscripts, respectively.

Proposition 1. *Any sequential equilibrium of the Simultaneous Game satisfies*

$$\begin{aligned} p_A &= p_B = p \in [0,1]; \\ q_A &= q_B = q \in [0,1]; \end{aligned}$$

with the supporting belief system is $\mu_{ij} = \frac{1}{2}$ *for every* $ij \in \{AA, AB, BA, BB\}$ *on the equilibrium path.*

Corollary 1. *The probability of observing an untruthful message by any of the senders in any sequential equilibrium is* $1/2$*.*

This says that no information is revealed in any equilibrium. Sender 1 plays B when the true state is A with probability $(1 - p_A)$ and choose A when the true state is B with probability p_B. As each state is equally likely and $p_A = p_B$ in any equilibrium, it is straightforward that the receiver expects to see an untruthful message from S_1 with probability one half. The same argument is true for the messages of sender 2.

Remark: The receiver's strategies should satisfy the following condition in order to have $p_A = p_B = p > 0$ and $q_A = q_B = q > 0$ as a sequential equilibrium:

$$p = \frac{r_{BB} - r_{BA}}{r_{AA} - r_{AB} + r_{BB} - r_{BA}} \quad \text{and} \quad q = \frac{r_{BB} - r_{AB}}{r_{AA} - r_{AB} + r_{BB} - r_{BA}}$$

These conditions imply that $r_{AA} > r_{AB}$, $r_{AA} > r_{BA}$, $r_{BB} > r_{AB}$ and $r_{BB} > r_{BA}$ in any equilibrium where the senders use completely mixed strategies.[2]

2.2 The Sequential Game

In the Sequential Game, sender 1 has two information sets, whereas sender 2 has four information sets. The strategies of S_1 when the actual state is $n \in \{A, B\}$ is denoted by p_n as before. The strategies of S_2 (i.e. the probability that message A

[2]For instance, $p = \frac{3}{4}$, $q = \frac{3}{4}$ and $r_{AA} = \frac{1}{3}$, $r_{BB} = \frac{1}{2}$, $r_{AB} = r_{BA} = \frac{1}{4}$ constitute an equilibrium.

is chosen) when the actual state is $n \in \{A, B\}$ and the sender 1 has communicated message $i \in \{A, B\}$ is denoted by $q_n(i)$. The receiver, again, has four information sets, at which r_{AA}, r_{AB}, r_{BA} and r_{BB} are the probabilities that action U is played corresponding to the observed messages of S_1 and S_2, denoted in the subscripts of r, respectively. The receiver forms the beliefs μ_{ij} showing the probability that the actual state is A after observing the message $i \in \{A, B\}$ from sender 1 and $j \in \{A, B\}$ from sender 2.

Proposition 2. *In any sequential equilibrium of the Sequential Game,*

$$\begin{aligned} p_A &= p_B = p \in [0,1]; \\ q_A(A) &= q_B(A) = q_1 \in [0,1]; \\ q_A(B) &= q_B(B) = q_2 \in [0,1]; \end{aligned}$$

with the supporting belief system $\mu_{ij} = \frac{1}{2}$ *for* $ij \in \{AA, AB, BA, BB\}$ *on the equilibrium path.*

Corollary 2. *The probability of observing an untruthful message by any of the senders in any sequential equilibrium is* $\frac{1}{2}$.

As S_1 plays B when the true state is A with probability $(1 - p_A)$ and choose A when the true state is B with probability p_B, it is straightforward that the receiver expects to see an untruthful message by S_1 with probability one half. The expected probability of seeing an untruthful message by S_2 is given by the following expression:

$$\frac{1}{2}\Big[(1-p_A)(1-q_A(B)) + p_A(1-q_A(A))\Big] + \frac{1}{2}\Big[p_B q_B(A) + (1-p_B)q_B(B)\Big]$$

which is also equal to 1/2 in any equilibria.

2.3 The Choice Game

Since the equilibria of the Simultaneous Game and the Sequential Game induce the same expected payoff to the receiver, she should be indifferent choosing between the two games. After the receiver's choice of the communication mode, one of the equilibria of the chosen game is played according to the requirements of sequential rationality.

2.4 Hypotheses

Based on the predictions of the model, we obtain several hypotheses regarding the truth-telling levels of the senders and trust levels of the receivers.

Hypothesis 1. (Truth-telling in the Simultaneous Game) Both senders will tell the truth with 50% probability in the Simultaneous Game.

Hypothesis 2. (Truth-telling in the Sequential Game) Both senders will tell the truth with 50% probability in the Sequential Game and truth-telling by Sender 2 will be independent of the observed message of Sender 1.

Hypothesis 3. (Trust in the Simultaneous Game) Upon observing a non-conflictive message, the receiver will trust with 50% probability in the Simultaneous Game.

Hypothesis 4. (Trust in the Sequential Game) Upon observing a non-conflictive message, the receiver will trust with 50% probability in the Sequential Game.

Hypothesis 5. (Receiver Behavior in the Choice Treatment) The receiver will choose each of the Simultaneous and Sequential Games with 50% probability.

3 Experimental Design and Procedures

All experimental sessions were conducted in the Social Sciences Laboratory at TOBB University of Economics and Technology during March 28-30, 2012. We sent a school wide invitation e-mail to undergraduate students informing that for the invited experiment they could register online for a date and time they choose. Those who registered also received reminder e-mails 1 day before the session. In total, the experiment was conducted over 8 sessions, one with 8 subjects the rest with 12 subjects. We had 92 Subjects in total and each session lasted abut 55-60 minutes.

Our design is a modification of the setup used in Sánchez-Pagés and Vorsatz (2007, 2008) and Peeters et al. (2008). Each session consisted of three treatments which we term as the Simultaneous Treatment, the Sequential Treatment and the Choice Treatment. The order of these treatments during a session could be either Simultaneous-Sequential-Choice or Sequential-Simultaneous-Choice. Each treatment lasted 12 periods. Before the experiment began, subjects were randomly assigned to groups of 4 and there were 23 groups in total. At the start of each period, two of these 4 subjects were assigned sender roles, one was assigned the receiver role and one was assigned the observer role.[3] During the 12 periods in a given treatment, each

[3] We consider the observer role so as to check whether our subjects, when they are neither the receiver nor a sender, are able to make correct guesses about the outcomes of the games.

subject played 6 times as a sender, 3 times as a receiver and 3 times as an observer. The order of role assignments was randomly determined.[4]

In the Simultaneous Treatment, Subjects played the following game for each period: First subjects learned about their role assignments for that period which could either be sender 1, sender 2, the receiver or the observer. Afterwards, sender 1 and sender 2 were informed about the true state (the payoff table being played) which could be either "Table A" or "Table B". Following this, sender 1 and sender 2 simultaneously and without seeing each other's decision, decided on the message they want to send to the receiver. The messages could be either "The payoff table is A" or "The payoff table is B". The observer, on the other hand, was also informed about the payoff table and chose one of the following guesses: "The receiver will earn 9 and sender 1 and sender 2 will each earn 0.5" or "The receiver will earn 1 and sender 1 and sender 2 will each earn 4.5". Next, the receiver was informed about the messages of sender 1 and sender 2 on the same screen and was asked which payoff table she thinks is more likely to be the correct one. Then the receiver choose among two possible actions: "U" or "D". After this choice of action, the payoffs were realized accordingly and a summary of the period was shown to the senders, the receiver and the observer. For the senders and the receiver, this summary includes information about the true state, the signals sent, the belief of the receiver, the action chosen by the receiver and the payoffs to the senders and to the receiver. For the observer the summary includes her guess, the earnings of the receiver and the senders and her own earning. If her guess was correct, the observer earned 5 TL for that period and if not 0 TL.

The Sequential Treatment differs from the above setup in the way the senders acted. In this treatment, sender 1 first chose the message to be sent and then this was showed first to sender 2, who in turn chose her message to be sent. The rest of the game is similar. In the Choice Treatment on the other hand, the receiver acted first and chose the way she preferred the messages to be sent. In particular, for each period, the subject with the receiver role chose if she wants to play the game as in the Simultaneous Treatment or the game as in the Sequential Treatment. Following this choice, the game corresponding to the choice of the receiver was played.

[4]Given that the subjects make choices in the same group for 36 periods, it may be a valid concern that anonymity may have been somewhat disregarded as the repetition could have an effect in the experiment even though the roles are randomly assigned in each period within a group. Since all treatments may be affected to some extent by the repetition, we believe that the differences in treatments are not due to the repetition effect. Moreover, our experimental results indicate that the behavior of the players are not significantly different than the theoretical predictions of the one-shot game in most of the cases (see Section 4). As the choice of running sessions with groups of 4 is essentially done for using non-parametric tests for the receiver behavior in the Choice Treatment, our estimation finding (Result 4 in Section 6) in that regard shows that the receiver values the information acquired in the previous period more than the information acquired in all other past periods in the Choice Treatment. These results imply that the learning effect due to repetition must be minimal.

After the three treatments were finished, subject answered several questions about their choices during the experiment. Following this, payments were displayed on the subject's screen. Each subject was paid the sum of her average earnings in the Simultaneous Treatment, average earnings in the Sequential Treatment and average earnings in the Choice Treatment plus a participation fee of 5 TL. Average total earnings (including the participation fee) were 14.26 TL and at the time of the experiment, 1 TL corresponded to 0.6325 USD.

4 Experimental Results

92 subjects in our experiment constituted 23 distinct groups. In the following three subsections (4.1, 4.2, and 4.3) we calculate the percentage of the variables of interest (truth-telling, trust, non-conflicting messages, truthfulness of non-conflicting messages etc.) for all distinct groups and use these independent observations in our analysis. Numerical values reported in the tables correspond to the mean value of the associated variable across all distinct groups. Below, we start with describing the sender behavior.

4.1 Senders

Considering all three treatments in the experiment, we find that the mean percentage of truthful messages per group is close to 53%. However, it is not significantly above the theoretical prediction of 50% (p-value is 0.057 in a Wilcoxon signed-rank test). Although this is consonant with the previous studies finding that subjects in general tell the truth more often than predicted, termed as overcommunication (see Section 1.1.), we see that adding a second sender overshadows this phenomenon.

In Table 2, we summarize the behavior of senders in plays where they act simultaneously. The two columns respectively show sender behavior under all plays in the Simultaneous Treatment and plays in the Choice Treatment where receivers preferred the senders to play simultaneously.[5] Senders exhibit excessive truth-telling in the Simultaneous Treatment by sending truthful messages with a frequency of 54%; however, we fail to reject Hypothesis 1 (p-value is 0.083 in a Wilcoxon signed-rank test). And, senders nearly randomize between truth and lie in the Choice Treatment in plays where the receiver prefers simultaneous messages.

Under simultaneous mode of communication, the two senders' agreement frequency is above 50%.[6] And, with a frequency of 58.2%, the non-conflicting messages

[5]Looking at the 276 instances during the Choice Treatment, we see that the receivers preferred simultaneous messages in 152 cases (55%) and sequential messages in 124 cases (45%).

[6]The theoretical predictions for the probabilities in the first and last rows are 1/2, whereas the theoretical prediction for the probability that the two senders' messages are non-conflictive in simultaneous plays is $p_A q_A + (1 - p_A)(1 - q_A) \in [0, 1]$.

in the Simultaneous Treatment are considerably more likely to be truthful than the theoretical prediction of 50% (p-value is 0.054 in a Wilcoxon signed-rank test).

Table 2. Sender Behavior with Simultaneous Messages[a]

	Simultaneous Treatment	Choice Treatment
% Sender is truthful	54.0*	49.0*
% Senders are non-conflictive	51.4**	53.4**
% Non-conflicting messages are correct	58.2*	50.2*
N	23	23

[a] Observations under the Choice Treatment only includes cases where receivers preferred the senders to act simultaneously.

* The theoretical prediction is 50.

** The theoretical prediction is arbitrary in [0,100].

Sender behavior when the two senders act sequentially is summarized in Table 3.[7] The first column reports sender behavior under all plays in the Sequential Treatment, the second column reports plays in the Choice Treatment where receivers preferred the senders to play sequentially. Our results are somewhat in line with Hypothesis 2 about truth telling. In the Sequential Treatment, while sender 1 perfectly randomizes, sender 2 tells the truth with a probability higher than 50% that is not significantly different than the theoretical prediction. However, truth-telling by Sender 2 is not independent of the earlier message of Sender 1. The probability with which sender 2 is truthful given that sender 1 lies is 58.9% compared to 54% when sender 1 is truthful (and in the Choice Treatment where the receivers choose sequential mode of communication, this figure goes up to 63 %). Hence, the contribution to the excessive truth-telling in sequential plays comes from sender 2.

We see that non-conflicting messages are observed less frequently in the Sequential Treatment (46.4%) than in the Simultaneous Treatment (51.4%). The lower frequency of non-conflicting messages in sequential plays is mainly due to the fact that the subjects in the role of sender 2 have a tendency to revert the message when sender 1 lies. Moreover, non-conflicting messages are more likely to be truthful in the Simultaneous Treatment (58.2%) thanin the Sequential Treatment (54.5%).

[7]The theoretical predictions for the probabilities in the first two rows and the last row are 1/2. The theoretical predictions for the probabilities in all the remaining rows are arbitrary in the interval $[0, 1]$. To see this, one can check that the probability that sender 2 is truthful when sender 1 is truthful is $p_A q_A(A) + (1 - p_B)(1 - q_B(B))$. Similarly, the probability that sender 2 is truthful when sender 1 lies is $(1 - p_A)q_A(B) + p_B(1 - q_B(A))$. One can also check that the probability that senders are non-conflictive is $p_A q_A(A) + (1 - p_A)(1 - q_A(B))$.

Table 3. Sender Behavior with Sequential Messages[a]

	Sequential Treatment	Choice Treatment
% Sender is truthful	53.3*	52.3*
% Sender 1 is truthful	50.0*	51.6*
% Sender 2 is truthful when sender 1 is truthful	54.0**	48.0**
% Sender 2 is truthful when sender 1 lies	58.9**	63.0**
% Senders are non-conflictive	46.4**	45.9**
% Non-conflicting messages are correct	54.5*	62.5*
N	23	23

[a] Observations under the Choice Treatment only includes cases where receivers preferred the senders to act sequentially.

* The theoretical prediction is 50.

** The theoretical prediction is arbitrary in [0,100].

4.2 Receivers

Prior to choosing their action, receivers in our experiment were asked to state their beliefs. This belief elicitation stage wasn't incentivized and each receiver was asked which payoff table she thinks is more likely to be the correct one (answering A, B, or *equally likely*). We focus on the cases where the messages by two senders are non-conflictive, and in Table 4 we present the frequency of beliefs that are in line with non-conflictive messages. The theoretical prediction for this frequency is 50% in all treatments. As Table 4 shows, this prediction holds true in the Sequential Treatment as well as in the Choice Treatment (with sequential or simultaneous messages). However, in the Simultaneous Treatment, the stated beliefs agree with the non-conflictive messages of senders 59.2% of the time and this frequency is significantly above 50%.

Table 4. Frequency of Beliefs in Line with Non-Conflicting Messages(%)[a]

Simultaneous Messages		Sequential Messages	
Simultaneous Treatment	**59.2***	Sequential Treatment	52.3*
Choice Treatment	50.7*	Choice Treatment	48.6*
N	23		23

[a] In the first and second columns, observations under the Choice Treatment only include cases where receivers preferred the senders to act simultaneously and sequentially, respectively. The values that are significantly different from 50% are given in bold.

* The theoretical prediction is 50.

A variable of particular interest is the receivers' trust frequency when the messages of the senders are non-conflictive. In the context of the game subjects played in the experiment, we define trust as choosing the optimal action by assuming that the non-conflictive messages of two senders is truthful. This corresponds to choosing action D when both senders claim that the payoff table is A and choosing action U when both senders claim that the payoff table is B. The theoretical predictions for the frequencies of these two actions are respectively represented by $1 - r_{AA}$ and r_{BB} in all games we consider and found to be arbitrary in $[0\%, 100\%]$. On the other hand, our experimental results in Table 5 show that the receiver's trust frequency is generally above 50% regardless of the way messages were sent.

In Table 5, we observe that the average of the fraction of trusted messages per group is 56.5% for the Simultaneous Treatment and 61.3% for plays in the Choice Treatment where receiver preferred simultaneous messages. Although the latter value is remarkably above 50%, we cannot reject Hypothesis 3 (p-value is 0.069 in a Wilcoxon signed-rank test). When messages were sent sequentially, the average of the fraction of trusted messages per group is 59.6% for the Sequential Treatment and 55.1% for plays in the Choice Treatment where receiver preferred sequential messages. The first one of these two values is significantly above 50% (p-value is 0.036 in a Wilcoxon signed-rank test), refuting Hypothesis 4.

Table 5. Receiver Trust Frequency (%)[a]

Simultaneous Messages		Sequential Messages	
Simultaneous Treatment	56.5*	Sequential Treatment	**59.6***
Choice Treatment	61.3*	Choice Treatment	55.1*
N	23		23

[a] In the first and second columns, observations under the Choice Treatment only include cases where receivers preferred the senders to act simultaneously and sequentially, respectively. The values that are significantly different from 50% are given in bold.

* The theoretical prediction is arbitrary in [0,100].

In Table 6, we summarize the preferences of receivers over game type in the Choice Treatment. We observe that the receivers preferred the Simultaneous mode of communication slightly more often, but the difference between the choice frequencies is not statistically significant, in line with Hypothesis 5.

Table 6. Receiver Behavior in the Choice Treatment

Number of Times Simultaneous Messages is Preferred	Number of Subjects
0	22
1	18
2	22
3	30

4.3 Observers

We summarize the behavior of observers in Table 7, which presents the mean fraction of guesses per group that the outcome of the play will be favorable for the receiver (i.e., the receiver earns 9 TL and senders earn 0.5 TL each) as well the mean fraction of correct guesses per group.

In the Simultaneous and Sequential Treatments, subjects are more likely to guess that the outcome of the play will be favorable for the senders. Contrary to this, in the Choice Treatment, subjects' guesses shift to the other direction in plays where the receiver preferred simultaneous messages (p-value is 0.058 in a Wilcoxon signed-rank test). Subjects' guesses are more likely to be wrong than correct during plays in the Choice Treatment where the receiver preferred sequential messages (p-value is 0.075 in a Wilcoxon signed-rank test).

Table 7. Observer Behavior

	% Guesses of Favorable Outcome for the Receiver	% Correct Guesses
Simultaneous Treatment	44.2*	45.7*
Sequential Treatment	48.2*	48.2*
Choice Treatment (Simultaneous)	59.1*	51.2*
Choice Treatment (Sequential)	55.2*	44.5*
N	23	23

* The theoretical prediction is 50.

To summarize our results, the experimental findings do not provide support to refute the first three of our hypotheses, although the truth-telling levels and trust levels are generally above 50% in both games. On the other hand, the frequency of receivers' trust to non-conflicting messages in the Sequential Treatment is significantly different than the theoretical prediction of one half, refuting Hypothesis 4. Moreover, Sender 1 perfectly randomizes between truth telling and lies with 50% and the behavior of Sender 2 seems to be highly dependent on the behavior of Sender 1 in the Sequential Game. In particular, Sender 2 is more likely to tell the truth when Sender 1 lies compared to when Sender 1 tells the truth. It seems that the overcommunication phenomenon disappears for senders acting as the first movers in sequential plays. Furthermore, in line with Hypothesis 5, the receiver chooses in the Choice Treatment the two modes of communication with (almost) equal probabilities. In the next two sections, we will try to explore the factors underlying the observed behavior of the subjects in our experiments.

5 The Logit Agent Quantal Response Equilibrium

As we have already noted, the observed overtrust in our experiments shows that during the plays the receiver might have learned that the senders were somewhat overcommunicating. However, she does not seem to have fully exploited this knowledge, for the probability of trust is less than one, unlike implied by the best response correspondences calculated for the games in Section 2. To explain this phenomenon that strategies with higher expected utilities are chosen with probabilities less than one, we will add noises to the payoff functions of the players, by following the logit-Agent Quantal Response Equilibrium (logit-AQRE) model of McKelvey and Palfrey (1998). This behavioral model assumes that each information set of a player is played by a different (hypothetical) agent. Each such agent will have responses in the form of choice probabilities following a multi-nominal logit distribution, since the noise terms added to the payoff functions are independently and identically distributed according to the log Weibull distribution. Because of these noise terms, the responses of each agent will be smooth in the sense that each strategy which has a higher expected utility is played with a higher probability that is less than one.

The logit-AQRE model that we will formally define in Sections 5.1 and 5.2 for the Simultaneous and Sequential Games respectively allows the players to have not only different rationality levels but also different non-monetary costs of lying as in Peeters et al (2013) and Gurdal et al (2014). In Section 5.3, calculating the maximum likelihood estimations of the parameters of this model separately for the Simultaneous and Sequential Games, we will be able to investigate whether the observed behavior of players differing with respect to the mode of communication can be explained by their estimated rationality and cost parameters. Briefly, our estimations will show that the rationality level of each player is independent of the game played and all behavioral differences can be explained by the cost of lying, which will be found to be different for each player in the two games. Our estimations will also reveal why receivers prefer the Simultaneous Game more frequently than the Sequential Game.

5.1 Simultaneous Mode of Communication

In order to apply the logit-AQRE model, we define two actions *truth* and *lie* for the two senders and two actions for the receiver in two situations: *trust to sender 1* and *distrust to sender 1* after observing *nonconflicting* and *conflicting* messages. For a sender, "truth" refers to sending the message that matches the actual payoff table and "lie" refers to doing the opposite. And, for a receiver, "trust to sender 1" refers to choosing the best response to the observed message of sender 1 and "distrust to sender 1" refers to choosing the opposite action. We would like to point out that if nonconflicting messages are observed and a receiver trusts to sender 1 this also implies that s/he trusts to sender 2. When conflicting messages are observed, trusting to sender 1 implies distrusting to sender 2 and vice versa. We denote the probability that sender 1 tells the truth by σ_1 and the same for sender 2 by σ_2. Similarly, we let σ_R^n stand for the probability of trusting to sender 1 upon observing nonconflicting messages and σ_R^c denote the probability of trusting to sender 1 upon observing conflicting messages. Then, sender 1 and sender 2 tell the truth with

$$\begin{aligned}\sigma_1 &= \frac{e^{\gamma E[u_1(\text{truth})]}}{e^{\gamma E[u_1(\text{truth})]} + e^{\gamma E[u_1(\text{lie})]}} = \frac{1}{1 + e^{\gamma(E[u_1(\text{lie})] - E[u_1(\text{truth})])}},\\ \sigma_2 &= \frac{e^{\gamma E[u_2(\text{truth})]}}{e^{\gamma E[u_2(\text{truth})]} + e^{\gamma E[u_2(\text{lie})]}} = \frac{1}{1 + e^{\gamma(E[u_2(\text{lie})] - E[u_2(\text{truth})])}}\end{aligned}$$

Similarly, we have receiver trusting to sender 1 (after observing nonconflicting or conflicting messages) with probability

$$\sigma_R = \frac{e^{\gamma E[u_R(\text{trust to S1})]}}{e^{\gamma E[u_R(\text{trust to S1})]} + e^{\gamma E[u_R(\text{distrust to S1})]}} = \frac{1}{1 + e^{\gamma(E[u_R(\text{distrust to S1})] - E[u_R(\text{trust to S1})])}}$$

The parameter $\gamma \in [0, \infty)$ in the above expressions (as well as in Section 5.2) can be positively associated with the rationality level of the players.[8] When γ is arbitrarily high, the players become fully rational and have standard best responses. On the other hand, when $\gamma = 0$, the players are fully irrational and act randomly.

Following Peeters et al. (2013) and Gurdal et al. (2014), we also assume that the senders have a non-monetary cost of lying denoted by c_i, $i = 1, 2$. Then,

Proposition 3. The unique logit-AQRE $(\sigma_1^*, \sigma_2^*, \sigma_R^{n*}, \sigma_R^{c*})$ of the simultaneous game solves the following four equations simultaneously:

$$\begin{aligned}\sigma_1 &= \frac{1}{1 + e^{\gamma[4(\sigma_R^n + \sigma_R^c - 1) - c_1]}}, \qquad \sigma_2 = \frac{1}{1 + e^{\gamma[4(\sigma_R^n - \sigma_R^c) - c_2]}},\\ \sigma_R^n &= \frac{1}{1 + e^{\gamma[8(1 - \sigma_1 - \sigma_2)]}}, \qquad \sigma_R^c = \frac{1}{1 + e^{\gamma[8(\sigma_2 - \sigma_1)]}}.\end{aligned}$$

5.2 Sequential Mode of Communication

Let σ_1 be the probability of sending truthful messages for sender 1, σ_2^t be the probability of sending truthful message for sender 2 after observing a truthful message of sender 1 and σ_2^l be the probability of sending truthful message for sender 2 after observing an untruthful message of sender 1. We let σ_R^n stand for the probability of trusting to sender 1 upon observing nonconflicting messages and σ_R^c represents the probability of trusting to sender 1 upon observing conflicting messages. We assume that senders' non-monetary cost of lying are denoted by c_1

[8] In fact, this parameter measures the precision of the probability density function associated with the noise term in each payoff function.

for sender 1, c_2^t for sender 2 who has observed a truthful message by sender 1 and c_2^l for sender 2 who has observed untruthful message.

Proposition 4. The unique logit-AQRE $(\sigma_1^*, \sigma_2^{t*}, \sigma_2^{l*}, \sigma_R^{n*}, \sigma_R^{c*})$ of the sequential game solves the following five equations simultaneously:

$$\begin{aligned}
\sigma_1 &= \frac{1}{1+e^{\gamma[4(\sigma_R^n+\sigma_R^c-1)+4(\sigma_R^c-\sigma_R^n)(\sigma_2^l-\sigma_2^t)-c_1]}}, \\
\sigma_2^t &= \frac{1}{1+e^{\gamma[4(\sigma_R^n-\sigma_R^c)-c_2^t]}}, \quad \sigma_2^l = \frac{1}{1+e^{\gamma[4(\sigma_R^n-\sigma_R^c)-c_2^l]}}, \\
\sigma_R^n &= \frac{1}{1+e^{\gamma[8(1-\sigma_1-\sigma_2^l)+8\sigma_1(\sigma_2^l-\sigma_2^t)]}}, \quad \sigma_R^c = \frac{1}{1+e^{\gamma[8(\sigma_2^l-\sigma_1)+8\sigma_1(\sigma_2^t-\sigma_2^l)]}}.
\end{aligned}$$

5.3 Maximum Likelihood Estimations

Now, we shall estimate the parameters of the logit-AQRE models we considered for the Simultaneous and the Sequential Game. We assume that the objective to be maximized in the Simultaneous Game is the log-likelihood function

$$L^{sim}(\lambda^{sim}, c^{sim}) = \sum_{s \in S^{sim}} n_s^{sim}\, ln(\sigma_s^{sim*}),$$

where S^{sim} = {truth-telling of sender 1, lie of sender 1, truth-telling of sender 2, lie of sender 2, receiver's trust when senders' messages are nonconflicting, receiver's distrust when senders' messages are nonconflicting, receiver's trust to sender 1 when senders' messages are conflicting, receiver's distrust to sender 1 when senders' messages are conflicting} denotes the collection of all strategies, n_s^{sim} denotes the number of times the strategy s has been chosen, and σ_s^{sim*} is the equilibrium probability of s in the Simultaneous Game given the rationality level λ^{sim} and the lying cost c^{sim} of the two senders.

The log-likelihood function to be maximized in the Sequential Game is

$$L^{seq}(\lambda^{seq}, c_1^{seq}, c_{2,t}^{seq}, c_{2,l}^{seq}) = \sum_{s \in S^{seq}} n_s^{seq}\, ln(\sigma_s^{seq*}),$$

where S^{seq} = {truth-telling of sender 1, lie of sender 1, truth-telling of sender 2 when sender 1 was truthful, lie of sender 2 when sender 1 was truthful, truth-telling of sender 2 when sender 1 lied, lie of sender 2 when sender 1 lied, receiver's trust when senders' messages are nonconflicting, receiver's distrust when senders' messages are nonconflicting, receiver's trust to sender 1 when senders' messages are conflicting, receiver's distrust to sender 1 when senders' messages are conflicting} denotes the collection of all strategies, n_s^{seq} denotes the number of times the strategy s has been chosen, and σ_s^{seq*} is the equilibrium probability of s in the Sequential Game given the rationality level λ^{seq}, the lying cost c_1^{seq} of sender 1, the lying cost $c_{2,t}^{seq}$ of sender 2 when sender 1 was truthful and the lying cost $c_{2,l}^{seq}$ of sender 2 when sender 1 lied.

Tables 8 and 9 present our estimation results for the rationality level, lying costs, and the expected utilities of the players in the Simultaneous and the Sequential Game, respectively. These two tables show that the hypothesis that 'the average bootstrapped value of the rationality parameter is zero' is rejected both in the Simultaneous Game (p-value: 0.05) and in the Sequential Game (p-value: 0.02), while λ^{sim} and λ^{seq} are not found to be statistically different (p-value: 0.71). Likewise, the hypothesis that 'the cost of lying is zero' is rejected for senders in the Simultaneous Game (p-value: 0.04) as well as for sender 2 in the Sequential Game when sender 1 lied (p-value: 0.03). In the Sequential Game, the same hypothesis cannot be rejected, however, for sender 1 (p-value: 0.28) or for sender 2 when sender 1 was truthful (p-value: 0.11).

Table 8. Logit-AQRE Estimation Results for the Simultaneous Game*

λ^{sim}	0.29 [0, 0.37] (0.19, 0.12)
c^{sim}	0.70 [0, 3.19] (1.87, 1.08)
Expected utility of each sender	2.41
Expected utility of receiver under nonconflicting messages	2.84
Expected utility of receiver under conflicting messages	2.48

* We exclude simultaneous plays in the Choice Treatment. In brackets, we report the 95 percent (standardized) confidence interval (obtained via bootstrapping with 1,000 repetitions using 70 percent of the experimental data). Below the brackets, we report the mean and the standard deviation of the bootstrapped parameters.

The results in Tables 8 and 9 also show that the expected utility of both sender 1 and sender 2 are higher in the Sequential Game than in the Simultaneous Game. Oppositely, the expected utility of the receiver is always lower in the Sequential Game. In addition, both in the Simultaneous and Sequential Game, the receiver becomes better off when the messages of the two senders are nonconflicting and becomes worse off otherwise. Below, we summarize these results.

Table 9. Logit-AQRE Estimation Results for the Sequential Game*

λ^{seq}	0.14 [0.05, 0.27] (0.14, 0.07)
c_1^{seq}	0.10 [0, 0.36] (0.08, 0.15)
c_{2t}^{seq}	0.85 [0, 1.43] (0.75, 0.61)
c_{2l}^{seq}	1.94 [0, 4.08] (2.65, 1.40)
Expected utility of sender 1	2.50
Expected utility of sender 2 when sender 1 was truthful	2.46
Expected utility of sender 2 when sender 1 lied	2.46
Expected utility of receiver under nonconflicting messages	2.61
Expected utility of receiver under conflicting messages	2.40

* We exclude sequential plays in the Choice Treatment. In brackets, we report the 95 percent (standardized) confidence interval (obtained via bootstrapping with 1,000 repetitions using 70 percent of the experimental data). Below the brackets, we report the mean and the standard deviation of the bootstrapped parameters.

Estimation Result 1. *Logit-AQRE estimations show that the subjects' rationality levels in the Simultaneous and Sequential Game are statistically the same and different from zero. Likewise, the cost of lying is statistically different from zero for senders in the Simultaneous Game and for sender 2 in the Sequential Game when sender 1 lied. In terms of expected utilities, the Sequential Game, as compared to the Simultaneous Game, makes both sender 1 and 2 better off while making the receiver worse off. In addition, in each game the receiver becomes better off when the two senders submit nonconflicting messages.*

6 Logistic Analysis for the Choice Treatment

Here, we estimate the determinants of the observed receiver behavior in the Choice Treatment. Table 10 reports the logistic regression results. The dependent variable is the simultaneous choice in all of the specifications. In the first specification, we consider the effects of receivers' average payoffs over the simultaneous and sequential plays, updated in the Choice Treatment. Average payoffs do not have a statistically significant effect on the choice probability. For the second specification, we find that receiver is 2.43 times more likely to select simultaneous play in cases where the previous play was simultaneous and the receiver earned the high payoff than in cases where the previous play was sequential and the receiver earned the low payoff. The receiver is 53% less likely to select simultaneous play if the previous play was sequential and the receiver earned the high payoff relative to the case in which the previous play was sequential and the receiver earned the low payoff. The probability of choosing simultaneous play when the previous play was simultaneous and the receiver earned the low payoff is not statistically significantly different from the case where the previous play was sequential and the receiver earned the low payoff.

Estimation Result 2. *The receiver is (i) more likely to select simultaneous play if the previous play was simultaneous and (ii) much more likely to select simultaneous play if the previous play was simultaneous and the receiver earned the high payoff relative to the case in which the previous play was sequential.*

Table 10 also shows that ratio of nonconflicting messages in the Simultaneous Treatment has a positive effect on the probability of selecting simultaneous choice. In our estimations, we have used the ratio of nonconflicting messages in the simultaneous and sequential treatments as a control, being representative of the groups' cooperative tendencies or abilities to coordinate. These establish the following.

Estimation Result 3. *High ratio of nonconflicting messages in both the Simultaneous and the Sequential Treatment increases the likelihood of simultaneous choice in the Choice Treatment; however the estimated impact is much larger in the Simultaneous Treatment than in the Sequential Treatment.*

In the first, fifth, sixth and seventh specifications, the updated average payoffs of the receivers in the simultaneous and sequential plays are also included. Our estimations show that both variables are statistically insignificant at 95% confidence level and the magnitudes of the coefficients are close to one, suggesting the following.

Estimation Result 4. *The receiver values the information acquired in the previous period more than the information acquired in all other past periods.*

Table 10. Logistic Analysis of Simultaneous Choice

	I	II	III	IV	V	VI	VII
Simwon† (1 if previous play was simultaneous and		2.43**	1.81	1.14	2.27*	1.72	1.12
receiver earned high payoff)		(2.06)	(0.84)	(0.32)	(1.92)	(0.8)	(0.28)
Seqwon† (1 if previous play was sequential and		0.47*	0.68	0.43**	0.43*	0.67	0.41**
receiver earned high payoff)		(-1.74)	(-0.71)	(-2.41)	(-1.93)	(-0.74)	(-2.44)
Simlost† (1 if previous play was simultaneous and		1.18	2.02		1.08	1.90	
receiver earned low payoff)		(0.42)	(1.33)		(0.21)	(1.24)	
Simwonnc† (1 if previous play was simultaneous with			3.67**	3.67**		3.70**	3.68**
nonconflicting messages and receiver earned high payoff)			(1.96)	(1.96)		(2.04)	(2.04)
Seqwonnc† (1 if previous play was sequential with			0.99			0.88	
nonconflicting messages and receiver earned high payoff)			(-0.01)			(-0.24)	
Simlostnc† (1 if previous play was simultaneous with			0.72			0.70	
nonconflicting messages and receiver earned low payoff)			(-0.71)			(-0.77)	
Seqlostnc† (1 if previous play was sequential with			2.05			2.10	
nonconflicting messages and receiver earned low payoff)			(1.33)			(1.45)	
Average payoff of the receivers over simultaneous plays,	0.97				0.95	0.90	0.91
updated in the Choice Treatment	(-0.14)				(-0.27)	(-0.59)	(-0.51)
Average payoff of the receivers over sequential plays,	1.26				1.27*	1.26*	1.26
updated in the Choice Treatment	(1.47)				(1.76)	(1.67)	(1.61)
Ratio of nonconflicting messages in the Simultaneous	8.88	2.88	2.59	2.53	5.26	4.73	4.68
Treatment	(1.6)	(0.98)	(0.95)	(0.90)	(1.33)	(1.37)	(1.28)
Ratio of nonconflicting messages in the Sequential	1.46	1.30	1.27	1.26	1.65	1.72	1.71
Treatment	(0.33)	(0.26)	(0.22)	(0.22)	(0.49)	(0.5)	(0.50)
Constant	0.11	0.54	0.40	0.64	0.14	0.13	0.19
	(-1.29)	(-0.76)	(-1.01)	(-0.59)	(-1.26)	(-1.21)	(-1.00)
Pseudo R2	0.015	0.063	0.086	0.079	0.072	0.095	0.088

Dependent variable is simultaneous choice. Odds ratios are reported, z-values are reported in parenthesis. Standard errors are clustered at the group level. * and ** denote significance at the 90% and 95% confidence levels respectively. † := Dummy variables.

In Table 10 we have also decomposed the results of the previous period depending on whether the messages were nonconflicting. The receiver is statistically significantly more likely to select simultaneous play if the previous play was simultaneous, the receiver earned the high payoff and the messages were nonconflicting than all other cases. Additionally, the receiver is statistically significantly less likely to select simultaneous play if the previous play was sequential and the receiver earned the high payoff than all other cases. Whether the messages were nonconlifcting in sequential play does not statistically significantly affect the probability of choosing silmultanoeus play.

Estimation Result 5. *If the previous play is simultaneous, the receiver is more likely to choose simultaneous play when the messages were nonconflicting and the receiver earned the high payoff relative to all other cases. On the contrary, if the previous play is sequential, whether the messages were conflicting or nonconflicting does not have a statistically significant effect on the probability of choosing simultaneous play and the receiver has the lowest probability of choosing simultaneous play when the previous play was sequential and the receiver earned the high payoff.*

7 Discussion and Concluding Remarks

Truth-telling frequencies tend to stay above 50% during the experiments, but the levels turn out to be not significantly different than the sequential equilibrium predictions. Interestingly, in the Choice Treatment all senders –except for those who act as Sender 2 and move after Sender 1 lies– randomize between truth-telling and lie almost perfectly; and Sender 1 in the Sequential Treatment chooses truth-telling with exactly 50%. This suggests that the addition of a second sender overshadows the overcommunication phenomenon that has been observed in the similar settings with a single sender.

Moreover, the nature of truth-telling seems to differ between sequential and simultaneous plays. With sequential messages, we observe that a substantial fraction of senders acting as Sender 2 deliberately try to revert the messages of Sender 1. In particular, they have much higher truth-telling frequencies in cases where sender 1 lied compared to the cases where sender 1 was truthful. This effect generates a higher frequency of non-conflicting sender messages during the Simultaneous Treatment compared to the Sequential Treatment. The reason is that when two senders act simultaneously, none of them can condition her message on the message of the other. In our study, we also observe that in both of the Simultaneous and Sequential Treatments, when a pair of messages by the two senders is non-conflictive, it is more likely to be truthful than being non-informative. This can be seen as the reminiscent of the overcommunication phenomenon observed in the previous studies.

In response to a non-conflicting pair of messages by the two senders, the receiver's trust frequency is calculated to be above 50% during both of the Simultaneous and Sequential Treatments. In this manner, the receiver behavior exhibits overtrust which is also observed in the previous experimental studies. Note that, given the observation that non-conflicting messages are more likely to be truthful than not, the best response of the receiver subjects in this experiment would be fully trusting them. When the receiver subjects are given the option of choosing between sequential and simultaneous plays at the last treatment of the experiment, we see that a slight majority is more likely to prefer simultaneous plays.

We have investigated whether these results could be explained by a logit-AQRE model where senders have non-monetary costs of lying. Maximum Likelihood Estimations of the model using the experimental data have showed that in the Simultaneous Game the presence of another sender does not eliminate a sender's intrinsic motive of truth-telling, recently observed in the laboratory experiments of Peeters et al. (2013) and Gurdal et al. (2014), both considering single sender-receiver games with simultaneous plays. However, in the Sequential Game sender 1 is found to be unburdened with the cost of lying, and this is also true for sender 2 when sender 1 was truthful. On the other hand, when sender 1 lied in the Sequential Game, sender 2 is observed to have a nonzero cost of lying. Evidently, for the Sequential Game one can argue that a sender will not have any intrinsic motives for truth-telling if and only if he knows that the other sender is likely (with some nonzero probability) to be truthful. Interestingly, we have also observed that the welfare of both senders are higher, while the welfare of the receiver is lower, in the Sequential Game than in the Simultaneous Game. This last finding suggests that the mode of communication may be a critical tool of design in principal-agent problems with multiple agents.

Lastly, we have estimated the determinants of the receiver behavior in the Choice Treatment using logistic regressions. We have found that the receiver is more likely to select simultaneous play if the previous play was simultaneous and the receiver earned the high payoff and much more likely to select simultaneous play if the messages were nonconflicting additionally. Whether the messages are conflicting in a sequential play, does not statistically significantly affect the probability of choosing simultaneous play the next period. The receiver is statistically significantly the least likely to select simultaneous play if the receiver earned the high payoff in a sequential play in the last period. Also, high ratio of nonconflicting messages in both the Simultaneous and the Sequential Treatment increases the likelihood of simultaneous choice in the Choice Treatment, while the estimated impact is larger in the Simultaneous Treatment than in the Sequential Treatment. In addition, we have found that the receiver values the information acquired in the previous period more than the information acquired in all other past periods.

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Appendix A. Instructions

Welcome!

Thank you for your participation. The aim of this study is to understand how people decide in certain situations. From now on, talking to each other is prohibited. Violation of this rule requires immediate termination of the experiment. Please raise your hand to ask questions. This way, everybody will hear your question and our answer.

The experiment will be conducted through the computer and you will make all your decisions using the computer. Your earnings depend on your decisions as well as the decisions of other participants. These earnings and your participation fee will be paid to you in cash at the end of the experiment. The experiment consists of 3 different parts. We start with describing Part 1.

Part 1

In this part of the experiment you will play a game which will last 12 periods. Before the first period, the system will assign you to groups of 4. These groups will remain the same throughout the experiment. A participant will only interact with participants from her own group but will not get to know the identity of other group members during or after the experiment.

Now, let's have a closer look at the game. Please do not hesitate to ask questions.

In the beginning of each period, 2 participants in your group will be assigned the sender roles, 1 participant will be assigned the receiver role and 1 participant will be assigned the observer role. At the end of 12 periods, each of you will have played 6 times as a sender, 3 times as a receiver and 3 times as an observer. The order of these role assignments is random.

During each period, after role assignments have been made, the system will choose one of the following: Table A or Table B. It is equally likely for the system to choose Table A or Table B. The earnings in that period will depend on the table chosen by the system and the choice of action U or action D by the receiver.

Payoff Tables

Table A	G1	G2	Receiver
Action U	4.5	4.5	1
Action D	0.5	0.5	9

Table B	G1	G2	Receiver
Action U	0.5	0.5	9
Action D	4.5	4.5	1

At each period, one of the senders in the group will be named as G1 and the other will be named as G2. These roles will be randomly assigned and G1 and G2 will earn the same amount for that period. For example, if the system chooses Table A and the receiver chooses action U, both G1 and G2 will earn 4.5 TL and the receiver will earn 1 TL for that period.

Senders' task

At the beginning of each period, G1 and G2 will be informed about the table chosen by the system for that period. G1 and G2 will make the first decisions of that period. This decision is the choice of the message to be delivered to the receiver and telling whether the system chose Table A or Table B. Since these messages are going to be sent simultaneously, no sender will get to know the message of the other sender. The senders are free to decide whether their messages are correct or not.

Receiver's task

The receiver will first see the messages of G1 and G2, but will not know the table chosen by the system. At the screen that the receiver observes these messages, she will be asked her belief about the actual table that will determine the payoffs for that round.

In the next screen, the receiver will choose action U or action D.

After the receiver makes her choice, the earnings will be determined based on the actual table chosen by the system and the choice of the receiver.

Observer's task

The observer will guess what the earnings of the senders and the receiver will be in a given period. Due to the structure of the game, her guess could be one of the two types:

1) Receiver: 9 TL; G1 and G2: 0.5 TL.
2) Receiver: 1 TL; G1 and G2: 4.5 TL.

If her guess is correct, the observer will earn 5 TL for that period and 0 TL otherwise.

At the end of each period, a summary screen will provide information about the choices in that period and the earnings.

Payment

Based on your earnings for each period, your average earnings per period will be calculated. You can see this amount at the bottom of the summary screen. The average earnings at the end of period 12 will be your earnings from part 1 of the experiment.

Your total earnings in the experiment will be “earnings in part 1” + “earnings in part 2” + “earnings in part 3” + “a participation fee of 5 TL”.

Part 2

Now, we will start part 2 of the experiment. In this part of the experiment, you will play a game that will last for 12 periods. Your group and the payoff tables in this part will be the same as in the first part of the experiment.

The new game is similar to the game used in the previous part of the experiment, but it has the following differences:

In this game, the sender chosen as G1 will first choose her message to the receiver and the other sender, G2, will see this message and then choose her own message. The receiver will see the messages of G1 and G2, and again she will not know the real payoff table chosen by the system.

The rest of the game is the same as in the previous part. The assignment of the roles G1 and G2 will be random as before.

Part 3

Now, we will start part 3 of the experiment. In this part of the experiment, you will play a game that will last for 12 periods. Your group and the payoff tables in this part will be the same as in the first part of the experiment.

But, during each period in this part of the experiment, the receiver will choose the way that the senders will convey their messages. In other words, the receiver will decide whether the senders will send their messages simultaneously or sequentially. As you may remember, these are the methods for sending messages used in the two parts of the experiment.

To summarize,

- If the receiver decides the messages to be sent simultaneously, both G1 and G2 will choose their messages at the same time, without seeing each other’s messages.

- If the receiver decides the messages to be sent sequentially, first G1 will choose her message and then G2 will observe this message and choose her message.

The assignment of the roles G1 and G2 will be random as before.

Appendix B. Proofs of Propositions

Proof of Proposition 1. First, we derive the best responses of the players at each information set. The best responses of S_1 after tables A and B have been observed are given as:

$$p_A \in \begin{cases} \{1\} & \text{if} \quad q_A(r_{AA} - r_{BA}) + (1 - q_A)(r_{AB} - r_{BB}) > 0 \\ [0,1] & \text{if} \quad q_A(r_{AA} - r_{BA}) + (1 - q_A)(r_{AB} - r_{BB}) = 0 \\ \{0\} & \text{if} \quad q_A(r_{AA} - r_{BA}) + (1 - q_A)(r_{AB} - r_{BB}) < 0 \end{cases}$$

$$p_B \in \begin{cases} \{1\} & \text{if} \quad q_B(r_{AA} - r_{BA}) + (1 - q_B)(r_{AB} - r_{BB}) < 0 \\ [0,1] & \text{if} \quad q_B(r_{AA} - r_{BA}) + (1 - q_B)(r_{AB} - r_{BB}) = 0 \\ \{0\} & \text{if} \quad q_B(r_{AA} - r_{BA}) + (1 - q_B)(r_{AB} - r_{BB}) > 0 \end{cases}$$

On the other hand, the best responses of S_2 after tables A and B have been observed are as follows:

$$q_A \in \begin{cases} \{1\} & \text{if} \quad p_A(r_{AA} - r_{AB}) + (1 - p_A)(r_{BA} - r_{BB}) > 0 \\ [0,1] & \text{if} \quad p_A(r_{AA} - r_{AB}) + (1 - p_A)(r_{BA} - r_{BB}) = 0 \\ \{0\} & \text{if} \quad p_A(r_{AA} - r_{AB}) + (1 - p_A)(r_{BA} - r_{BB}) < 0 \end{cases}$$

$$q_B \in \begin{cases} \{1\} & \text{if} \quad p_B(r_{AA} - r_{AB}) + (1 - p_B)(r_{BA} - r_{BB}) < 0 \\ [0,1] & \text{if} \quad p_B(r_{AA} - r_{AB}) + (1 - p_B)(r_{BA} - r_{BB}) = 0 \\ \{0\} & \text{if} \quad p_B(r_{AA} - r_{AB}) + (1 - p_B)(r_{BA} - r_{BB}) > 0 \end{cases}$$

The receiver's best responses after observing a message $ij \in \{AA, AB, BA, BB\}$ depend on the beliefs formed at that information set:

$$r_{ij} \in \begin{cases} \{1\} & \text{if} \quad \mu_{ij} < \frac{1}{2} \\ [0,1] & \text{if} \quad \mu_{ij} = \frac{1}{2} \\ \{0\} & \text{if} \quad \mu_{ij} > \frac{1}{2} \end{cases}$$

And, the beliefs, calculated by Bayes' rule (whenever possible), are as follows:

$$\begin{aligned} \mu_{AA} &= \frac{p_A q_A}{p_A q_A + p_B q_B}, \qquad \mu_{AB} = \frac{p_A(1 - q_A)}{p_A(1 - q_A) + p_B(1 - q_B)}, \\ \mu_{BA} &= \frac{(1 - p_A) q_A}{(1 - p_A) q_A + (1 - p_B) q_B}, \quad \mu_{BB} = \frac{(1 - p_A)(1 - q_A)}{(1 - p_A)(1 - q_A) + (1 - p_B)(1 - q_B)}. \end{aligned}$$

We want to show that the senders use the same strategy at the two information sets. To arrive at a contradiction, we consider the following cases: (1) One of the senders uses different strategies, while the other sender uses the same strategy at the two information sets; (2) Both of the senders use different strategies at the two information sets.

Case 1: Suppose that S_1 uses different strategies, i.e. $p_A \neq p_B$; and, without loss of generality, let's assume $p_A > p_B$. First, consider the case $q_A = q_B = q \in (0,1)$. Then, the consistency of beliefs requires $\mu_{AA} > \frac{1}{2}$, $\mu_{AB} > \frac{1}{2}$, $\mu_{BA} < \frac{1}{2}$, and $\mu_{BB} < \frac{1}{2}$. The best responses of the receiver at each information set under these beliefs become $r_{AA} = 0$, $r_{AB} = 0$, $r_{BA} = 1$, and $r_{BB} = 1$. But then, S_1's best responses are $p_A = 0$ and $p_B = 1$, which contradicts to our hypothesis that $p_A > p_B$. Now, suppose that $q_A = q_B = q = 0$. With these strategies, the beliefs become $\mu_{AB} > \frac{1}{2}$ and $\mu_{BB} < \frac{1}{2}$. Having these beliefs, the receiver's best responses can be found as $r_{AB} = 0$ and $r_{BB} = 1$. Then, the best responses of S_1 are $p_A = 0$ and $p_B = 1$, again contradicting to our hypothesis. Next, assume that $q_A = q_B = q = 1$. Under these strategies (given the hypothesis $p_A > p_B$), the beliefs can be calculated as $\mu_{AA} > \frac{1}{2}$, and $\mu_{BA} < \frac{1}{2}$ with the associated best responses for the receiver being $r_{AA} = 0$ and $r_{BA} = 1$. This in turn suggests that the best responses of S_1 should be $p_A = 0$ and $p_B = 1$, which provides the desired contradiction to $p_A > p_B$.

Case 2: Suppose that $p_A \neq p_B$ and $q_A \neq q_B$. Without loss of generality, we assume that $p_A > p_B \geq 0$ and $q_A > q_B \geq 0$. Then, the beliefs can be calculated as $\mu_{AA} > \frac{1}{2}$ and $\mu_{BB} < \frac{1}{2}$. The best responses of the receiver at these information sets become $r_{AA} = 0$ and $r_{BB} = 1$. If $q_A < 1$, for $p_A > 0$ to be the best response of S_1, the best responses of the receiver should satisfy $r_{AA} = r_{BA} = 0$ and $r_{AB} = r_{BB} = 1$. But if $r_{AA} = r_{BA} = 0$ and $r_{AB} = r_{BB} = 1$, then $q_A = 0$, which is a contradiction as $q_A > q_B \geq 0$, by assumption. If $q_A = 1$, then for having $p_A > 0$ as a part of equilibrium, the best response of the receiver should satisfy $r_{AA} = r_{BA} = 0$. In turn, $q_A = 1$ can be a best response to these strategies only if $r_{AB} = 0$ and $p_A = 1$ (in addition to $r_{AA} = r_{BA} = 0, r_{BB} = 1$). But, then p_B equals to 1 if $q_B < 1$ and q_B equals to 1 if $p_B < 1$, which is the desired contradiction (since by assumption $p_B \neq 1$ and $q_B \neq 1$ as $p_B < p_A$ and $q_B < q_A$).

Since the senders are symmetric we exclude the symmetric situations. In all the other cases, we get at least one of the beliefs different than $\frac{1}{2}$. The corresponding best responses of the receiver at such information sets are pure strategies; and, the best responses of the senders against these pure strategies give the desired contradiction unless the senders use the same strategies at each information sets. Also, when $p_A = p_B \in (0,1)$ and $q_A = q_B \in (0,1)$, the beliefs can be easily calculated as $\mu_{ij} = \frac{1}{2}$ and they can be assigned in a consistent way off the equilibrium path. □

Proof of Proposition 2. The best response of S_1 after table A is observed is as follows:

$$p_A \in \begin{cases} \{1\} & \text{if} \quad q_A(A)r_{AA} + (1-q_A(A))r_{AB} - q_A(B)r_{BA} - (1-q_A(B))r_{BB} > 0 \\ [0,1] & \text{if} \quad q_A(A)r_{AA} + (1-q_A(A))r_{AB} - q_A(B)r_{BA} - (1-q_A(B))r_{BB} = 0 \\ \{0\} & \text{if} \quad q_A(A)r_{AA} + (1-q_A(A))r_{AB} - q_A(B)r_{BA} - (1-q_A(B))r_{BB} < 0 \end{cases}$$

The best response of S_1 after table B is observed is as follows:

$$p_B \in \begin{cases} \{1\} & \text{if} \quad q_B(A)r_{AA} + (1-q_B(A))r_{AB} - q_B(B)r_{BA} - (1-q_B(B))r_{BB} < 0 \\ [0,1] & \text{if} \quad q_B(A)r_{AA} + (1-q_B(A))r_{AB} - q_B(B)r_{BA} - (1-q_B(B))r_{BB} = 0 \\ \{0\} & \text{if} \quad q_B(A)r_{AA} + (1-q_B(A))r_{AB} - q_B(B)r_{BA} - (1-q_B(B))r_{BB} > 0 \end{cases}$$

The best response of S_2 when the actual table is A and the sender 1 has sent message A is given by:

$$q_A(A) \in \begin{cases} \{1\} & \text{if} \quad r_{AA} - r_{AB} > 0 \\ [0,1] & \text{if} \quad r_{AA} - r_{AB} = 0 \\ \{0\} & \text{if} \quad r_{AA} - r_{AB} < 0 \end{cases}$$

The best response of S_2 when the actual table is A and the sender 1 has sent message B is given by:

$$q_A(B) \in \begin{cases} \{1\} & \text{if} \quad r_{BA} - r_{BB} > 0 \\ [0,1] & \text{if} \quad r_{BA} - r_{BB} = 0 \\ \{0\} & \text{if} \quad r_{BA} - r_{BB} < 0 \end{cases}$$

The best response of S_2 when the actual table is B and the sender 1 has sent message A is given by:

$$q_B(A) \in \begin{cases} \{1\} & \text{if} \quad r_{AB} - r_{AA} > 0 \\ [0,1] & \text{if} \quad r_{AB} - r_{AA} = 0 \\ \{0\} & \text{if} \quad r_{AB} - r_{AA} < 0 \end{cases}$$

The best response of S_2 when the actual table is B and the sender 1 has sent message B is given by:

$$q_B(B) \in \begin{cases} \{1\} & \text{if} \quad r_{BB} - r_{BA} > 0 \\ [0,1] & \text{if} \quad r_{BB} - r_{BA} = 0 \\ \{0\} & \text{if} \quad r_{BB} - r_{BA} < 0 \end{cases}$$

The receiver's best response after observing message $ij \in \{AA, AB, BA, BB\}$ is given by:

$$r_{ij} \in \begin{cases} \{1\} & \text{if} \quad \mu_{ij} < \frac{1}{2} \\ [0,1] & \text{if} \quad \mu_{ij} = \frac{1}{2} \\ \{0\} & \text{if} \quad \mu_{ij} > \frac{1}{2} \end{cases}$$

where the beliefs calculated by the Bayes' rule (whenever possible) are as follows:

$$\mu_{AA} = \frac{p_A q_A(A)}{p_A q_A(A) + p_B q_B(A)}, \quad \mu_{BB} = \frac{(1-p_A)(1-q_A(B))}{(1-p_A)(1-q_A(B)) + (1-p_B)(1-q_B(B))}$$

$$\mu_{AB} = \frac{p_A(1-q_A(A))}{p_A(1-q_A(A)) + p_B(1-q_B(A))}, \quad \mu_{BA} = \frac{(1-p_A)q_A(B)}{(1-p_A)q_A(B) + (1-p_B)q_B(B)}.$$

In the first step, we want to show that S_1 uses the same strategy at the two information sets. To do that, first, we are going to assume that S_2 uses the same strategies at her information sets, then we will allow for the case in which S_2 may use different strategies.

Case 1: Suppose that S_2 uses the same strategy $q_A(A) = q_B(A)$ and $q_A(B) = q_B(B)$. For a contradiction, without loss of generality, we assume that $p_A > p_B$.

Case 1.a: Assume that $q_A(A) = q_B(A) \in (0,1)$ and $q_A(B) = q_B(B) \in (0,1)$. Then, the beliefs can be calculated as $\mu_{AA} > \frac{1}{2}$, $\mu_{AB} > \frac{1}{2}$, $\mu_{BA} < \frac{1}{2}$, and $\mu_{BB} < \frac{1}{2}$. The associated best responses of the receiver are $r_{AA} = 0$, $r_{AB} = 0$, $r_{BA} = 1$, and $r_{BB} = 1$. The best responses of S_1 in turn become $p_A = 0$ and $p_B = 1$, which contradicts to our hypothesis.

Case 1.b: Now, assume that $q_A(A) = q_B(A) = 0$ and $q_A(B) = q_B(B) = 0$. Then, the beliefs become $\mu_{BB} < \frac{1}{2}$ and $\mu_{AB} > \frac{1}{2}$. The best responses of the receiver corresponding to these beliefs are $r_{BB} = 1$ and $r_{AB} = 0$. The best responses of S_1 in turn become $p_A = 0$ and $p_B = 1$, which again contradicts to our hypothesis $p_A > p_B$.

Case 1.c: Now, assume that $q_A(A) = q_B(A) = 1$ and $q_A(B) = q_B(B) = 1$. Then, the beliefs become $\mu_{BA} < \frac{1}{2}$ and $\mu_{AA} > \frac{1}{2}$. The best responses of the receiver corresponding to these beliefs are $r_{BA} = 1$ and $r_{AA} = 0$. The best responses of S_1 in turn become $p_A = 0$ and $p_B = 1$, which gives the desired contradiction.

Case 1.d: We next assume that $q_A(A) = q_B(A) = 0$ and $q_A(B) = q_B(B) \in (0,1)$. Then, the beliefs become $\mu_{BB} < \frac{1}{2}$, $\mu_{BA} < \frac{1}{2}$, and $\mu_{AB} > \frac{1}{2}$. The best responses of the receiver corresponding to these beliefs are $r_{BB} = 1$, $r_{BA} = 1$, and $r_{AB} = 0$. The best responses of S_1 in turn become $p_A = 0$ and $p_B = 1$, which contradicts to our hypothesis.

Case 1.e: We next assume that $q_A(A) = q_B(A) = 0$ and $q_A(B) = q_B(B) = 1$. Then, the beliefs become $\mu_{BA} < \frac{1}{2}$ and $\mu_{AB} > \frac{1}{2}$. The best responses of the receiver corresponding to these beliefs are $r_{BA} = 1$ and $r_{AB} = 0$. The best responses of S_1 in turn become $p_A = 0$ and $p_B = 1$, which contradicts to our hypothesis.

Case 1.f: We next assume that $q_A(A) = q_B(A) = 1$ and $q_A(B) = q_B(B) \in (0, 1)$. Then, the beliefs become $\mu_{BB} < \frac{1}{2}$, $\mu_{BA} < \frac{1}{2}$, and $\mu_{AA} > \frac{1}{2}$. The best responses of the receiver corresponding to these beliefs are $r_{BB} = 1$, $r_{BA} = 1$, and $r_{AA} = 0$. The best responses of S_1 in turn become $p_A = 0$ and $p_B = 1$, which provides a contradiction.

Case 1.g: We next assume that $q_A(A) = q_B(A) = 1$ and $q_A(B) = q_B(B) = 0$. Then, the beliefs become $\mu_{AA} > \frac{1}{2}$ and $\mu_{BB} < \frac{1}{2}$. The best responses of the receiver corresponding to these beliefs are $r_{AA} = 0$ and $r_{BB} = 1$. The best responses of S_1 again become $p_A = 0$ and $p_B = 1$, which is a contradiction.

The other symmetric cases give the similar contradictions, and thus, are omitted.

Case 2: We now consider that case where S_2 uses different strategies. Without loss of generality, we assume that $q_A(A) > q_B(A) \geq 0$ and $q_A(B) > q_B(B) \geq 0$. Again, suppose for a contradiction that $p_A > p_B \geq 0$. Then, the beliefs are calculated as $\mu_{AA} > \frac{1}{2}$ and $\mu_{BB} < \frac{1}{2}$. The corresponding best responses of the receiver at these information sets become $r_{AA} = 0$ and $r_{BB} = 1$. Note that for $q_A(A) > q_B(A)$ and $q_A(B) > q_B(B)$ to be part of an equilibrium, the receiver's strategies should satisfy $r_{AA} \geq r_{AB}$ and $r_{BA} \geq r_{BB}$. As $r_{AA} = 0$ and $r_{BB} = 1$, we get $r_{AB} = 0$ and $r_{BB} = 1$. Then, the best response of S_1 against the receiver's strategies become $p_A = 0$ and $p_B = 1$, which is the desired contradiction.

In the next step, we show that S_2 must use the same strategy in equilibrium, i.e. $q_A(A) = q_B(A) = q_1$ and $q_A(B) = q_B(B) = q_2$.

Case 1: We first assume that S_1 uses the same strategy.

Case 1.a: Suppose that $p_A = p_B \in (0, 1)$. Assume for a contradiction that $q_A(A) > q_B(A)$. This implies $\mu_{AA} > \frac{1}{2}$ and $\mu_{AB} < \frac{1}{2}$. The best responses of the receiver in turn becomes $r_{AA} = 0$ and $r_{AB} = 1$. The best responses of S_2 against the receiver's strategy is $q_A(A) = 0$ and $q_B(A) = 1$, which contradicts to our hypothesis.

Case 1.b: Suppose that $p_A = p_B = 0$. Assume for a contradiction, $q_A(B) > q_B(B)$. This implies $\mu_{BA} > \frac{1}{2}$ and $\mu_{BB} < \frac{1}{2}$. The best responses of the receiver in turn becomes $r_{BB} = 1$ and $r_{BA} = 0$. The best responses of S_2 against the receiver's strategy is $q_A(B) = 0$ and $q_B(B) = 1$, which contradicts to our hypothesis.

Case 1.c: Suppose that $p_A = p_B = 1$. Assume for a contradiction, $q_A(A) > q_B(A)$. This implies $\mu_{AA} > \frac{1}{2}$ and $\mu_{AB} < \frac{1}{2}$. The best responses of the receiver in turn becomes $r_{AA} = 0$ and $r_{AB} = 1$. The best responses of S_2 against the receiver's strategy is $q_B(A) = 1$ and $q_A(A) = 0$, which contradicts to our hypothesis.

All other symmetric cases give the desired results.

Case 2: We now assume that S_1 uses different strategies; and without loss of generality assume $p_A > p_B \geq 0$. To arrive at a contradiction, without loss of generality, we assume that $q_A(A) > q_B(A)$ and $q_A(B) > q_B(B)$. The beliefs can be calculated as $\mu_{AA} > \frac{1}{2}$ and $\mu_{BB} < \frac{1}{2}$. The best responses of the receiver in turn becomes $r_{AA} = 0$ and $r_{BB} = 1$. For $q_A(A) > q_B(A)$ and $q_A(B) > q_B(B)$ to be a part of equilibrium, the receiver's equilibrium strategies should satisfy $r_{AA} \geq r_{AB}$ and $r_{BA} \geq r_{BB}$. As $r_{AA} = 0$ and $r_{BB} = 1$, we get $r_{AB} = 0$ and $r_{BA} = 1$. Against these strategies of the receiver, the best responses of S_1 satisfy $p_A = 0$ and $p_B = 1$, which contradicts to the hypothesis. □

Proof of Proposition 3. For sender 1 the expected payoff of choosing truth is as follows:

$$E[u_1(\text{truth})] = \sigma_2 \left[\sigma_R^n 0.5 + (1-\sigma_R^n)4.5\right] + (1-\sigma_2)\left[\sigma_R^c 0.5 + (1-\sigma_R^c)4.5\right].$$

Similarly, expected payoff of choosing lie is:

$$E[u_1(\text{lie})] = \sigma_2 \left[\sigma_R^c 4.5 + (1-\sigma_R^c)0.5\right] + (1-\sigma_2)\left[\sigma_R^n 4.5 + (1-\sigma_R^n)0.5\right] - c_1.$$

Then, $\sigma_1 = \frac{1}{1+e^{\gamma[4(\sigma_R^n+\sigma_R^c-1)-c_1]}}$.

Sender 2's expected payoff of choosing truth is:

$$E[u_2(\text{truth})] = \sigma_1 \left[\sigma_R^n 0.5 + (1-\sigma_R^n)4.5\right] + (1-\sigma_1)\left[\sigma_R^c 4.5 + (1-\sigma_R^c)0.5\right].$$

Similarly, sender 2's expected payoff by choosing lie is:

$$E[u_2(\text{lie})] = \sigma_1 \left[\sigma_R^c 0.5 + (1-\sigma_R^c)4.5\right] + (1-\sigma_1)\left[\sigma_R^n 4.5 + (1-\sigma_R^n)0.5\right] - c_2.$$

So, $\sigma_2 = \frac{1}{1+e^{\gamma[4(\sigma_R^n-\sigma_R^c)-c_2]}}$. Next, we find the expected payoff of a receiver who has observed the same -nonconflicting- messages sent by the two senders and trusts to sender 1.

$$E[u_R(\text{trust to S1})] = 9\sigma_1\sigma_2 + (1-\sigma_1)(1-\sigma_2).$$

Similarly, the expected payoff of a receiver who distrusts to sender 1 upon seeing nonconflicting messages is given by:

$$E[u_R(\text{distrust to S1})] = \sigma_1\sigma_2 + 9(1-\sigma_1)(1-\sigma_2).$$

We can conclude that $\sigma_R^n = \frac{1}{1+e^{\gamma[8(1-\sigma_1-\sigma_2)]}}$. The expected payoff of a receiver who trusts to sender 1 upon observing conflicting messages can be given as:

$$E[u_R(\text{trust to S1})] = 9\sigma_1(1-\sigma_2) + (1-\sigma_1)\sigma_2.$$

The expected payoff of a receiver who distrusts to sender 1 upon observing conflicting messages is:

$$E[u_R(\text{distrust to S1})] = \sigma_1(1-\sigma_2) + 9(1-\sigma_1)\sigma_2.$$

Finally, $\sigma_R^c = \frac{1}{1+e^{\gamma[8(\sigma_2-\sigma_1)]}}$.

The uniqueness is ensured by $\frac{\partial\sigma_1}{\partial\sigma_R^c} < 0, \frac{\partial\sigma_1}{\partial\sigma_R^n} < 0$ and $\frac{\partial\sigma_R^c}{\partial\sigma_1} > 0, \frac{\partial\sigma_R^n}{\partial\sigma_1} > 0$; $\frac{\partial\sigma_2}{\partial\sigma_R^n} < 0, \frac{\partial\sigma_2}{\partial\sigma_R^c} > 0$ and $\frac{\partial\sigma_R^n}{\partial\sigma_2} > 0, \frac{\partial\sigma_R^c}{\partial\sigma_2} < 0$. □

Proof of Proposition 4. Expected utility of sender 1 by being truthful is as follows:

$$E[u_1(\text{truth})] = \sigma_2^t\left[\sigma_R^n 0.5 + (1-\sigma_R^n)4.5\right] + (1-\sigma_2^t)\left[\sigma_R^c 0.5 + (1-\sigma_R^c)4.5\right].$$

Similarly, expected payoff of choosing to lie is:

$$E[u_1(\text{lie})] = \sigma_2^l\left[\sigma_R^c 4.5 + (1-\sigma_R^c)0.5\right] + (1-\sigma_2^l)\left[\sigma_R^n 4.5 + (1-\sigma_R^n)0.5\right] - c_1.$$

Thus, we get σ_1. Then, we derive the expected payoff of sender 2 by telling the truth after observing a truthful message of sender 1.

$$E[u_2(\text{truth})] = \sigma_R^n 0.5 + (1-\sigma_R^n)4.5.$$

Similarly, sender 2's expected payoff by choosing lie after observing a truthful message is:

$$E[u_2(\text{lie})] = \sigma_R^c 0.5 + (1-\sigma_R^c)4.5 - c_2^t.$$

So, we get that σ_2^t. Next, we find the expected payoff of sender 2 by telling the truth after observing an untruthful message of sender 1.

$$E[u_2(\text{truth})] = \sigma_R^c 4.5 + (1-\sigma_R^c)0.5.$$

Similarly, sender 2's expected payoff by choosing lie after observing an untruthful message is:

$$E[u_2(\text{lie})] = \sigma_R^n 4.5 + (1-\sigma_R^n)0.5 - c_2^l.$$

Thus, we arrive at σ_2^l. Now, we find the expected payoff of a receiver who trusts to sender 1 after observing nonconflicting messages:

$$E[u_R(\text{trust to S1})] = 9\sigma_1\sigma_2^t + (1-\sigma_1)(1-\sigma_2^l).$$

Similarly, the expected payoff of a receiver who distrusts to sender 1 upon seeing nonconflicting messages is given by:

$$E[u_R(\text{distrust to S1})] = \sigma_1\sigma_2^t + 9(1-\sigma_1)(1-\sigma_2^l).$$

And, we get that σ_R^n equals to the expression in the proposition. Finally, we calculate the expected payoff of a receiver who trusts to sender 1 upon observing conflicting messages.

$$E[u_R(\text{trust to S1})] = 9\sigma_1(1-\sigma_2^t) + (1-\sigma_1)\sigma_2^l.$$

The expected payoff of a receiver who distrusts to sender 1 upon observing conflicting messages is:

$$E[u_R(\text{distrust to S1})] = \sigma_1(1-\sigma_2^t) + 9(1-\sigma_1)\sigma_2^l.$$

Then, we find that σ_R^c.

The uniqueness is ensured by $\frac{\partial\sigma_1}{\partial\sigma_R^c} < 0$, $\frac{\partial\sigma_1}{\partial\sigma_R^n} < 0$ and $\frac{\partial\sigma_R^c}{\partial\sigma_1} > 0$, $\frac{\partial\sigma_R^n}{\partial\sigma_1} > 0$; $\frac{\partial\sigma_2^t}{\partial\sigma_R^n} < 0$, $\frac{\partial\sigma_2^t}{\partial\sigma_R^c} > 0$ and $\frac{\partial\sigma_R^n}{\partial\sigma_2^t} > 0$, $\frac{\partial\sigma_R^c}{\partial\sigma_2^t} < 0$; and $\frac{\partial\sigma_2^l}{\partial\sigma_R^n} < 0$, $\frac{\partial\sigma_2^l}{\partial\sigma_R^c} > 0$ and $\frac{\partial\sigma_R^n}{\partial\sigma_2^l} > 0$, $\frac{\partial\sigma_R^c}{\partial\sigma_2^l} < 0$. □