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Beliefs and truth-telling: A laboratory experiment*

Ronald Peeters† Marc Vorsatz‡ Markus Walzl§

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Abstract

We conduct a laboratory experiment with a constant-sum sender-receiver game to investigate the impact of individuals' first- and second-order beliefs on truth-telling. While senders are more likely to lie if they expect the receiver to trust their message (which is in line with expected payoff maximization), they are also more likely to tell the truth if they believe the receiver expects them to tell the truth. We observe no such dependence on second-order beliefs in a payoff equivalent game of matching pennies. Our results therefore indicate an impact of second-order beliefs as derived in models of guilt aversion in an antagonistic setting which is specific to strategic information transmission.

JEL Classification: C70, C91, D03.

Keywords: experiment, sender-receiver games, strategic information transmission, belief elicitation, guilt aversion.

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1 Introduction

A robust finding in experimental studies on strategic information transmission is that individuals reveal more private information than predicted by (sequential) equilibrium (e.g., Blume et al., 2001; Cai and Wang, 2006). As argued by Gneezy (2005), an individual's willingness to misreport private information thereby seems to be a matter of weighing costs and benefits: The higher the possible gains from deception and the lower the associated losses for those being deceived, the more keen individuals are to deceive. Many contributions emphasize that the costs and benefits of deception are not entirely captured by the corresponding monetary consequences (e.g., Sánchez-Pagés and Vorsatz, 2007; Kartik, 2009; Hurkens and Kartik, 2009). In fact, it has been shown recently that some individuals prefer Pareto-inferior allocations (in monetary terms) if a Pareto-improvement would involve deception (Erat and Gneezy, forthcoming) or refuse to lie at a cost for themselves even if the other player's payoff is unaffected (López-Pérez and Spiegelman, forthcoming).

The literature offers various explanations for truth-telling beyond (sequential) equilibrium predictions: Following Crawford (2003), Kawagoe and Takizawa (2009) and Wang et al. (2010) explain their experimental findings in sender-receiver games with a model that assumes individuals to maximize payoffs but to differ in their depth of reasoning. In contrast, Kartik (2009) remains in the sequential rationality paradigm and enriches the original analysis with payoff-maximizing agents (see Crawford and Sobel, 1982) with the introduction of exogenous lying costs for senders. This approach has been useful for an interpretation of the experimental findings in Hurkens and Kartik (2009), Sánchez-Pagés and Vorsatz (2009) and López-Pérez and Spiegelman (forthcoming).

Lying costs as in Kartik (2009) are purely action-based (i.e. the individual suffers from uttering a lie) and an analysis of the sender's trade-off between costs of lying and gains from truth-telling therefore only requires a consideration of the sender's actions and her (first-order) beliefs over the receiver's actions. Other contributions, however, suggest an impact of the sender's second-order beliefs (i.e. whether the sender thinks that the receiver expects her to lie or to tell the truth). Using the framework of psychological games (Geanakoplos et al., 1989; Battigalli and Dufwenberg, 2007 and 2009), Charness and Dufwenberg (2011) and Battigalli et al. (2012) propose guilt aversion as a motivation for truth-telling. Battigalli et al. (2012) demonstrate that the data in Gneezy (2005)'s experiment can be explained by senders who feel guilty if they let down the receiver relative to his payoff expectations. In this case, the sender's lying costs are increasing in the probability that she assigns to the receiver expecting the truth (i.e. the sender's second-order belief).

In our laboratory experiment with a constant-sum sender-receiver game, we ask whether the behavior of senders given their (first-order) beliefs about the receivers reaction can be explained by payoff-maximization without or with exogenous lying costs and whether second-order beliefs happen to have a decisive impact. In the game, the sender is privately informed which of the two possible tables (X or Y) represents the payoff consequences and sends a message (X or Y) to the receiver with which she (not necessarily truthfully) reports the actual state to him. The receiver, who only knows the two possible payoff tables and that each is chosen with equal probability, receives the sender's message and chooses between two options (X or Y). If the receiver's choice matches the actual payoff table (i.e. option X if the table is X or option Y if the table is Y), he receives 3 and the sender receives 1. If his choice does not match the table (i.e. option X if the table is Y or option Y if the table is X), payoffs are reversed. For this, we elicit the sender's and receiver's actions *and* the sender's first- and second-order belief as well as the receiver's first-order belief. For the elicitation of the first-order beliefs, we use the quadratic scoring rule and for the second-order belief we use the truncated interval scoring rule.

In line with the literature, we find that senders tell the truth (i.e. the message coincides with the selected payoff table) in significantly more than 50% of the cases (i.e. more often than predicted by sequential equilibrium with standard preferences). A probit maximum likelihood estimation reveals that truth-telling is decreasing in the senders' first-order and increasing in the senders' second-order belief. Hence, controlling for second-order beliefs, a sender is less likely to tell the truth if she expects the receiver to trust (which is predicted by expected payoff maximization). But, more importantly, controlling for first-order beliefs, a sender is more likely to tell the truth if she believes that the receiver expects her to tell the truth.

To further investigate the observed impact of second-order beliefs, we sort senders into six distinct groups according to their action (i.e. truth or lie) and their first-order belief (i.e. whether they expect the receiver to trust in more than, less than, or exactly 50% of the cases). For 69.05% of our experimental population, we cannot reject the hypothesis of rational payoff maximization. 47.62% of senders either lie while expecting the receiver to trust in more than 50% of the cases or tell the truth while expecting the receiver not to trust in more than 50% of the cases. The remaining 21.43% expect receivers to trust in exactly 50% of the cases so that both telling the truth and lying are payoff maximizing actions. Interestingly though, out of the 36 senders who have this first-order belief, 27 tell the truth and only 9 lie, which suggests truth-telling as a "tie-breaking rule", this being in line with (small) lying costs for the truth-tellers in this group. Additionally, the liars in this group appear to have second-order beliefs significantly below 50%; that is, they believe that the receiver expects them to lie, such that lying would be in line with guilt aversion because telling the truth to a receiver who expects a lie would mean to "let the receiver down".

The behavior of the two remaining groups, containing senders who tell the truth while expecting the receiver to trust and senders who lie while expecting the receiver not to trust (together 30.95% of the total population) is at odds with payoff maximization. While the senders who tell the truth and expect the receiver to trust have second-order beliefs that are not significantly different from 50%, the senders who lie and expect the receiver not to trust also believe that the receiver expects them to lie. Telling the truth while expecting trust seems to be very much in line with exogenous lying costs, but lying while expecting distrust provides an indication for costs that are based on second-order beliefs. Analogously to Sutter (2009), who calls truth-tellers that expect a receiver to distrust "sophisticated liars", one could call the liars who expect the receiver to distrust "sophisticated truth-tellers". These sophisticated truth-tellers seem to be (partially) responsible for the residual impact of second-order beliefs on truth-telling frequencies.

It should be observed that using guilt aversion to explain our observation that second-order beliefs (for given first-order beliefs) have an impact on truth-telling is not entirely straightforward. Social psychologists (see, for instance, Baumeister et al., 1994) and economists (see, for instance, Charness and Dufwenberg, 2006) emphasize that guilt motivates or coordinates pro-social behavior in social dilemma situations, but do not report a strong impact of guilt in antagonistic settings. To analyze whether the second-order belief dependence in our experiment is driven by payoff considerations or the particular communication structure of our sender-receiver game, we run a second treatment in which no messages are sent; i.e. both players choose actions and the first player (the sender in our original set-up) receives 1 whereas the second player (the receiver in our original set-up) who does not observe the first player's choice receives 3 if both choose the same action, and vice versa if choices do not match. For this game of "matching pennies", we find that second-order beliefs have no impact on choices and that the percentage of subjects for which non-standard preferences are needed in order to rationalize their behavior is significantly reduced from 32% to about 21%. Hence, the second-order belief dependence in our sender-receiver game is not an indication for guilt aversion in antagonistic games per se, but for guilt aversion in antagonistic games of information transmission where a sender can communicate her private information to the receiver. It does not seem to be the case that the sender is afraid to let-down the receiver in a game of matching pennies where one can hardly call one choice more appealing than another from a normative point of view. In contrast, our findings suggest an aversion against letting down the receiver with a lie if this is unexpected by the receiver, i.e. an aversion against violating the norm of truth-telling if this norm is expected to be acknowledged.

In Section 2, we present our experimental design. Results are discussed in Section 3. Finally, we discuss our findings. Appendix A contains a translation of the instructions into English and Appendix B displays screenshots of our experimental software.

2 The experiment

2.1 Design and procedures

Our experiment comprises of two treatments: The sender-receiver game (*treatment SR*) and the matching pennies game (*treatment MP*). Table 1 illustrates the sender-receiver game.

There are two players: the sender and the receiver. The payoff of both players depends on the payoff table that is selected by nature in the very beginning of the game (Table X or

	Table X		Table Y	
	Option X	Option Y	Option X	Option Y
Sender	1	3	3	1
Receiver	3	1	1	3

Table 1: Sender-receiver setting.

Table Y; each selected with equal chance) and the option chosen by the receiver (Option X or Option Y). In case the option chosen by the receiver matches the table selected, the receiver gets the larger payoff of 3 ECU; otherwise, he gets the lower payoff of 1 ECU. The payoffs of the sender are the opposite in either case. All this is known to both players. At the moment of deciding which option to choose, the receiver does not hold any private information about the table selected by nature. The sender, on the contrary, is perfectly informed about nature's table choice. Before the receiver chooses an option, the sender has to send one of the following two messages to the receiver: "Table X has been selected" (Message X) or "Table Y has been selected" (Message Y). Finally, both players receive their payoffs.

In our experiment, we elicit step-by-step (1) the sender's message choice in response to the selected payoff table, (2) the sender's belief about the receiver's option choice in response to the message sent, (3) the sender's belief about the receiver's belief regarding the actual payoff table conditional on the message sent, (4) the receiver's option choice in response to the message received, and (5) the receiver's belief about the actual payoff table conditional on the message sent by the sender. In short, we elicit (1) the sender's action, (2) the sender's first-order belief, (3) the sender's second-order belief, (4) the receiver's action, and (5) the receiver's first-order belief.[1]

Due to the symmetry of the game, we can consider state-independent strategies. For instance, in task (1) we only elicit the sender's message choice in response to Table X, and infer that in case of a truthful (untruthful) message, a truthful (untruthful) message would also have been chosen in response to Table Y. Participants are informed that symmetric analogues for their actions and beliefs are implemented in all events. So, in essence, both the sender and the receiver have to choose between two possible actions: The sender either *tells the truth* (the message coincides with the table selected by nature) or *lies* (the message does not coincide with the table selected by nature); the receiver either *trusts* (the option chosen coincides with the observed message) or *distrusts* (the option chosen does not coincide with the observed message). Likewise, beliefs are elicited regarding the coincidence of the actual table with the message sent (without mentioning the label "truth-telling") and the coincidence of the message sent with the option chosen by the receiver (without mentioning

[1] A screenshot of the description of the game as displayed throughout the experiment can be found in Figure 1 in Appendix B. Screenshots for the decisions (1)–(5) can be found in Figures 2–6, respectively. Results are disclosed to the participants on a screen as in Figure 7.

the label "trust").[2]

Beliefs are elicited in an incentive compatible way. For the two first-order beliefs, we use the Quadratic Scoring Rule (QSR; see Offerman et al., 2009); for the second-order belief, we apply the Truncated Interval Scoring Rule (TISR; see Schlag and van der Weele, 2009).[3] To elicit the first-order belief of the sender (henceforth, denoted by *FOB–S*), we ask how likely she regards the event that the receiver will choose Option X in case she sends the message that "Table X has been selected". To take this decision, the subject is provided with a slider that contains as grid points all numbers from 0 up to 100 and a triangular pointer that can be moved over the grid. The extreme values 0 and 100 correspond to the extreme beliefs "totally unlikely" and "totally likely" respectively. The answer z yields a payoff of

$$50 - 100\left(1 - \tfrac{z}{100}\right) + 50\left[\left(\tfrac{z}{100}\right)^2 + \left(1 - \tfrac{z}{100}\right)^2\right] \text{ ECU}$$

in case the receiver's action indeed coincides with the message sent and a payoff of

$$50 - 100\,\tfrac{z}{100} + 50\left[\left(\tfrac{z}{100}\right)^2 + \left(1 - \tfrac{z}{100}\right)^2\right] \text{ ECU}$$

in case the receiver's action does not coincide with the message sent.[4] When a participant moves the triangular pointer over the grid, the payoffs in each of the two potential cases are displayed on screen in real-time. Hence, participants are always aware of the potential payoff consequences of their choices.

To elicit the first-order belief of the receiver (henceforth, *FOB–R*), a similar slider is provided. The question we ask in this case is how likely it is that Table X has indeed been selected by nature given that the sender transmitted the message that "Table X has been selected". The payoff consequences are as those used for the sender's first-order belief.

For the second-order belief of the sender (henceforth, *SOB–S*), the same type of slider is used, but instead of one value, two values x and y have to be chosen. These two values indicate the lower- and upper-bound of the interval that the sender believes to contain the value z chosen by the receiver when asked about his first-order belief. In case the value z indeed happens to be contained in the interval $[x, y]$, the sender gets a payoff of

$$25 + 100\left(1 - \tfrac{y-x}{100}\right)^2 \text{ ECU}$$

from this task; otherwise she gets 0 ECU. Note that in the TISR mechanism, the payoff corresponding to a correct guess is decreasing in the size of the chosen interval.[5]

[2] The questions asked to elicit beliefs from the participants are documented in the screenshots in Figure 3, 4, and 6.

[3] Second-order beliefs have also been elicited (e.g., in Vanberg, 2008) by asking point-guesses about the co-player's point-guess on someones own strategic decision. In our setting, the TISR mechanism is more convenient as it allows to elicit information about the location *and* the dispersion of the belief distribution.

[4] So, the extreme guesses $z = 0$ and $z = 100$ yield a payoff of 0 ECU if the guess is wrong and 100 ECU if the guess is right. The safe guess $z = 50$ yields a payoff of 25 ECU for sure.

[5] To provide the two extreme cases: selecting one point ($y = x$) yields 125 ECU in case the guess is correct, while selecting the full domain ($x = 0$ and $y = 100$) yields 25 ECU for sure.

During the experiment, participants were not informed about the role (sender or receiver) they would finally employ. Hence, all subjects had to state their actions and beliefs for both roles before learning the outcome of the interaction. After all responses were collected, role assignment took place. For that objective subjects participating in the same session were randomly divided into pairs. In the next step, the two subjects from the same pair were randomly assigned distinct roles. The actions and beliefs of a participant in her/his actual role were then combined with the actions and beliefs of her/his match in the opposing role in order to calculate the payoffs from each of the tasks. Finally, for each sender (receiver), one of the three (two) sender-related decisions (receiver-related decisions) was independently chosen for actual payment. One ECU in an action-related task was worth 5 Euros and one ECU in a belief-related task was worth 20 Eurocents. The feedback screen of a subject revealed the decisions of both participants in a pair in their actual roles, her/his payoff relevant task, and her/his final payoff in Euro. Subjects knew from the beginning that feedback about actions and beliefs will be provided at the end of the experiment.

In *treatment MP*, we conduct the same experiment but without the communication structure. That is, both players decide between Option X and Option Y (and report corresponding beliefs). One player (the sender in treatment SR) receives 1 ECU while the other player (the receiver in treatment SR) receives 3 ECU if the choices of both players coincide. If choices do not coincide, payoffs are reversed. To focus the treatment variation on the presence or absence of communication, we maintain the sequential nature of the sender-receiver game also in treatment MP. The player who receives the low payoff in case of a coincidence of choices (the sender in treatment SR) chooses first and the player who receives the high payoff in case of a coincidence of choices (the receiver in treatment SR) chooses second but without being informed about the other players choice.[6]

The experiments were conducted in the experimental laboratory at Universidad Carlos III de Madrid in June 2012 (treatment SR) and October 2012 (treatment MP). We recruited undergraduate students from various disciplines via ORSEE (Greiner, 2004). All interactions took place anonymously via computer clients that where connected to a central server. The experiments were programmed in z-Tree (Fischbacher, 2007). The instructions and all screenshots corresponding to treatment SR are presented in Appendices A and B, respectively. In total, 254 students participated in the experiment: 168 in the sender-receiver and 86 in the matching pennies game. A typical session lasted about 45 minutes and the average payoff was 13.50 Euros (including a 5 Euro show-up fee).

[6]In order to keep the notation intuitive, the sender will be called *first-mover* and the receiver will be termed *second-mover* (or *last-mover*) in this treatment. Beliefs are abbreviated *FOB–F* and *SOB–F* for the first-mover and *FOB–L* for the last-mover.

2.2 Hypotheses

For both treatments, it is straightforward to adapt the model of simple guilt introduced by Battigalli and Dufwenberg (2007) and tailored to Gneezy (2005)'s deception game by Battigalli et al. (2012) to our setting and to establish an impact of the sender's or first-mover's second-order beliefs on her choices. In the sequel of this section, we call the two players sender and receiver, but the same analysis also applies for treatment MP.[7]

Let the receiver expect the sender to tell the truth with probability α_R. Then, he expects a payoff of $3\,\alpha_R + (1-\alpha_R) = 1 + 2\,\alpha_R$ from trust and a payoff of $\alpha_R + 3\,(1-\alpha_R) = 3 - 2\,\alpha_R$ from distrust. Denote the receiver's payoff for strategy profile z by $\pi_R(z)$ and his expected payoff from his optimal choice for a given α_R by $E[\pi_R]$. Now suppose the sender is guilt averse and suffers whenever the receiver is left with a payoff below his expectations. To be specific, assume that the sender's utility for strategy profile z is $u_S(z) = \pi_S(z) - \theta\, G(z)$, where $\pi_S(z)$ is the sender's monetary payoff for strategy profile z, θ is her sensitivity to guilt, and $G(z) = \max\left(E[\pi_R] - \pi_R(z), 0\right)$ measures how much the receiver is let down by the sender relative to his payoff expectations. By construction of the game, let down $G(z)$ can only be positive if the receiver trusted a lie or distrusted the truth and therefore earns the low payoff of 1. When he trusted a lie, let down is $G(\text{lie,trust}) = (1 + 2\alpha_R) - 1 = 2\,\alpha_R$ and when he distrusted the truth it is $G(\text{truth,distrust}) = (3 - 2\,\alpha_R) - 1 = 2 - 2\,\alpha_R$. To get the sender's expected utility from telling the truth and lying, denote her first-order belief (i.e. the probability with which she expects the receiver to trust) by α_S and her second-order belief (i.e. her prediction of α_R) by β_S. Then, the sender's expected utility from telling the truth is

$$E[u_S](\text{truth}) = \alpha_S \cdot 1 + (1-\alpha_S) \cdot (3 - \theta\,[2 - 2\,\beta_S]) = 3 - 2\,\alpha_S - 2\,\theta\,(1-\alpha_S)\,(1-\beta_S)$$

and the expected utility from a lie is

$$E[u_S](\text{lie}) = (1-\alpha_S) \cdot 1 + \alpha_S \cdot (3 - \theta\,[2\,\beta_S]) = 1 + 2\,\alpha_S - 2\,\theta\,\alpha_S\,\beta_S.$$

So, whenever senders or first-movers maximize expected utility and feel guilty if they let down receivers or second-movers relative to their payoff expectations (i.e. $\theta > 0$), the model implies the following hypothesis.

Hypothesis 1 (Payoff-based guilt)**.** *For given first-order beliefs, (i) senders are more likely to tell the truth if they believe the receiver expects them to tell the truth and (ii) first-movers are more likely to choose the action that they believe the second-mover expects them to choose.*

However, individuals may exhibit a different sensitivity to guilt in the two treatments. Rather than suffering from guilt as soon as they let down the receiver by a certain amount of money, individuals could also care about *how* they let the receiver down. The literature in social

[7] The analysis translates if we identify the strategies of truth and lie by the sender with the strategies Option X and Option Y by the first-mover and if we identify the strategies of trust and distrust by the receiver with the strategies Option X and Option Y by the second-mover.

psychology (see, e.g., Baumeister et al., 1994) and previous findings in the economic literature (see, e.g., Charness and Dufwenberg, 2006) emphasize the role of guilt for the maintenance, protection, and strengthening of interpersonal relationships. In particular, guilt motivates individuals to exhibit pro-social behavior. In an antagonistic setting as in our experiment, however, all actions that are at the individual's disposal generate the same total value of the relationship. As a consequence, one would expect a low sensitivity to guilt in the matching pennies game. In the sender-receiver game, the different options for the sender (telling the truth or lying) also generate the same total value of the relationship. But lying to someone who expects the truth could well be regarded as anti-social behavior as it violates the norm of truth-telling that, in general, is regarded as effective for the strengthening of interpersonal relationships. On this background we hypothesize that individuals are more sensitive to guilt in the sender-receiver game, where the communication structure introduces truth-telling as a normative benchmark for pro-social behavior, than in the matching pennies game where no such normative benchmark is present.

Hypothesis 2 (Communication-based guilt)**.** *For given first-order beliefs, (i) senders in the sender-receiver game are more likely to tell the truth if they believe the receiver expects them to tell the truth and (ii) the behavior of first-movers in the matching pennies game is not affected by second-order beliefs.*

3 Results

Since participants do not receive any feedback before all decisions are made, the number of independent observations equals the number of participants. So, we have 168 independent observations in treatment SR and 86 independent observations in treatment MP.

3.1 Treatment SR

Table 2 presents the aggregate data.

	Actions		Beliefs		
	Truth	Trust	FOB–S	SOB–S	FOB–R
Sender	0.6429		0.5383	0.4814	
	(0.0001)		(0.1397)	(0.0606)	
Receiver		0.4940			0.4486
		(0.8744)			(0.0041)

Table 2: Proportions of truth and trust. In addition, we show the average first- and second-order beliefs of the sender and the receiver. In parentheses, we present the two-sided p-values of the Wilcoxon signed-rank tests on the population average coinciding with the equilibrium prediction of 0.5.

Consistent with the existing literature (see introduction), we find that senders tell the truth excessively compared to the sequential equilibrium prediction by Crawford and Sobel

(1982). To be specific, senders tell the truth in about 64.29% of the cases, which is significantly above the standard sequential equilibrium prediction of 50%. On the other hand, the aggregate level of trust equals 49.40%, and this number is not significantly different from the respective theoretical prediction of 50%.

One reason why messages are more truthful than according to the standard equilibrium prediction could be that many senders expect the receiver to distrust. In that case, a high frequency of truth-telling can be rationalized with payoff maximization (even though these beliefs cannot be sustained in equilibrium). Yet, it is easy to see that such beliefs are rather unlikely to be the main reason for the observed behavioral pattern, as the average first-order belief of the sender is not significantly different from 50%. Likewise, the aggregate behavior of the receiver also presents some pattern that does not coincide with equilibrium play: While the proportion of trust is very close to the equilibrium prediction, the first-order belief of the receiver is significantly lower than 50%. The average second-order belief of the senders (i.e. the average of the midpoints of the intervals chosen by the senders) is only marginally below the equilibrium prediction of 50%.

Given these findings, our first objective is to uncover some aggregate relations between beliefs and actions. To be specific, we ask – in line with payoff maximization – whether a subject in the role of the sender is more likely to tell the truth if she considers it less likely that the receiver trusts the message and whether a subject in the role of the receiver is more likely to trust if he considers it more likely that the sender tells the truth. Most importantly, we would like to see whether there is any impact of second-order beliefs as claimed in Hypotheses 1 and 2. The results of a probit maximum likelihood estimation can be found in Table 3.

	Truth	Trust
Constant	0.2495	-1.0463^{***}
	(0.3420)	(0.0001)
FOB–S	-0.0084^{**}	
	(0.0044)	
SOB–S	0.0120^{**}	
	(0.0065)	
FOB–R		0.0230^{***}
		(0.0001)

Table 3: Probit ML estimations on the determinants of truth-telling and trust. In parentheses, we present the standard deviations. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

The probability that the sender tells the truth and the probability that the receiver trusts correlate to their respective first-order beliefs in a way that is consistent with payoff maximization. An indication for motives beyond payoff maximization, however, is the clear impact of second-order beliefs that we observe: For a given first-order belief, truth-telling is more likely when individuals believe that the receiver expects the truth to be told – as predicted by our model of guilt aversion and in line with Hypotheses 1 and 2.

To shed more light on the behavior of the senders, we now partition the subject pool into six different subgroups according to the message sent and the first-order belief held in the role of the sender. The relevant data can be found in Table 7.[8]

Partition	Number	Proportion	Average SOB–S	
Truth-Tellers				
Subgroup A: FOB–S > 0.5	35	0.2083	0.5149	(0.3529)
Subgroup B: FOB–S $= 0.5$	27	0.1607	0.5194	(0.0866)
Subgroup C: FOB–S < 0.5	46	0.2738	0.4622	(0.0100)
Liars				
Subgroup D: FOB–S > 0.5	34	0.2024	0.5026	(0.4150)
Subgroup E: FOB–S $= 0.5$	9	0.0536	0.4283	(0.0240)
Subgroup F: FOB–S < 0.5	17	0.1012	0.3894	(0.0028)

Table 4: Division of subjects by subgroups (depending on the message sent and the first-order belief in the role of the sender). We show the number/proportion of subjects in each subgroup and the average second-order belief in the role of the sender with the corresponding one-sided p-value of the Wilcoxon signed-rank tests on the average SOB–S at the subgroup level being equal to the standard sequential equilibrium prediction of 0.5 (in parentheses).

The behavior of two subgroups is perfectly in line with payoff maximization. Subgroup C consists of truth-tellers who believe that the receiver is more likely to distrust the message than to trust it. As a result, these subjects maximize their expected payoff given their subjective belief about the behavior of the receiver. The same can be said about the subjects belonging to subgroup D – liars who believe that the receiver is more likely to trust than to distrust the message. These two subgroups contain 47.62% of the experimental population.

Subjects from subgroup A – who account for a total of 20.83% of the experimental population – tell the truth and believe that the receiver is more likely to trust than to distrust, which is at odds with the assumption of expected payoff maximization. However, assuming guilt aversion as discussed in Subsection 2.2 or a cost of lying as in Kartik (2009) could explain this behavior. Since the average FOB–S of subgroup A is 76.35% and the average SOB–S is 51.49%, a representative agent for this subgroup expects a payoff of $1 \cdot 0.7635 + 3 \cdot (1 - 0.7635) = 1.473$ from telling the truth and of $3 \cdot 0.7635 + 1 \cdot (1 - 0.7635) = 2.527$ from lying. Hence, it is optimal to tell the truth as soon as the lying cost is larger than 1.054. Likewise, as we have $\alpha_S > 0.5$ and $\beta_S > 0.5$ for this subgroup, expected guilt (i.e. the term proportional to θ in $E[u_S]$(truth) and $E[u_S]$(lie)) is larger for a lie than for telling the truth. Hence, truth-telling is also optimal if the sender is sufficiently sensitive to guilt. For the representative agent of

[8] In this contribution we focus on the behavior of senders. We have already seen that the receivers aggregate behavior is very close to the standard equilibrium prediction. It also turns out that, as receivers, only 17% of the subjects do not take the action that maximizes their expected payoff given their subjective beliefs.

subgroup A, θ has to be larger than 1.8930 for the superiority of truth-telling in the absence of lying costs.

Subgroup F (10.12% of the experimental population) consists of subjects who lie and believe that the receiver is more likely to distrust than to trust. The behavior of these subjects is again at odds with payoff maximization, but there is a subtle difference with respect to subgroup A: Subjects from subgroup F cannot have fixed lying costs because of the message that they are sending. Moreover, the average second-order belief of these subjects is not only significantly lower than 50% (by a wide margin of about 11 percentage points), it is also significantly lower than the corresponding average belief of the liars in subgroup D (the one-sided p-value of the corresponding Mann Whitney U test equals 0.0045). Hence, individuals in subgroup F expect the receiver to distrust *and* believe that he expects a lie. Therefore, telling the truth would "let down" the receiver and a sufficiently pronounced guilt aversion can explain lying by the sender. To be specific, with an average FOB–S of 24.53% and an average SOB–S of 38.94%, the expected utilities of a representative guilt averse sender for this subgroup read $E[u_S](\text{truth}) = 2.5094 - 0.9216\,\theta$ and $E[u_S](\text{lie}) = 1.4906 - 0.1910\,\theta$. This sender minimizes guilt if she lies and does so whenever her sensitivity θ is larger than 1.3945.

Finally, let us consider the subjects who believe the receiver trusts with probability one-half (subgroups B and E). For these subjects both telling the truth and lying is consistent with payoff maximizing behavior. However, only 9 out of these 36 subjects choose to lie, when, on the aggregate, we should observe truth-telling and lying in equal proportions (if these subjects are truly indifferent and randomize between these options). Although this difference can be explained by subjects incurring a fixed lying cost, the data is also consistent with guilt aversion as the subjects who tell the truth (subgroup B) rather believe that the receivers expect a truthful message (the average SOB–S is 0.5194), while subjects who lie (subgroup E) rather believe that the receivers expect a lie (the average SOB–S is 0.4283). The second-order beliefs are significantly different across these two subgroups ($p = 0.0098$, one-sided).

To conclude: Our analysis of treatment SR has shown that 69.05% of the data can be explained if one assumes that subjects are rational payoff maximizers (subgroups B, C, D, and E), another 20.83% of the subjects seem to have either fixed lying costs or show guilt aversion (subgroup A), and 10.12% of the data can hardly be explained without a reference to higher-order beliefs. Interestingly, observed excessive truth-telling with respect to the standard equilibrium prediction seems to be driven both by inaccurate first-order beliefs and by non-standard preferences such as lying costs or guilt aversion. In fact, 62.93% of the rational payoff maximizers and 67.30% of the subjects with non-standard preferences tell the truth.

3.2 Treatment MP

While the data from treatment SR is in line with Hypothesis 1 and 2, we continue with an analysis of treatment MP that will allow to distinguish between the two hypotheses. Again, we first present the aggregate data.

	Actions		Beliefs		
	Option X	Option X	FOB–F	SOB–F	FOB–L
First-mover	0.3605 (0.0097)		0.5737 (0.0006)	0.5291 (0.0044)	
Second-mover		0.5349 (0.5176)			0.4850 (0.8817)

Table 5: Proportion with which the first-mover and second-mover choose Option X. In addition, we show the average first- and second-order beliefs of the players. In parentheses, we present the two-sided p-values of the Wilcoxon signed-rank tests on the population average coinciding with the equilibrium prediction of 0.5.

While the behavior and the beliefs of the second-movers are not different from the standard equilibrium prediction of 0.5, the first-movers choose Option Y in significantly more than 50% of the cases. However, average first- (and second-) order beliefs are significantly greater than 0.5 so that a representative agent who maximizes payoffs would indeed choose Option Y. As for treatment SR, we continue with an analysis of the effect of first- and second-order beliefs on choices. The results are presented in Table 6.

	Option X	Option X
Constant	0.1764 (0.6429)	−0.1485 (0.3238)
FOB–F	-0.0097^{*} (0.0064)	
SOB–F	0.0002 (0.0098)	
FOB–L		0.0048 (0.0060)

Table 6: Probit ML estimations on the determinants of the choices in treatment MP. In parentheses, we present the standard deviations. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

Table 6 reveals some fundamental differences compared to the game of strategic information transmission. While all beliefs were significant at the 5% level in the estimation for the sender-receiver game, now only the first-order beliefs of the first-movers have an impact on actions (at the 10% level). This impact is as expected from payoff maximization, as first-movers are less likely to choose Option X the higher the probability with which they expect the second-mover to choose Option X. Most importantly, however, the marginal impact of second-order beliefs of the first-mover on her own choice vanishes. This provides strong evidence in favor of Hypothesis 2 (over Hypothesis 1) as second-order beliefs only matter in the sender-receiver game suggesting that individuals are sensitive to guilt when violating the social norm of truth-telling, but not when playing a payoff equivalent game of matching pennies without the communication structure. To provide additional support for this interpretation, we next present the results from the subgroup analysis.

Partition	Number	Proportion	Average SOB–F	
Option X				
Subgroup A: FOB–F > 0.5	10	0.1163	0.5530	(0.1418)
Subgroup B: FOB–F $= 0.5$	15	0.1744	0.5070	(0.1422)
Subgroup C: FOB–F < 0.5	6	0.0698	0.5417	(0.2844)
Option Y				
Subgroup D: FOB–F > 0.5	31	0.3605	0.5339	(0.0050)
Subgroup E: FOB–F $= 0.5$	16	0.1860	0.4956	(0.2478)
Subgroup F: FOB–F < 0.5	8	0.0930	0.5794	(0.1438)

Table 7: Division of subjects by subgroups (depending on the option chosen and the first-order belief in the role of the first-mover). We show the number/proportion of subjects in each subgroup and the average second-order belief in the role of the first-mover with the corresponding one-sided p-value of the Wilcoxon signed-rank tests on the average SOB–F at the subgroup level being equal to 0.5 (in parentheses).

In treatment SR, we identified one very clear impact of second-order beliefs: Subjects from subgroup F who lie and think that the receiver is not going to trust the message, tend to believe that the receiver expects them to lie. In fact, the average second-order belief of this subgroup in treatment SR amounted to 0.3894. The average second-order belief of the same subgroup in treatment MP, which still comprises about 10% of the total population, is now equal to 0.5794. This number is not significantly different from 0.5 (see the p-value in the last column of the table) and significantly greater than the respective value in treatment SR ($p = 0.0004$, one-sided). Hence, the former impact of the second-order belief vanishes once the communication structure is eliminated from the game.

A second, less conclusive impact of second-order beliefs on actions in treatment SR was that those subjects who believe that the receiver trusts their message with probability one-half (subjects who are indifferent between telling the truth and lying under standard preferences), showed the tendency to sort themselves according to their second-order beliefs: The subjects with a second-order belief above 0.5 had the tendency to tell the truth, and those with a second-order belief below 0.5 rather chose to lie. Overall, more subjects had a second-order belief above 0.5 than below 0.5 and 75% of the subjects who under payoff maximization would be indifferent between both actions told the truth. This effect vanishes in treatment MP as well. First, the average second-order beliefs of subgroups B and E are not significantly different any more ($p = 0.1419$, one-sided) and second, among the 31 subjects who are a priori indifferent between choosing Option X and Option Y, 15 opt for Option X and 16 select Option Y.

Finally, observe that the percentage of subjects in treatment MP who are not rational payoff maximizers (subgroups A and F; 20.93%) is significantly lower than in treatment SR (the two-sided p-value of the Fisher exact test is 0.0286). Hence, non-standard preferences play less of a role if the communication structure is removed from the game. Interestingly, the lengths of the intervals that individuals choose for their second-order beliefs are on average 30.81 in treatment SR but only 23.63 in treatment MP. This difference is significant at $p = 0.0012$ (two-sided Mann Whitney U test). The communication structure with its implicit norm of truth-telling therefore appears to have a negative impact on the individuals' level of confidence regarding their opponents' beliefs.

4 Discussion

Our experiment with action and belief elicitation in a constant-sum setting with and without strategic information transmission helps to address several research questions.

Belief formation. Our data on first-order beliefs allows to analyze in how far individual and aggregate beliefs match actual choices in the presence and absence of strategic information transmission. At the individual level, there is a considerable amount of individuals who hold beliefs that are at odds with aggregate behavior in both treatments. For instance, more than 40% of the senders in treatment SR expect trust in more than 50% of the cases, which does not match with trust being chosen overall in less than 50% of the cases. Likewise, there are first-movers (less than 18% of the population) who expect the second-mover to choose Option X in less than 50% of the cases even though Option X is chosen by the second-mover in slightly more than 50% of the cases.

At the aggregate level, however, the relationship between own beliefs, own actions, and aggregate behavior differs across treatments. In treatment MP, first-order beliefs do not match actual aggregate behavior. First-movers expect Option X to be chosen by the second-movers in more than 50% of the cases while actual choices by the second-movers do not significantly differ from 50–50. Likewise, the second-mover's expectation regarding the choice of Option X by the first-mover is not significantly different from 50% while first-movers predominately choose Option Y. Choices, however, are consistent with first-order beliefs. First-movers expect Option X to be more often chosen by second-movers and predominately choose Option Y themselves while second-movers do not expect choice probabilities to differ from 50–50 and are also equally likely to choose both options on the aggregate level. In contrast, senders' first-order beliefs in treatment SR are not significantly different from 50–50 and therefore consistent with actual choices by the receiver. However, senders tell the truth in more than 50% of the cases which is too much given their beliefs (assuming that senders try to maximize payoffs). Receivers do not expect this kind of excessive truth-telling. They rather expect excessive lying but do not respond to this with significant distrust.

To conclude, we can see that in treatment MP, aggregate first-order beliefs fail to match actual aggregate behavior but aggregate behavior is payoff maximizing given aggregate beliefs. For senders in treatment SR this relationship is reversed: Aggregate sender beliefs match aggregate receiver actions, but aggregate sender behavior is not payoff maximizing given these beliefs. This nicely illustrates the point that in sender-receiver games there is not only too much truth-telling relative to equilibrium predictions – termed "overcommunication" by Cai and Wang (2006) – but also relative to the senders' aggregate beliefs. The receivers do not expect this but rather expect more than 50% lies. Interestingly, aggregate receiver behavior does not exhibit significant distrust in response to this but rather excessive trust relative to first-order beliefs (under the assumption of payoff maximization).

Motives for truth-telling. The elicitation of first- *and* second-order beliefs in our experiment allows to disentangle several reasons for truth-telling beyond the standard equilibrium prediction. The separate analysis for senders with distinct behavior (truth/lie) and first-order beliefs (above/below/equal to 50–50) provides direct evidence that individuals are not only telling the truth (or lie) because they hold inaccurate beliefs. In fact, 30.95% of all senders in treatment SR do not react to their first-order beliefs in a payoff-maximizing way. That this deviation from payoff maximization can (at least partially) be attributed to norms specific to information transmission follows from the observation that in treatment MP significantly less first-movers (20.93%) exhibit a behavior which is at odds with payoff maximization.

While the behavior of those senders who tell the truth and expect to be trusted could be explained with lying costs as introduced by Kartik (2009) and successfully applied in previous experiments on strategic information transmission by Hurkens and Kartik (2009), Sánchez-Pagés and Vorsatz (2009) and López-Pérez and Spiegelman (forthcoming), this interpretation does not help understanding why 10.12% of the senders lie even though they expect to be distrusted. A model of simple guilt aversion where the sender suffers from letting down the receiver relative to the receiver's payoff expectations, however, would predict that a sender who expects to be distrusted *and* believes that the receiver expects her to lie feels less guilty if she indeed lies and thereby creates a payoff for the receiver which does not fall short of his expectations. As, in fact, senders who expect distrust and lie hold the belief that the receiver expects a lie, our data supports this explanation.

But, even more importantly, the second-order belief dependence as introduced by guilt aversion also reveals its impact on the aggregate level. For a given first-order belief, a sender is more likely to tell the truth if she believes that the receiver expects the truth. This contrasts the findings in López-Pérez and Spiegelman (forthcoming) who also find a residual impact of second-order beliefs, yet their data can still be explained with (belief-independent) lying costs alone. In their framework, the receiver's payoff is unaffected by the sender's decision and there cannot be any let-down relative to the receiver's payoff expectations. Their dependence on second-order beliefs, therefore, rather suggests that the sender suffers from not meeting the receiver's expectations about norms in communication per se.

Guilt in antagonistic games. Suggesting guilt as a driving force behind the second-order belief dependence in the antagonistic setting of our experiment extends the typical scope of guilt-based models in economics where guilt is typically generated whenever an individual fails to engage in an action that increases total surplus (see, e.g., Charness and Dufwenberg, 2006 and 2011). But, guilt in an antagonistic setting seems to be at odds with the literature in social psychology that emphasizes the importance of guilt for the strengthening of relationships in social dilemma situations (see Baumeister et al., 1994) or the role of guilt as a motive for helping other people (see, e.g., Miller, 2010).[9] And, indeed, as soon as we remove the communication structure from our experimental setting and participants play a game of matching pennies, no impact of second-order beliefs (as an imprint of guilt) can be found. Hence, it is not the antagonistic payoff structure that induces a sufficiently strong sensitivity to guilt and generates a second-order belief dependence. It needs a norm that is typically associated with pro-social behavior in social dilemma situations (such as truth-telling) to induce guilt and its associated second-order belief dependence. This kind of guilt may then be sufficiently pronounced to affect behavior even in an antagonistic setting.

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[9] The explanation of Gneezy (2005)'s results using a model of guilt in Battigalli et al. (2012) may be regarded as an economic application for guilt that motivates help as in two of Gneezy's treatments payoffs are also antagonistic but the receiver is not informed about this. This induces an additional asymmetry compared to our setting as the sender in Gneezy's experiment is the only one who knows "what is good for the receiver" such that she may feel guilt if she refuses to help the receiver out of his unawareness and recommend the action that maximizes the receiver's payoff.

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A Instructions (translated from Spanish)

General instructions

Thank you for participating in the experiment. The objective of the session is to study how individuals take decisions in a particular situation. The session is going to last about 1 hour. In addition to the 5 Euros show up fee you receive for your participation, you can earn additional money depending on the decisions taken during the experiment. In order to ensure that the experiment takes place in an optimal environment, we are asking you to respect the following norms:

- Do not speak with other participants.
- Turn off your mobile phone.
- If you have a question, raise your hand.

If you do not follow these rules, it is impossible for us to use of the data, and we have to exclude you from the session. In this case, you will not receive any compensation. During the experiment, payoffs are expressed in ECU (experimental currency units). At the end of the instructions, we will explain you how ECU are converted into Euro so that the money earned can be calculated.

Procedures

In the experiment, you are going to take a series of decisions using the computer terminal. Throughout the experiment, you are randomly matched with another participant to form a pair. Neither you nor the other participant in the pair knows or will ever learn the identity of her/his match. In each pair, one of the two participants will be assigned the role of Player 1 and the other participant will be assigned the role of Player 2. The computer will randomly determine your actual role after all payoff relevant decisions have been made. This means that you will have to take decisions as both Player 1 and Player 2.

The situation

There are two tables, Table X and Table Y, one of which is randomly selected by the computer. Both payoff tables equally likely being selected (payoffs are in ECU):

Only Player 1 knows which payoff table has been selected by the computer. Next, Player 1 has to send one of the following two messages to Player 2: "Table X has been selected" or "Table Y has been selected." Note that Player 1 can send any message she/he likes to. Then, Player 2 observes the message of Player 1 and has to choose one of the following to options: "Option X" (that is, Player 2 chooses the left column) or "Option Y" (that is, Player 2 chooses the right column). The final payoffs depend on the table selected by the computer

Table X	Option X	Option Y
Player 1	1	3
Player 2	3	1

Table Y	Option X	Option Y
Player 1	3	1
Player 2	1	3

Table 8: Payoff tables.

and the option chosen by Player 2. For example, if Player 2 chooses Option X and Table Y has been selected by the computer, then Player 1 gets 3 ECU and Player 2 gets 1 ECU.

Procedures – continued

In this experiment, you are given three tasks (Task A, B, and C) in the role of Player 1 and two tasks (Tasks A and B) in the role of Player 2. Task A asks you how you would behave in the situation described above. Tasks B and C relate to the question of how you think others behave. In the end, you are going to be paid for one of the tasks corresponding to your role – which is randomly determined by the central computer.

To be more precise, after all five tasks have been completed, the central computer assigns you and your match to one of the roles such that each of you takes a distinct role. For example, if you are assigned to the role of Player 1 (and your match to that of Player 2), we take your decisions as Player 1 and combine them with the decisions of your match as Player 2. Next, the computer determines the task that is paid for (each task is chosen with equal chance). If Task A (Task B or C) is randomly chosen for payment, you will receive 5 Euro (0.2 Euro) for every ECU earned during this particular task on top of the 5 Euro show up fee. At this point you will also be informed about (a) your actual role, (b) your payoffs from each of the tasks in your actual role (and the decisions of your match that are needed to calculate this payoff), (c) the task that is payoff relevant for you, and (d) your final payoff in Euro.

Since your final payoff depends on the quality of your decisions, it is of utmost importance that you read the instructions on the computer screen very carefully and think very carefully about your decision before clicking the OK button (which advances you to the next task). If you are not sure to fully understand the functioning of the experiment at any point in time, please, do not hesitate to raise your hand and ask.

B Screenshots (translated from Spanish)

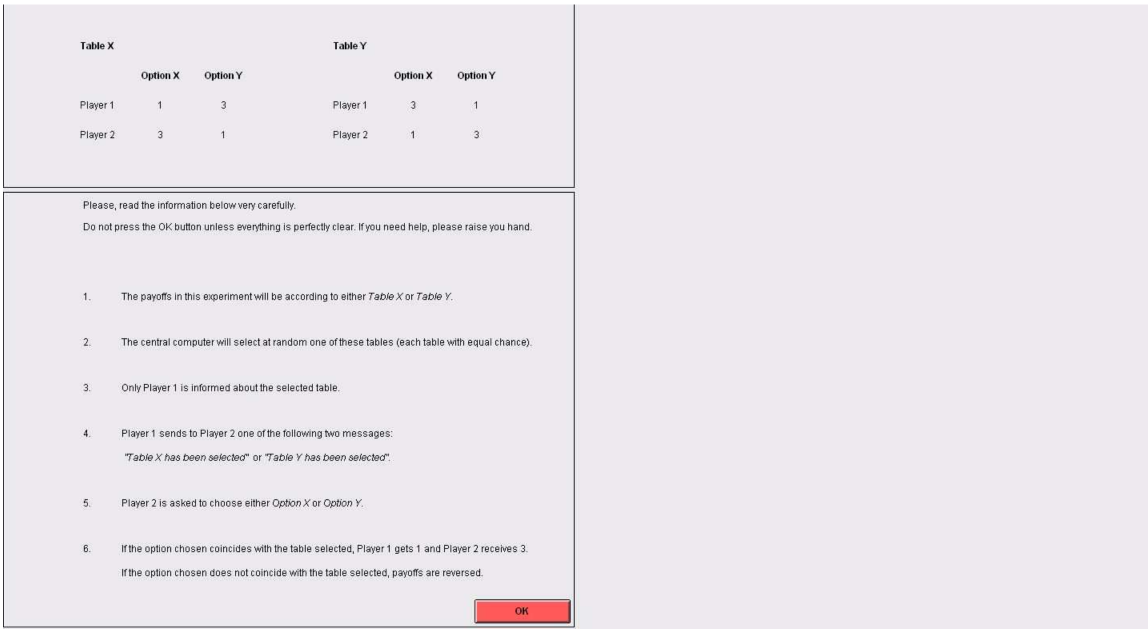

Figure 1: Screen 1 repeats the formal definition of the sender-recveiver game. This description is present on the left-hand side of each screen throughout the whole experiment.

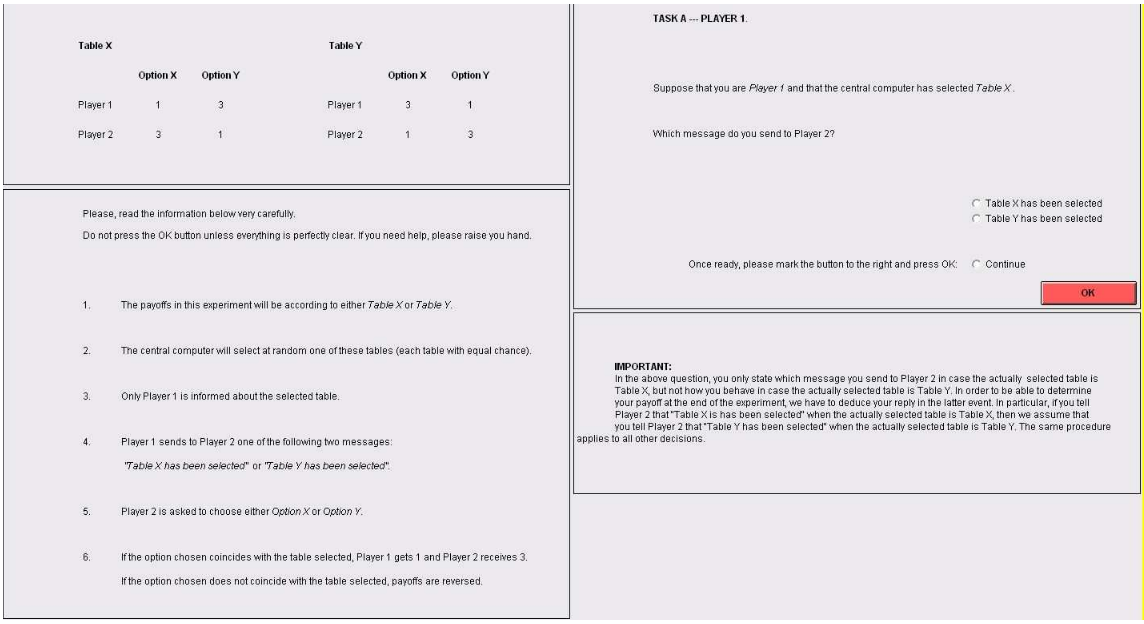

Figure 2: Screen 2 corresponds to Task A for Player 1. Subjects decide which message to send if the actual table is Table X and it is explained how the decision for Table Y is determined.

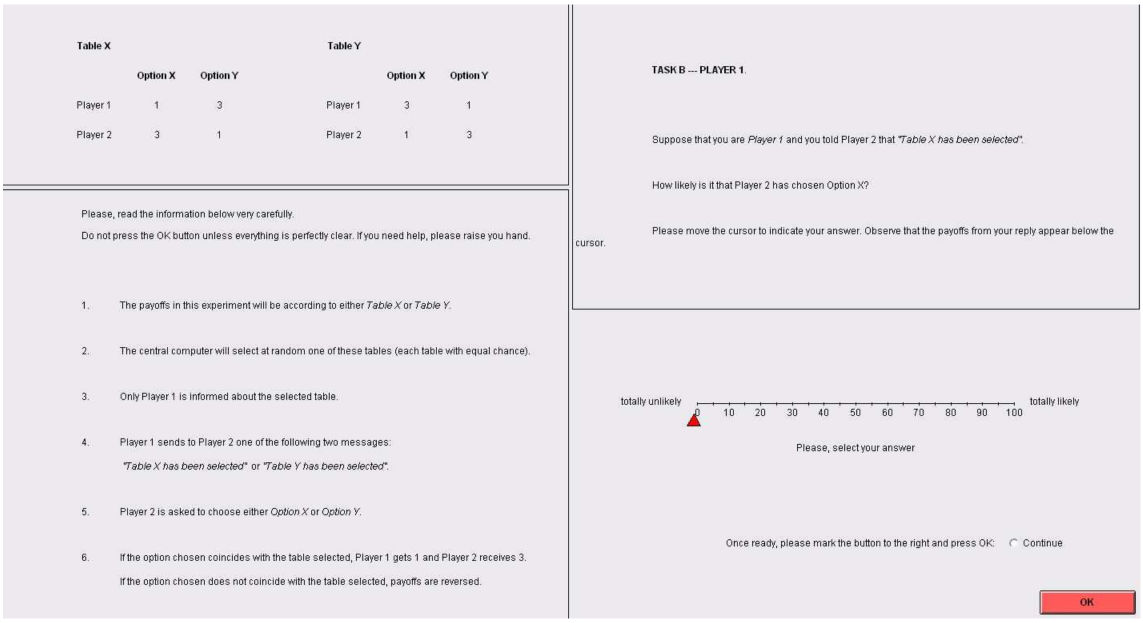

Figure 3: Screen 3 corresponds to Task B for Player 1. Subjects have to state their first-order belief in the role of the sender (the probability that the receiver trusts). As soon as the subject moves the cursor, the payoffs from the resulting decision emerge below the scrollbar. Hence, the subject can revise her/his decision until she/he feels confident about her/his choice.

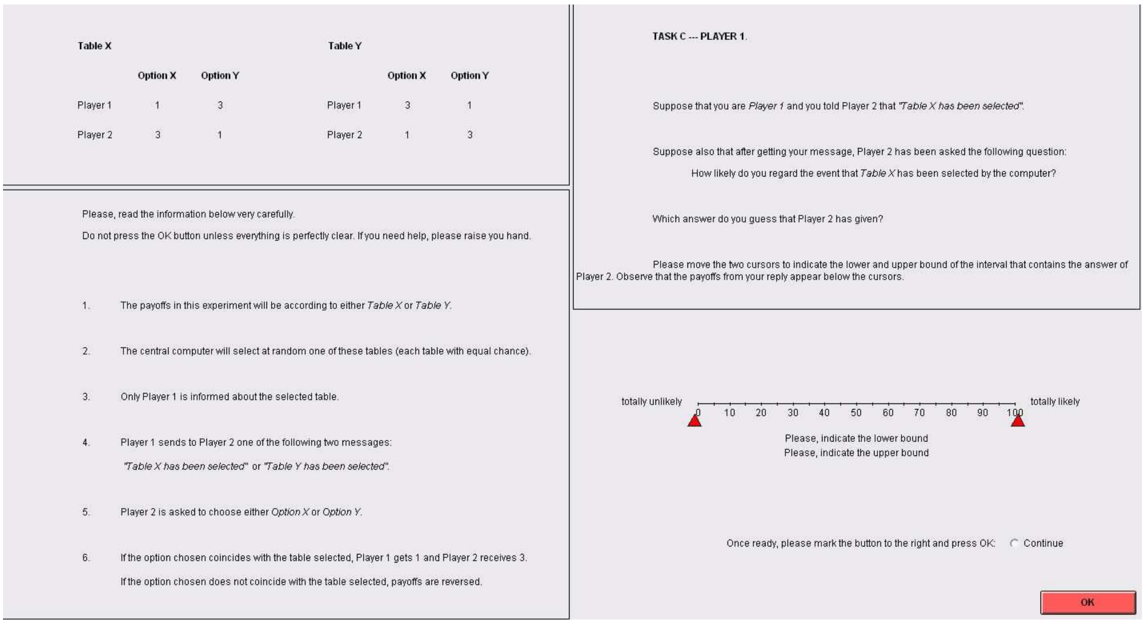

Figure 4: Screen 4 corresponds to Task C for Player 1. Subjects have to state their second-order belief in the role of the sender (the probability that the receiver thinks that the sender's message is truthful). As soon as the subject moves the cursor, the payoffs from the resulting decision emerge below the scrollbar. Hence, the subject can revise her/his decision until she/he feels confident about her/his choice.

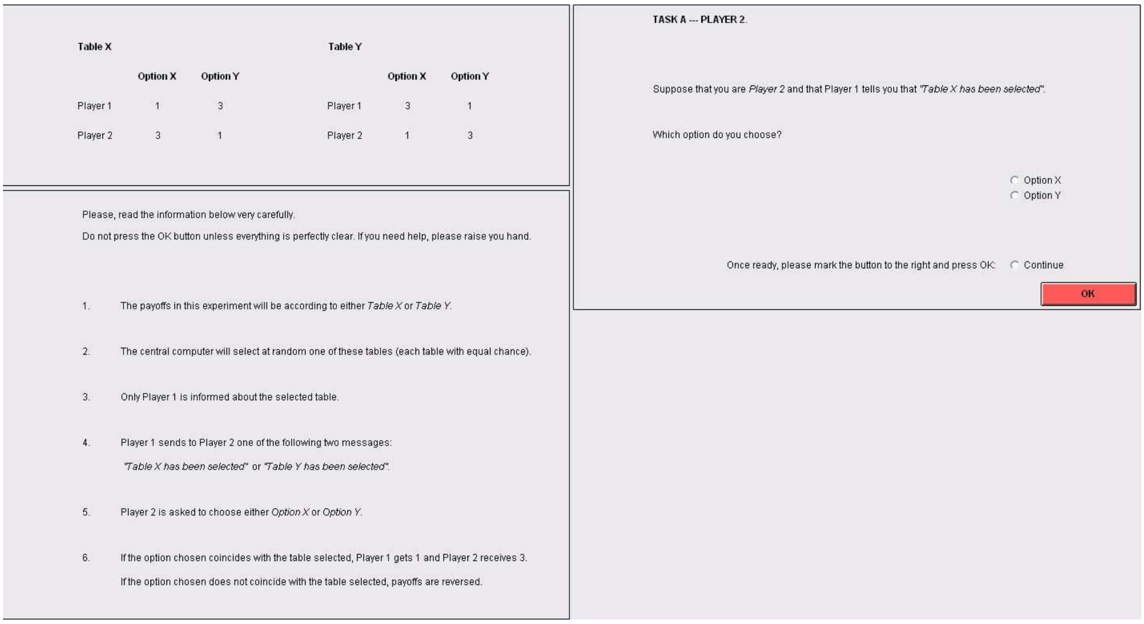

Figure 5: Screen 5 corresponds to Task A for Player 2. Subjects decide whether to trust or distrust the sender's message.

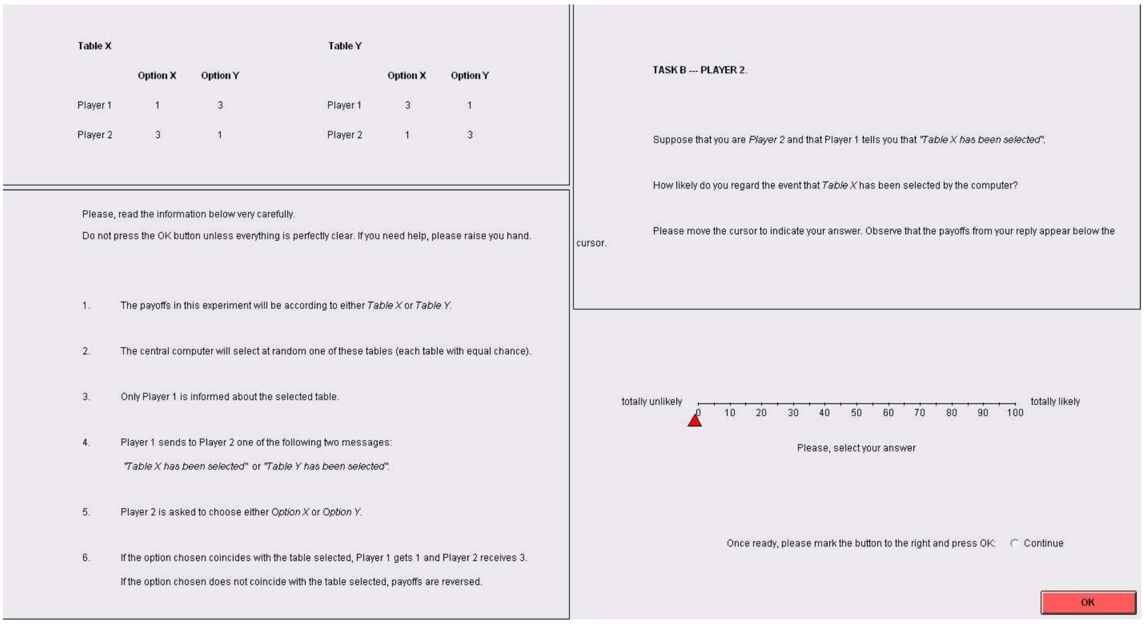

Figure 6: Screen 6 corresponds to Task B for Player 2. Subjects have to state their first-order belief in the role of the receiver (the probability that the sender tells the truth). As soon as the subject moves the cursor, the payoffs from the resulting decision emerge below the scrollbar. Hence, the subject can revise her/his decision until she/he feels confident about her/his choice.

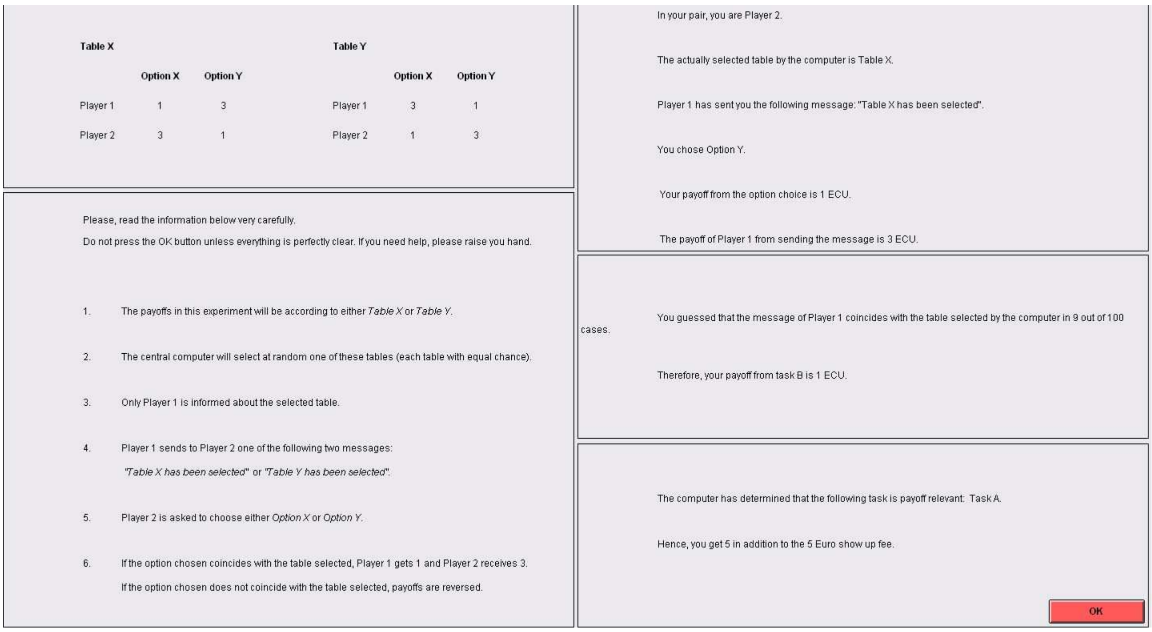

Figure 7: Screen 7 shows the outcome for the receiver. The subjects get 1 ECU from Task A (the sender tells the truth, but she/he distrusts the message). This subject guessed that the sender tells the truth with probability 0.09. Given that her/his match actually tells the truth, the payoff from Task B is 1 ECU. Finally, the computer randomly selected Task A to be payoff relevant for this subject. Consequently, she/he gets a total of 10 Euro.

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Ronald Peeters, Marc Vorsatz, Markus Walzl

Beliefs and truth-telling: A laboratory experiment

Abstract
We conduct a laboratory experiment with a constant-sum sender-receiver game to investigate the impact of individuals' first- and second-order beliefs on truth-telling. While senders are more likely to lie if they expect the receiver to trust their message, they are more likely to tell the truth if they belief the receiver expects them to tell the truth. Our results therefore indicate that second-order beliefs are an important component of the motives for individuals in strategic information transmission.

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