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Communication with Partially Verifiable Information: An Experiment

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COMMUNICATION WITH PARTIALLY VERIFIABLE INFORMATION: AN EXPERIMENT

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Abstract

We use laboratory experiments to study communication games with partially verifiable information. In these games, based on Glazer and Rubinstein (2004, 2006), an informed sender sends a two-dimensional message to a receiver, but only one dimension of the message can be verified. We compare a treatment where the receiver chooses which dimension to verify with one where the sender has this verification control. We find significant differences in outcomes across treatments. Specifically, receivers are more likely to observe senders' best evidence when senders have verification control. However, receivers' payoffs do not differ significantly across treatments, suggesting they are not hurt by delegating verification control. We also show that in both treatments the receiver's best reply to senders' observed behavior is close to the optimal strategy identified by Glazer and Rubinstein.

Keywords: communication, partially verifiable messages, verification control, experiment

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1 INTRODUCTION

We report experiments based on games in which an informed sender wishes to persuade an uninformed receiver to take a certain action, and we ask how the receiver can best protect himself against false claims by the sender. Such situations are commonplace. For example, in a job interview an applicant wishes to persuade an employer to hire them; in a car showroom a salesman wishes to persuade a customer to purchase a car. Also, in such situations the uninformed party is often able to gather some hard evidence to assist making a good decision, e.g. by testing the applicant or test-driving the car, but typically it is infeasible or prohibitively costly to eliminate all asymmetric information. Thus, we focus on games in which the sender's information is only partially verifiable. These games are based on theoretical models of Glazer and Rubinstein (2004, 2006) and we bring experimental evidence to bear on them.

In the games we study the players' interests are aligned in some states of the world but opposed in others. The state of the world is based on the values of two aspects which are known to the sender, but not to the receiver. In our first game the sender sends a message about the two aspects to the receiver, who can then choose one of the aspects to observe before taking an action (we refer to this as the "Receiver Verifies" game). This game is based on the model introduced in Glazer and Rubinstein (2004), who use a mechanism design approach to identify a receiver's optimal strategy assuming that the receiver is able to commit to a strategy. In this optimal commitment strategy the receiver verifies the aspect with the higher announced value and accepts if the observed value is sufficiently high. The game we implement is an extensive-form game in which the receiver cannot commit. Nevertheless, it has a sequential equilibrium where the receiver uses the optimal commitment strategy and attains the optimal payoff of the game with commitment (Glazer and Rubinstein, 2004, section 7). We note that there are many other sequential equilibria giving a lower payoff to the receiver, and no obvious reason why the receiver's preferred equilibrium would be played.

The second game we study differs from the first in that the sender decides which aspect will be observed by the receiver. This "Sender Reveals" game is similar to the model introduced in Glazer and Rubinstein (2006), except that in their model there are no messages and the receiver can commit to a strategy. Using a mechanism design approach, they show that the payoff from the receiver's optimal strategy is the same as in the model where the receiver decides which aspect to verify. Again, our laboratory extensive form game has multiple sequential equilibria including one in which the receiver attains this optimal payoff. This equilibrium has simple and intuitive features: the sender reveals the aspect with the highest value and, realizing this, the receiver best replies.

In summary, each game has multiple equilibria and the maximum equilibrium payoff for the receiver is the same in both games. Thus, equilibrium theory (absent any refinement criteria) does not offer a sharp prediction about which game is better for the receiver. However, the equilibrium supporting the receiver's optimal payoff offers a useful benchmark with which to compare behavior. We refer to this benchmark as the "GR prediction" since it is based on the optimal commitment strategy identified by Glazer and Rubinstein (2004, 2006). Moreover, because the equilibrium supporting the receivers' optimal payoff is particularly simple and intuitive in Sender Reveals, we expect behavior to be close to this equilibrium in Sender Reveals. For Receiver Verifies, we find the corresponding equilibrium less compelling, and hence we hypothesize that observed behavior will be further from the GR prediction. Consequently, we expect the receiver to be better off in Sender Reveals.

One contribution of this paper is the empirical study of behavior in settings based on the Glazer and Rubinstein (2004, 2006) models. As far as we are aware, this is the first experimental study of strategic information transmission in which both cheap talk and hard information are present. Moreover, we compare treatments in which either the receiver or the sender has verification control. As expected, we find fewer deviations from the GR prediction in the Sender Reveals than in the Receiver Verifies treatment. This difference doesn't translate into higher payoffs for the receiver because the pattern of deviations varies across treatments. In Sender Reveals, senders' behavior is very close to the GR prediction, but receivers fail to best respond, resulting in receiver payoffs significantly below the GR prediction. In Receiver Verifies, there are more deviations from the GR prediction, but not all deviations are detrimental to the receiver. The net effect is that the receiver's payoffs are similar in the two treatments.

A broader contribution of our experiment relates to addressing the question of how the receiver can best protect himself against false claims. As we anticipated, in our experiment senders almost always reveal their best evidence, making it optimal for receivers to follow the GR prediction in Sender Reveals type of games. More surprisingly, despite the noisy behavior of the sender in Receiver Verifies, the GR strategy of verifying the strongest claim is close to being optimal for the receiver also in this setting. Overall, we do not find support that one environment is better for the receiver rather than the other, suggesting that the receiver has nothing to lose from delegating verification control. This could explain why certain practices such as letting candidates choose the competence/subject they need to provide evidence for, are common in auditions, job interviews or academic exams.

The rest of the paper is organized as follows. In the next Section we discuss the related literature. In Section 3 we introduce the games and the theoretical predictions. Section 4 presents the experimental design and hypotheses. Section 5 describes the results. Section 6 analyses an alternative parametrization of the game while Section 7 concludes with a discussion.

2 RELATED LITERATURE

Our experiment studies strategic communication in a setting where an informed sender can send messages about private information and these messages are partially verifiable. To this end, our paper stands at the intersection between the cheap talk and the disclosure research agendas.

A substantial experimental literature has examined cheap talk games based on the model of Crawford and Sobel (1982) (see Blume et al., 2017 for a review), and similarly, previous experiments have studied verifiable message (disclosure) games based on the models of Milgrom (1981) and Grossman (1981) (see e.g. Forsythe et al., 1989, 1999; Hagenbach and Perez-Richet, 2018; Jin et al., 2018; King and Wallin, 1991; Li and Schipper, 2018; Penczynski and Zhang, 2017). The game we use differs from a cheap talk game in that messages can be (partially) backed by evidence, and differs from a verifiable message game in that we force partial disclosure (whereas in verifiable message games senders may remain silent or fully reveal their type). This combination has important theoretical implications. For example, the typical theoretical result in verifiable message games is that senders always reveal their type (the unraveling principle). This does not apply to games with partial disclosure such as ours.

Only a few theoretical studies combine elements of cheap talk games and disclosure games. Among these, Lipman and Seppi (1995) examine the role of competition between senders in a model where information is partially verifiable while Forges and Koessler (2005) characterize the equilibrium set of such games when a communication mediator is present. Though these aspects seem useful in increasing the amount of reliable information the receiver can extract from the sender, in this paper we focus solely on 2-person interactions. Carroll and Egorov (2017) provide a theoretical analysis of situations that are similar to those studied in Glazer and Rubinstein (2004). They find that for a specific class of sender payoff functions the receiver can learn the sender's private information fully. The models that we consider in this study do not belong to this class.

Our setup is based on theoretical models introduced by Glazer and Rubinstein (2004, 2006). Glazer and Rubinstein (2004) analyze a situation where a sender is privately informed about a multi-dimensional state of the world and can send a message about this to a receiver.[1] The receiver can then choose a single dimension of the state to observe, and can thus verify part of the message, before taking one of two actions, Accept or Reject. The sender prefers the receiver to accept independent of the state, whereas the receiver's optimal action depends on the state. The authors identify optimal mechanisms from the receiver's point of view, i.e. mechanisms that maximize the receiver's expected payoff, when the receiver can commit. Glazer and Rubinstein (2006) modify this model by removing messages and the receiver's option to verify and instead allowing the sender to reveal truthfully one dimension of the state. They show that the receiver's optimal mechanism in this case yields the same expected payoff to the receiver. Thus, theoretically the receiver does not suffer by losing verification control.

Glazer and Rubinstein (2004, 2006) also discuss the corresponding extensive form games where the receiver cannot commit to a strategy. In both settings they show that the receiver's payoff from the optimal mechanism can still be achieved in a sequential equilibrium of these games. Our study is designed to test the effect of losing verification control on the receiver's payoff in these extensive form games. In the next section we discuss this setup in more detail.

[1] Glazer and Rubinstein (2004) refer to this setting as a persuasion game. This is not to be confused with the more recent concept of Bayesian persuasion games (Kamenica and Gentzkow, 2011). These are sender-receiver games where the sender can commit to a message strategy so as to induce certain receiver beliefs about the true state of the world. In contrast, Glazer and Rubinstein (2004) do not allow sender commitment in the model they study.

3 PARTIALLY VERIFIABLE INFORMATION GAMES

The Receiver Verifies game (henceforth Rv) is based on Glazer and Rubinstein (2004).[2] The sender is dealt 2 cards, one orange and one blue, each taking a value between 1 and 9. Each combination of cards represents a state of the world and is equally likely. The sum of the two cards determines whether the state is good (the sum is at least T) or bad (the sum is lower than T). We focus on the cases where this threshold is equal to 11. After observing the two cards, the sender sends a (possibly untruthful) message reporting the values of the two cards.[3] After observing the message, the receiver chooses a card to observe. Next, upon observing the true value of the selected card, the receiver decides whether to accept or reject. The sender prefers the receiver to accept, irrespective of the state of the world, whereas the receiver would like to accept only when the state is good and reject otherwise. The interests of the two players are aligned if the hand is good and opposed if the hand is bad. More specifically, payoffs are as given in table 1. Note that both types of errors (accepting a bad hand or rejecting a good hand) are equally costly for the receiver.

Table 1: Payoff Matrix (sender's payoff listed first in each cell)

	Receiver accepts	Receiver rejects
Sender has a good hand	(1, 1)	(0, 0)
Sender has a bad hand	(1, 0)	(0, 1)

The Sender Reveals game (henceforth Sr) is based on Glazer and Rubinstein (2006) and differs from the Rv game only in that, after the message is sent, it is the sender who chooses which card is observed by the receiver.[4] For the equilibrium analysis it is convenient to begin with the Sr game.

[2] Our parametrization is taken from the online experiment of Glazer and Rubinstein at http://gametheory.tau.ac.il/exp5/. In their experiment, the receiver is a computerized player playing an undisclosed strategy.

[3] Hence, communication must be precise; the sender cannot leave the message blank or send a vague message (cf. Serra-Garcia et al., 2011).

[4] Glazer and Rubinstein (2006) did not include cheap-talk communication in their model. We have done so in this study to enhance comparability between the experimental treatments and because we are intrinsically interested in the effect of messages on receivers' behavior.

Sequential equilibria of Sr

The Sr game has many sequential equilibria. Among these, the following stands out as particularly compelling because the sender's strategy is simple and intuitive: the sender claims to have a good hand and displays the card with the highest value. The receiver accepts if the reported hand is good and, taking into account that the value observed is the highest of the two, the hand is more likely to be good than bad. In this equilibrium the receiver accepts if the observed value is at least 7 (henceforth 7+).

Note that this equilibrium makes deterministic predictions about outcomes, i.e. which hands are accepted: hands with a high card (7+) are accepted, while hands without a 7+ are rejected. This results in some bad hands (such as (7,1)) being accepted and some good hands (such as (6,5)) being rejected.

Glazer and Rubinstein (2006) show that in an Sr type of game without messages the same outcomes are obtained in the sequential equilibrium that yields the highest expected payoff to the receiver. There, the sender simply reveals his best card and the receiver accepts if this is 7+. Adding messages does not change the set of equilibrium payoffs. Holding the value and color of the observed card constant, if the receiver behaves differently for messages m and m′ then the less favorable message will not be observed on the equilibrium path.[5]

We use this equilibrium as a benchmark for predicting behavior in our experiment. Because it leads to the same outcome as the optimal mechanism in the Glazer and Rubinstein model, we refer to it as the "GR prediction":

GR prediction (Sr). *The sender claims to have a good hand and reveals the higher of the two cards. The receiver accepts if and only if the observed value is 7+ and the reported hand is good.*

There are other equilibria which result in the same outcome. One such equilibrium involves the sender sending a random message and displaying his highest card. The receiver then ignores the message and accepts if and only if the revealed

[5]Communication may be informative in equilibrium (i.e., the receiver's beliefs may be affected by the message) but cannot be persuasive (the receiver's optimal action cannot change as a result of the message); see Lipnowski and Ravid (2017).

card is 7+. There are also equilibria which give rise to different outcomes and a lower payoff for the receiver.[6]

Sequential equilibria of Rv

As in the Sr game there are many equilibria in the Rv game. Among these, there is a family of equilibria that yield the same outcome as the GR prediction in the Sr game: senders who have a 7+ card are accepted, and senders who do not are rejected. In one such equilibrium, the sender truthfully reports good hands that include a 7+ card. If the hand is bad but the highest card is 7+, the sender inflates the lower card in such a way that the reported values for the two cards add up to at least 11 while keeping the highest report truthful (for example, (7,1) may report (7,5)). The receiver checks the highest message and accepts if it is true (and the value is 7+).[7] These equilibria provide a benchmark for Rv:

GR prediction (Rv). *The sender reports good hands truthfully, and reports bad hands as good (while keeping the higher report truthful) if one of the cards is 7+. If the sender reports a bad hand, the receiver rejects. If the sender reports a good hand, the receiver checks the higher of the two messages, and accepts if and only if the observed value coincides with the message and is 7+.*

Because there are many equilibrium strategies that lead to the same outcome, we have not specified complete strategies in the GR prediction. Instead, we focus on features of the strategies that are common to all or most of these equilibria.[8]

There are also many other sequential equilibria that lead to different payoffs, including cases where messages are not informative (babbling) and equilibria that are better for the sender.[9] Glazer and Rubinstein (2004) show that no equilibrium gives the receiver a higher expected payoff than the GR prediction. Note that the GR predictions in Sr and Rv result in exactly the same outcome.

[6]See Appendix A.3 for an equilibrium example that gives the receiver his lowest expected equilibrium payoff.

[7]There are many other equilibrium strategies that lead to the same payoffs. For example, it is not essential that the receiver always checks the highest message. The receiver may check a card at random if both reports are 7+; the sender then takes care not to inflate the lower card above these values if the hand is bad. There are also equilibria where messages are not interpreted literally; for example, there are equilibria where only two (arbitrary) messages are used, and the receiver checks the blue card after one message and the orange card after the other. For our analysis of the experiment we will assume that subjects intend the messages to have a literal meaning.

[8]The coincidence of the observed value with the message is not essential to the equilibrium, but it is explicitly required in the optimal mechanism of Glazer and Rubinstein (2004).

[9]We discuss the babbling equilibrium in Appendix A.2.

GR prediction (focusing on outcomes, Sr and Rv). *Hands with a high card (7+) are accepted, while hands without a high card are rejected.*

How compelling is the GR prediction in Rv? While displaying the highest card in Sr is very natural, it is not obvious that the receiver should always check the highest message, or, having checked the highest message, that he should accept whenever the observed value is 7+.

Suppose the receiver checks the highest message and accepts if the message is true and the value is 7+. Glazer and Rubinstein (2004) show that there exists a best response for the sender which leads to a sequential equilibrium. However, there are other best responses for the sender that do not lead to a sequential equilibrium. That is, the GR family of equilibria require that the sender breaks ties in a specific way.

As an illustration, suppose the message is (7,4). The GR equilibrium requires the receiver to check the first card and accept if it is 7. However, having checked that the 7 is correct does not imply that the receiver should necessarily accept. If the sender only inflates bad hands up to the bare minimum needed to make up a good hand, after receiving message (7,4) and verifying that the 7 is correct, the hand is equally likely to be (7,4), (7,3), (7,2) and (7,1). Only one out of four is a good hand, hence the receiver should reject. In order to have an equilibrium, the sender cannot concentrate the lies on messages that add up exactly to the threshold; one possibility is that (7,3) reports (7,6), (7,2) reports (7,5) and (7,1) reports (7,4).[10]

Another question is whether the receiver should always verify the card with the highest reported value in the first place. If the lowest reported value is more likely to be a lie, it would be optimal for the receiver to check the lowest report instead. For example, if the message (7,4) is sent only by the (7,4) and (7,1) types, the receiver would want to check the 4 since that would ensure discovering the bad hand. The GR equilibrium would require some types (e.g. (1,4)) to send (7,4) as well even though it has no benefit for them.

The GR equilibrium also requires the receiver to reject some good hands, such as (6,6). If (6,6) is the only type that sends message (6,6), then the receiver would know for sure that this is a good hand and should accept instead. In order to obtain the GR equilibrium, one needs to assume that either (6,6) reports one of the

[10]See Appendix A.1 for an example of a message strategy compatible with the GR equilibrium.

cards as 7+ (even though this will be discovered for sure given the strategy of the receiver) or there are bad hands that also report (6,6), so that a report of (6,6) is not unambiguously a good hand. In both cases, there are sender types that are lying even though they have nothing to gain from doing so. A lexicographic preference for telling the truth (i.e., players only lie if they have something to gain) would eliminate this equilibrium.[11]

Following these considerations we view the GR prediction as less compelling in Rv than in Sr and hypothesize that behavior will be closer to predictions in Sr. The next section describes our experiment and formally states the hypotheses it is designed to test.

4 EXPERIMENTAL DESIGN AND HYPOTHESES

The experiment was conducted in the CeDEx laboratory at the University of Nottingham, UK. There were 192 subjects, recruited from a university-wide pool of undergraduate and graduate students using ORSEE (Greiner, 2015). The experiment was programmed in z-Tree (Fischbacher, 2007).

Our experiment varies the game (Sr and Rv) across sessions. 4 sessions of each treatment were conducted with 24 subjects per session, and each session was divided into two matching groups. This gives us 8 independent observations per treatment. 65% of participants in the Sr treatment and 64% in the Rv one were female.

Upon arrival at a session, subjects were randomly allocated a seat number and given a set of instructions, which were then read out loud by the experimenter.[12] The decision-making part of the experiment consisted of 30 rounds, where in each round, subjects were randomly matched to play the relevant game. Subjects were rematched within their matching group at the beginning of each round, but retained the same role (sender or receiver) during the entire session.

At the beginning of each round, each sender is dealt two cards (blue and orange). Each of the cards is equally likely to be any integer value between 1 and 9, and all

[11] A similar refinement has recently been used by Hart et al. (2017).

[12] See Appendix D for a copy of the instructions.

draws are independent across colors and senders.[13] A hand is defined as "good" if the sum of the values of the two cards is at least 11. Having observed the two cards, the sender sends a message to the receiver of the form "The value of the orange card is __; The value of the blue card is __". Next, the receiver chooses one of the cards to observe (Rv treatment) or the sender chooses one of the cards for the receiver to observe (Sr treatment). The receiver then accepts or rejects. The sender earns 1 point if the receiver accepts and 0 if the receiver rejects; the receiver earns 1 point if he accepts a good hand or rejects a bad hand, and 0 otherwise.

At the end of each round, a summary screen displayed the true values of the two cards, the message sent by the sender, the card chosen to be observed (by the receiver or by the sender, depending on treatment), the receiver's decision, and the point-earnings of the two subjects.

At the end of the experiment subjects received their accumulated earnings for the 30 rounds (1 point = £0.50) plus a £3 participation fee. There was a total of 1440 independent draws for each treatment out of which 631 were good hands. Each session lasted around 90 minutes, and average earnings were £12.92.

With this design, we are able to test whether behavior conforms more closely to GR predictions in Sr or Rv. GR predictions are deterministic and identical in both treatments: any given hand will be either accepted or rejected. Hence, we use a hit rate metric to test conformance of behavior with predictions. Specifically, we count how often the receiver's actual decision matches the predicted decision.[14] Given the discussion in the previous section, our first Hypothesis is:

Hypothesis 1. The proportion of GR outcomes is higher in Sr than in Rv.

We can also test whether receiver's payoff is higher in Sr or Rv. Since the GR prediction yields the maximum equilibrium payoff for the receiver, we also hypothesize:

Hypothesis 2. The receiver achieves a higher average payoff in Sr than in Rv.

[13]For the Rv treatment the card draws were randomized using the random number generator during the session. To enhance comparability across games, we then used these realizations in the corresponding sessions of the Sr treatment. This allows us to perform the statistical comparisons on paired observations.

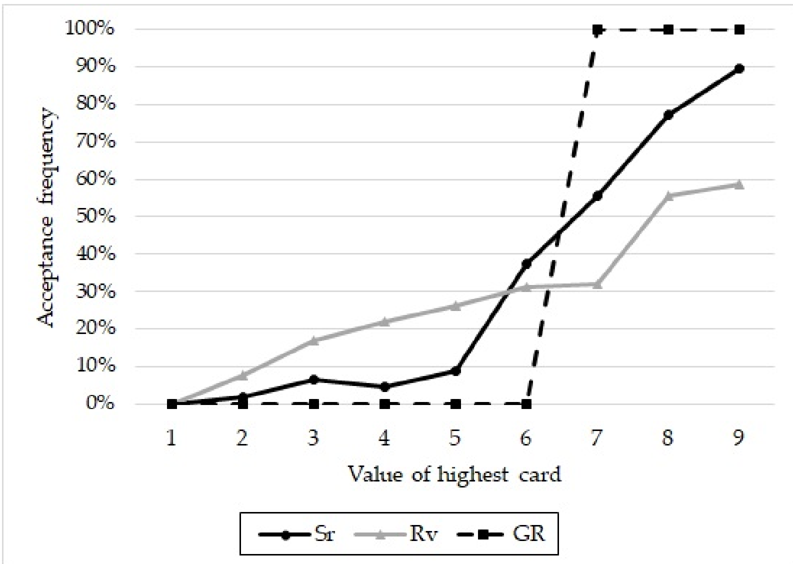
[14]This metric has the advantage of summarizing the closeness to the prediction by a single number. A disadvantage is that it potentially overestimates the compliance with equilibrium predictions, since an equilibrium outcome may arise from non-equilibrium strategies. We discuss the closeness of the strategies to equilibrium predictions as well.

5 RESULTS

5.1 *Main findings*

The prediction is for a hand to be accepted if and only if it contains a 7+. Figure 1 reports the observed acceptance frequencies conditional on the value of the higher of the two cards, for good hands and bad hands separately. The dashed lines represent the GR prediction.

(a) Bad hands



(b) Good hands

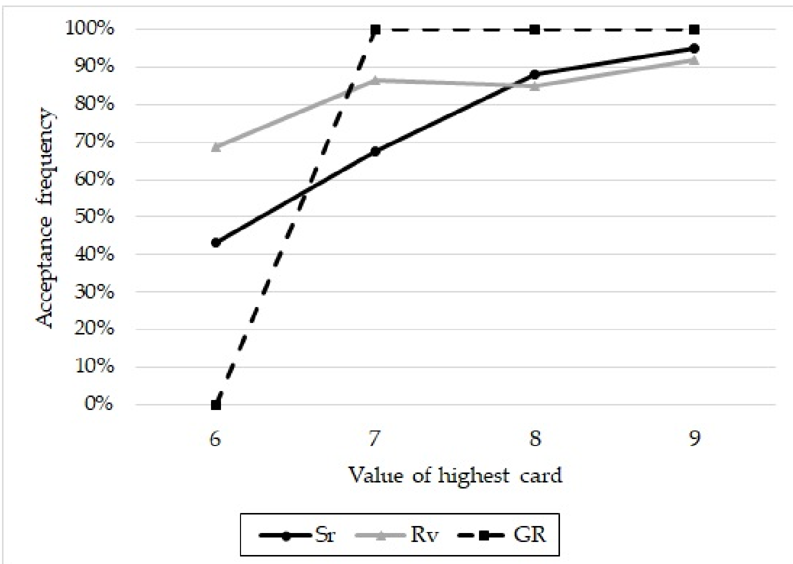


Figure 1: Acceptance frequencies for a given value of the highest card

Looking at figure 1, it is clear that there are deviations from the GR prediction in both treatments. However, outcomes are usually closer to the GR prediction in Sr, the only exceptions being bad hands where the highest card is 6 and good hands where the highest card is 7.

Table 2 presents the acceptance frequencies conditioning on the type of hand (good or bad) and on whether this is predicted to be accepted or rejected in the GR equilibrium. The table confirms that Sr is significantly closer to the GR prediction than Rv: hands that should be rejected (highest card < 7) are more likely to be rejected in Sr than in Rv and this is true for both good and bad hands. Regarding hands that should be accepted (highest card ≥ 7), Sr is closer to the prediction for bad hands, and there is no significant difference for good hands.[15]

Table 2: Aggregate acceptance frequencies for good and bad hands

Type of hand		Freq. GR	Freq. Sr	Freq. Rv	count	p-value
Bad hands	Highest card < 7	0.000	0.139	0.228	591	0.039
	Highest card ≥ 7	1.000	0.679	0.440	218	0.039
	All bad hands	0.270	0.284	0.286	809	1.000
Good hands	Highest card < 7	0.000	0.431	0.686	51	0.016
	Highest card ≥ 7	1.000	0.869	0.885	580	0.468
	All good hands	0.919	0.834	0.869	631	0.250

Note: Counts are for each treatment. P-values refer to the comparison between the Sr and Rv frequencies.

Turning to our hypotheses, we first look at hit rates, our overall measure of conformance with GR outcomes. We find that the GR equilibrium predicts the outcome of 82.64% of interactions in Sr and 75.07% of interactions in Rv ($p - value =$ 0.008). Our results thus confirm Hypothesis 1.

Result 1 *The proportion of GR outcomes is higher in Sr than in Rv.*

Next we consider Hypothesis 2, which compares the receiver's payoffs across treatments. Note that the receiver's average payoff from good hands is the acceptance frequency for those hands; his average payoff from bad hands is one minus the acceptance frequency for those hands. Table 2 suggests no significant payoff difference, since the overall acceptance frequencies for bad hands are very similar

[15]Recall that our design allows us to perform statistical comparisons on paired observations. Unless otherwise specified, all statistical tests are two-tailed signed-rank tests at the 5% significance level and taking the matching group as the unit of observation.

for the two treatments and likewise for good hands. Formal testing confirms this (see table 3). Also note that the sender's average payoff is simply the acceptance frequency and, incidentally, it does not differ significantly across treatments either.

Table 3: Average payoffs

	Sr	Rv	GR	Sr vs. Rv (p-value)	Rv vs. GR (p-value)	Sr vs. GR (p-value)
Receiver	0.767	0.782	0.813	0.641	0.187	0.008
Sender	0.525	0.541	0.554	0.468	0.328	0.203

Result 2 *The receiver's average payoffs do not differ significantly between treatments.*

We find a difference between treatments when comparing players' average payoffs in each treatment with the corresponding GR prediction. Namely, the receiver's average payoff in Sr is significantly below the prediction while in Rv there is no significant difference (see table 3). This is due to a difference in payoff variability across treatments: receiver's average payoff in Sr is consistently lower than the prediction across all matching groups while in Rv it is sometimes lower and sometimes higher.[16] In the following section, we analyze in more detail the differences in behavior between treatments.

5.2 *Strategy analysis*

5.2.1 *Senders' reporting strategy*

Figure 2 presents the distribution of the realized and the reported hands. The middle panel (b) contains the distribution of the values observed by senders. Recall that the random draws are identical across treatments. There are 1,440 random hands in each of the treatments.

As each combination of values was equally likely, the distribution of the realized draws is approximately uniform. Panel (a) presents the distribution of the values reported by senders in the Sr treatment; panel (c) presents the distribution of reports in the Rv treatment.

[16] See Appendix B for the observed and predicted average payoffs per matching group across treatments.

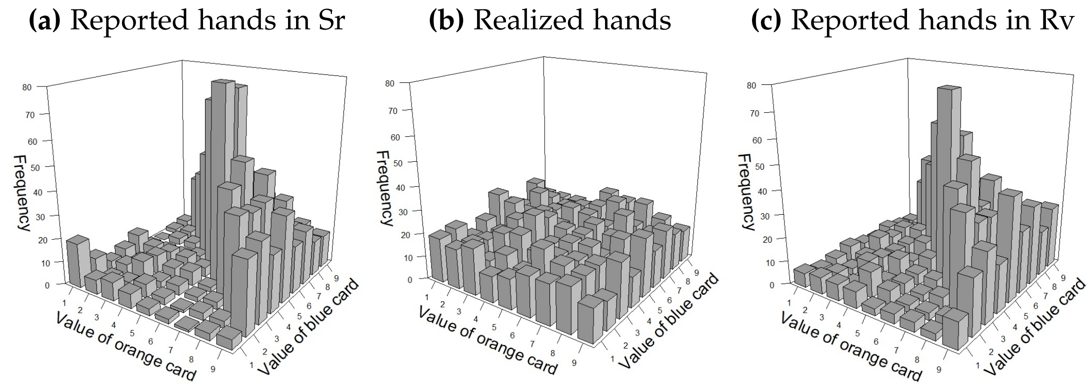


Figure 2: Distribution of realized vs. reported hands in Sr and Rv

Result 3 *Senders inflate bad hands in their reports in both treatments.*

If senders were always truthful, there would be no difference between the realized and the reported distributions. Instead, looking at the (a) and (c) panels we observe a shift in the distribution of reported values towards the area where these add up to at least 11. We also note that very few subjects can be characterized as truth-tellers (never misreporting). Out of 48 senders per treatment, we observed only 2 truth-tellers in the Rv treatment and 1 in the Sr treatment.[17]

Table 4 confirms that the majority of bad hands are misreported in both treatments: around 80% of bad hands are misreported (nearly always as good hands). A small proportion of good hands are misreported as well (nearly always as good hands, and usually inflated).

Table 4: Proportion of misreported hands

	Sr	Rv	p-value
Overall	0.517	0.490	0.461
Good Hands	0.152	0.082	0.016
Bad Hands	0.801	0.807	0.813

Even though the overall frequency of misreports is similar for bad hands in Sr and Rv, there are some differences in how these reports are distributed and in the type of misreports used across treatments. Focusing on bad hands, figure 3 presents the frequency with which the sender reports a good hand for each possible value of the highest of the two cards.

[17] Thus, our setting does not induce a very strong norm of honesty (cf. Abeler et al. (2016)). We conjecture that this is due to the conflict of interests which has been shown to crowd out lying aversion (Cabrales et al., 2016; Minozzi and Woon, 2013).

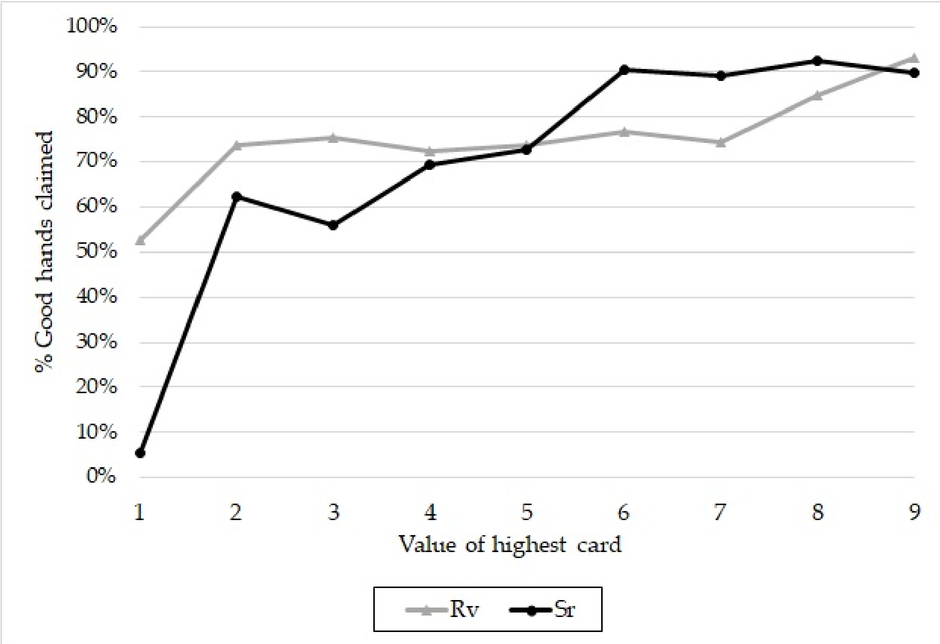


Figure 3: Proportion of bad hands reported as good hands

This proportion is relatively flat in Rv, where either of the two messages can be checked, but tends to increase with the value of the highest card in Sr.[18] The proportion of senders who own up to having a bad hand is similar in both treatments, but such reports tend to be more useful for the receiver in Rv (in Sr they are more concentrated on hands where both cards are very low and the receiver would be very likely to guess a bad hand from the observed card alone).

Recall that, from the point of view of the GR theoretical prediction, there are two types of bad hands: hands that contain one high card (7+) and hands that do not. The first ones are predicted to always be accepted (after the receiver observes the highest of the two cards), while the latter ones are predicted to always be rejected (irrespective of which card the receiver observes). The theoretical prediction is more precise for bad hands that involve one high card. For Rv, it is expected that the sender reports a good hand by inflating the value of the lower card only, while keeping it below the value of the higher card. For example, a sender with cards

[18]The plausibility of a lie in Sr depends heavily on the value of the highest of the two cards. For example, a sender with cards (4,2) would have to display the 4 and report the non-displayed card to be at least 7 (or, worse, display the 2 and report the other card to be 9), while a sender with cards (1,7) can display the 7 and report the other card to be at least 4. Intuitively, receivers should be skeptical in the first case (since the sender claims to be displaying the lower of the two cards) but not necessarily in the second. In contrast, in Rv, both (4,2) and (1,7) could send message (4,7), and the lie may potentially be discovered or go unnoticed in each case depending on the card checked by the receiver (under the GR prediction the receiver would always check the 7, but not all receivers behave this way).

(7,2) may report (7,5) but not (9,2) or (7,8) in a GR equilibrium. The latter reports would result in the hand being rejected if the receiver checks the higher message as predicted. For Sr, we would expect a similar messaging behavior to occur in the experiment. Specifically, a reported bad hand is expected to be interpreted as such and thus rejected. Moreover, senders should report truthfully the higher card while inflating the lower card not above the revealed value. Coming back to the example of a sender with a (7,2) hand, if the report is (9,2) or (7,8) then irrespective of the revealed card we would expect the receiver to reject. This is because the sender is either lying about the displayed card or claiming that his other card is higher than the one revealed.

Table 5: Frequencies of different types of reports (bad hands with one high card)

	Sr	Rv
Both messages are true	7%	17%
Only lower message is a misreport	79%	61%
Other misreports	14%	22%

From table 5 we note that overall, for bad hands that would be accepted in equilibrium, the proportion of senders that comply with the theoretical prediction is low in Rv: 61% of senders report a good hand while keeping the highest of the two reports truthful, compared with 79% in Sr. This difference is significant ($p - value = 0.031$). The counterpart result is that senders in Rv are more truthful than in Sr or misreport both values more often, actions that unequivocally help the receiver.

Result 4 *In Rv, the sender deviates from the GR prediction in ways that may help the receiver to reject bad hands. The analogous behavior in Sr is less frequent.*

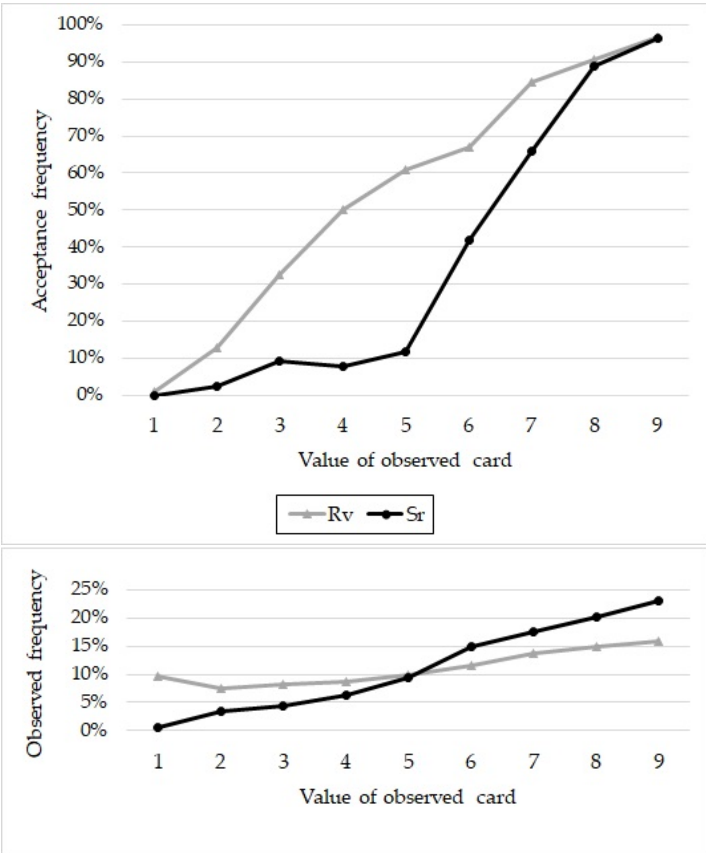
5.2.2 *Verification/revelation strategy*

When the sender reports a bad hand, the verification strategy is immaterial since the sender is almost certainly telling the truth (indeed, more than 98% of all reported bad hands are actually bad hands in both treatments). In what follows we focus on cases where the sender reports a good hand. As we conjectured, senders nearly always reveal the higher of the two cards in Sr: 96.23% overall. In Rv, receivers check the higher of the two reports only in 64.86% of the cases. This difference is significant ($p - value = 0.008$).[19] Clearly, revealing the higher card is a more compelling strategy for senders than verifying the higher report is for receivers.

Result 5 *Senders reveal the higher of the two cards significantly more often than receivers check the higher of the two reports.*

5.2.3 *Receivers' decision strategy*

When the sender reports a bad hand, the receiver nearly always rejects (over 96% of cases in both treatments). Focusing on cases where a good hand is reported, figure 4 presents the acceptance frequency conditional on the value observed by the receiver. The lower graph depicts how often each value was observed by receivers.



Note: 1245 counts for Sr; 1242 counts for Rv

Figure 4: Acceptance frequencies conditional on the value of the verified card and corresponding observed frequencies of each value (reported good hands only)

[19] The overall frequencies increase slightly (to 97.43% and 67.51% respectively) if we restrict ourselves to cases in which only one card or only one message is at least 7, but the general conclusion is unaffected. Those are the cases where the GR prediction is strict, since the receiver is predicted to accept cards with values of at least 7 and reject lower cards.

Comparing the Rv acceptance patterns with the Sr ones we see that the acceptance frequencies are greater in Rv than in Sr.[20] This is consistent with receivers in Sr holding more skeptical beliefs regarding the probability of a good hand than in Rv. Accordingly, we formulate the following result:

Result 6 *Receivers act more skeptically in the Sr treatment than in the Rv one.*

Even though the same random draws are used for both treatments, some differences in the distributions of the observed values (lower graph in figure 4) arise from different behavior across treatments. Specifically, due to differences in the revelation/verification strategy, the observed card in Sr is almost certain to be the highest of the two, while this is not the case in Rv. Consequently, the distribution of observed cards in Sr is very similar to the distribution of the maximum value out of the two cards, while the distribution in Rv is comparatively flat. The lower skepticism in Rv is thus partially justified: for a given value of the observed card, the hand is more likely to be good in Rv than in Sr.

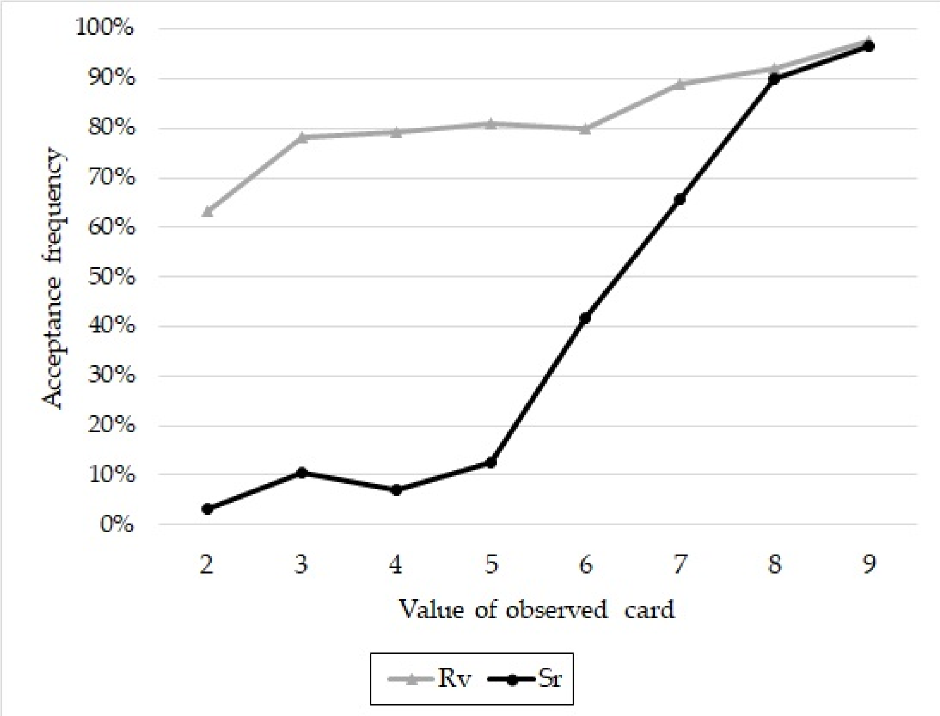
Note however that the overall acceptance rates conditional on the sender claiming to have a good hand are very similar: 60% in Sr versus 62% in Rv. While the receiver is more likely to accept for a fixed value of the observed card in Rv, he is also more likely to observe lower cards in Rv (and lower cards are less likely to be accepted). Overall, the lower skepticism in Rv has no significant effect on the acceptance probability.

Result 7 *Even though receivers are more lenient in Rv conditional on the value observed, they are also more likely to observe lower values as a result of the verification strategy. As a result, overall acceptance frequencies (and hence sender's payoffs) do not differ between treatments.*

Note also that figure 4 does not take into account how the message compares with the observed card. This information makes little difference in Sr, since senders hardly ever misreport the card they reveal (less than 4% of reported good hands involve misreporting the revealed card). It does make a difference in Rv, where in 30% of cases a misreport is observed. Receivers typically reject when observing a

[20] For some of the observed values the counts are too low to allow for meaningful testing (counts for low observed numbers in Sr are generally small). For each of the middle values 4-5-6-7, the difference is significant.

misreport (only 5% accept in Rv, 7% in Sr). This is optimal since only about 10% of such hands are actually good hands. As figure 5 shows, the receiver is very likely to accept in Rv if he finds no reason to the contrary.



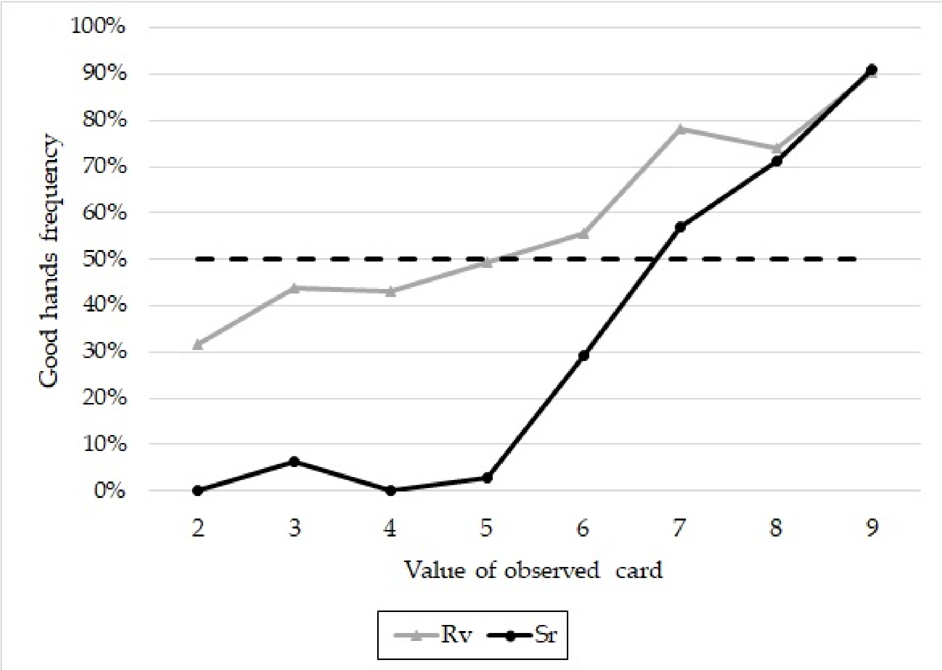
Note: 1199 counts for Sr; 862 counts for Rv

Figure 5: Acceptance frequencies when a good hand is reported and no misreport is observed

This behavior is not as costly as one may think since a) some bad hands have been weeded out when a misreport is discovered (the sender's messaging behavior facilitates this) and b) the receiver's verification strategy implies that the card observed is not always the higher of the two. This is confirmed by looking at the frequency of good hands when a good hand is reported and no misreport is observed, as shown in figure 6 (the figure includes a dotted line at 50% - above this line, it is optimal on average to accept, while below this line it is optimal on average to reject).

On average, in Sr it is optimal for the receiver to accept after observing a 7+, just as in the theoretical prediction (figure 6); however, the receiver's actual acceptance behavior is noisy around values 6-7 (see figure 5).[21] In Rv however, given that

[21]Figures 5 and 6 do not include information on the correlation between good hands and accepted hands for a given observed value. In principle, if the message sent by the sender is (unwittingly) informative (for example, by always inflating bad hands up to the bare minimum) it would be possible for the receiver to "see through the message" and use the message to improve the accuracy of the acceptance decision. The data suggest that this was not the case: conditional on a good hand being reported and holding the value observed constant, acceptance frequencies of good hands and



Note: 1199 counts for Sr; 862 counts for Rv

Figure 6: Frequency of good hands given that a good hand was claimed and no misreport was observed

the receiver sometimes checks the lower message and given that misreports are sometimes discovered and eliminated from the sample in the figure, the probability of a good hand remains close to 0.5 even for values as low as 3, such that the cost of an acceptance decision is small in terms of payoffs. Hence, even though the receiver is still too lenient for low observed values in Rv, this doesn't hurt the receiver too much (recall also that more misreports are detected in Rv, and the receiver is doing well for those hands, which are not included in figures 5 and 6). The figures give us some pointers on why average payoffs do not differ between treatments despite the differences in behavior.

Result 8 *Receiver's acceptance strategy is noisy in Sr. In Rv, the receiver rejects too seldom when no misreport is discovered. However, this leniency is not very costly given other deviations by both the sender (reporting strategy, which makes it easier for the receiver to reject bad hands) and the receiver (verification strategy).*

bad hands are not significantly different. Hence, the noisy acceptance behavior corresponds, on average, to mistakes by the receiver.

5.3 *How can the receiver best protect himself?*

We answer this question by identifying the optimal strategy for the receiver given the sender's behavior in each game (Sr or Rv). In doing so, in Rv we allow the verification decision to depend on the exact message, and we allow the acceptance decision to depend on the message and whether the verified card was equal to the claim or misreported. For Sr, we allow the receiver to condition his strategy on the observed value and the value of the unverified claim. [22]

5.3.1 *Receiver verifies*

Given the actual sender behavior in the Rv experiment, should the receiver check the card corresponding to the highest or to the lowest message? Moreover, should he pay attention to the unverified report? Lastly, which values should the receiver accept?

First, if the sender reports a bad hand, the hand is almost certainly bad (only 1 out of 198 reported bad hands is good). In this case, it is optimal to reject independent of which card is checked and whether the check reveals a truthful claim or a lie.

What about the hands that are reported as good? In table 6 we present the payoffs corresponding to each checking and acceptance decision for all messages representing reported good hands. We see that checking the highest report and accepting if this is true is the better choice for most messages since it leads to a higher expected payoff. Why is it better for the receiver to accept only if the checked report turns out to be true? This is because the vast majority of discovered misreports (i.e. 89.76%) represent bad hands.

[22] The observed value is different from the claimed one only in 4.86% of cases and 91.43% of these are hands that would be rejected anyway by the strategies that we will consider.

Table 6: Calculating the best response to the empirical distribution for Rv (claimed good hands)

Message	Absolute frequency of message	Absolute frequency of good hands given message	Expected payoff from: check highest report & accept if true[23]	Expected payoff from: check lowest report & accept if true[24]	Expected payoff from: check either report & always reject[25]	Expected payoff from: check either report & always accept[26]
(9,9)	55	32	0.773	0.773	0.418	0.582
(9,8)	40	35	0.900	0.900	0.125	0.875
(9,7)	45	38	0.978	0.933	0.156	0.844
(9,6)	36	34	0.972	0.944	0.056	0.944
(9,5)	55	45	0.909	0.945	0.182	0.818
(9,4)	29	24	0.966	0.862	0.172	0.828
(9,3)	55	35	0.800	0.836	0.364	0.636
(9,2)	73	23	0.932	0.438	0.685	0.315
(8,8)	31	22	0.726	0.726	0.290	0.710
(8,7)	40	29	0.850	0.850	0.275	0.725
(8,6)	51	40	0.941	0.843	0.216	0.784
(8,5)	52	37	0.885	0.827	0.288	0.712
(8,4)	69	27	0.739	0.681	0.609	0.391
(8,3)	117	32	0.786	0.496	0.726	0.274
(7,7)	47	24	0.872	0.872	0.489	0.511
(7,6)	41	31	0.902	0.927	0.244	0.756
(7,5)	81	30	0.691	0.704	0.630	0.370
(7,4)	129	38	0.798	0.527	0.705	0.295
(6,6)	56	25	0.696	0.696	0.554	0.446
(6,5)	140	30	0.586	0.621	0.786	0.214

Note: Highlighted cells represent receiver's optimal payoff for a given message.

[23] Computed by counting the instances in which the highest report is untrue and the hand is bad and those where the highest report is true and the hand is good. This is then divided by the frequency of the corresponding message.

[24] Computed by counting the instances in which the lowest report is untrue and the hand is bad and those where the lowest report is true and the hand is good. This is then divided by the frequency of the corresponding message.

[25] Computed by counting the number of bad hands and then dividing by the frequency of the corresponding message.

[26] Computed by counting the number of good hands and then dividing by the frequency of the corresponding message.

Next, the receiver should check the highest report as this report is more likely to be false. Since a misreport is very often a bad hand, checking the highest report allows the receiver to take as many bad hands out of the sample as possible by rejecting. This also increases the probability that the hand is good conditional on the message being true and reduces the number of errors in case of acceptance. In cases where this probability is less than 50% for both messages, it is optimal to reject all hands and which message is checked is immaterial. This is the case of the (6,5) message when the receiver is better off rejecting even if the observed value is as reported. The receiver's expected payoff from always choosing optimally conditional on the observed message is 0.854. Given the sender's strategy, following the GR prediction gives the receiver an expected payoff of 0.844. Therefore, we formulate the following result:

Result 9 *Following the GR prediction gives the receiver 98.83% of his optimal expected payoff given the sender's actual behavior in Rv.*

5.3.2 *Sender reveals*

In the Sender reveals game, the receiver has only an acceptance decision to make. The information available to the receiver when making this decision consists of the revealed value and the sender's message. Given senders' behavior, how should the receiver use this information optimally? Table 7 presents the proportion of good hands conditional on the revealed value and on the value of the unobserved claim. If this proportion is greater than 50%, it is optimal for the receiver to accept. When the proportion of good hands is equal to 50%, any decision is a best response. The revealed value is almost always equal to its corresponding report (95.14% of the time). Therefore, we analyze the optimal decision without differentiating between cases based on whether an untruthful claim was revealed.[27]

From table 7 we notice that when the revealed value and the unverified report add up to less than 11 it is always best for the receiver to reject. When the sum is at least 11, the optimal decision is very often in line with the GR prediction: accept hands that show a 7+ card and reject otherwise. The cases where it is optimal to accept are highlighted in the table, while in the rest of cases it is optimal to

[27]The conclusions from this analysis are unaffected by this approach. This is because the optimal decision in 95.71% of the cases where a misreport was revealed is identical to the one in which we do not condition on whether a misreport was observed.

reject. The optimal strategy given the senders' behavior for each combination of revealed values and unobserved claims gives the receiver an expected payoff of 0.827. Best response and GR strategy give a different payoff only in two cases: when the revealed value is 7 and the unobserved claim is 4 or 5 and even in these cases the difference is very small.

Table 7: Proportion of good hands given revealed value and unobserved claim

	Revealed Value								
Unobserved Claim	1	2	3	4	5	6	7	8	9
1	0%	0%	0%	0%	11%	0%	50%	33 %	0%
2	0%	0%	0%	0%	0%	0%	0%	0%	78%
3	0%	0%	0%	0%	0%	0%	0%	55%	88%
4	0%	0%	0%	0%	0%	0%	49%	52%	75%
5	0%	0%	0%	0%	0%	27%	43%	74%	89%
6	0%	NA	0%	0%	0%	32%	74%	86%	98%
7	0%	0%	0%	0%	4%	50%	63%	88%	100%
8	NA	0%	10%	0%	10%	20%	67%	75%	100%
9	0%	3%	0%	0%	0%	0%	50%	100%	100%

Note: Highlighted cells represent the cases where it is optimal for the receiver to accept.

Following the GR prediction and rejecting all claimed bad hands while accepting the good ones conditional on observing a 7+ card, gives an average payoff to the receiver equal to 0.822. The next result follows from this analysis:

Result 10 *Following the GR prediction gives the receiver 99.40% of his optimal expected payoff given the sender's actual behavior in Sr.*

Finally, the receiver could also ignore the messages. In this case it would still be optimal to accept only upon observing a 7+ card. As a result, the receiver's expected payoff from this strategy would be 0.803 which is close to but lower than if he would follow the GR prediction.

6 A DIFFERENT PARAMETRIZATION

To examine the robustness of these results to the parametrization, we also conducted sessions of the same two games but with a different threshold (T) defining good hands. In this implementation of the Sr and Rv games the two cards have to add up to at least 9 to represent a good hand. We used the same experimental design and procedures. There were 180 subjects in total (66% of subjects in Rv were female while in Sr this percentage was 65%). One session in the Rv treatment had 20 instead of 24 subjects. The corresponding session in Sr as well as one other also had only 20 subjects. In the following analysis, for the sessions in which the Rv treatment had more subjects than the Sr one, we drop the equivalent extra observations in Rv to maintain comparability between the underlying draws. The main analysis is therefore performed on 8 independent observations, but now 4 of them comprise of 10 individuals rather than 12.

In this section, we present the main results regarding our two hypotheses using the data from these additional treatments. Recall that our two main hypotheses are that outcomes are closer to GR predictions in Sr than in Rv and that consequently, payoffs are higher in the former than in the latter. We begin the analysis of the T=9 treatments, by looking at the receivers' acceptance strategy (figure 7 and table 9).

We observe a similar pattern as in T=11: receivers' acceptance strategy is closer to GR predictions in Sr than in Rv since they reject more low-valued hands (highest card < 6) and accept more high valued ones (highest card ≥ 6). The difference is less marked than in T=11 though and this is reflected also by the hit rate analysis: 84.01% of outcomes are predicted by the GR equilibrium in Rv and 85.76% in Sr. This difference is not statistically significant ($p - value = 0.172$).

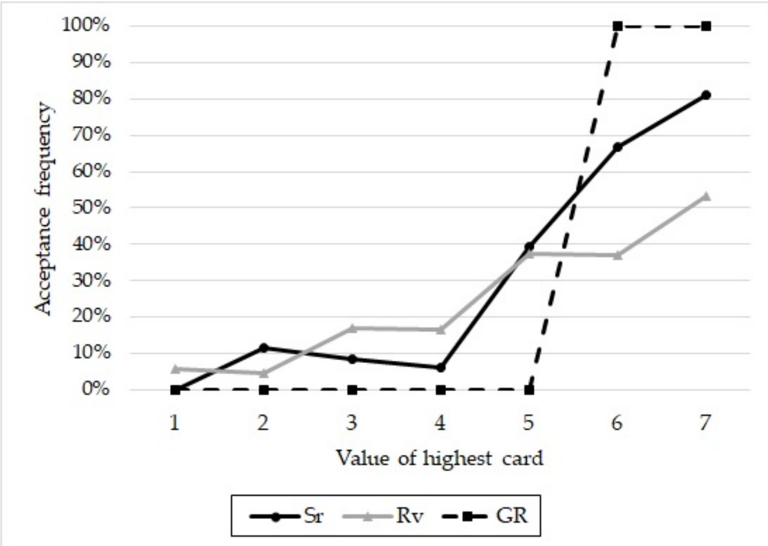
As in T=11 payoffs in Sr and Rv are not significantly different at the 5% level (see table 8). Moreover, we note that also in this parametrization the receiver's average payoff is significantly below the GR prediction in Sr, while in Rv there is no significant difference.

Table 8: Average payoffs when T=9

	Sr	Rv	GR	Sr vs. Rv (p-value)	Rv vs. GR (p-value)	Sr vs. GR (p-value)
Receiver	0.830	0.872	0.891	0.086	0.172	0.008
Sender	0.678	0.701	0.680	0.266	0.125	1

With regard to specific strategies, the results from the T=9 treatments are consistent with those from the T=11 treatments. First, we note that senders' reporting strategies are in line with Result 4. For bad hands that would be accepted in equilibrium, senders in Sr report a good hand while keeping the highest of the two reports

(a) Bad hands



(b) Good hands

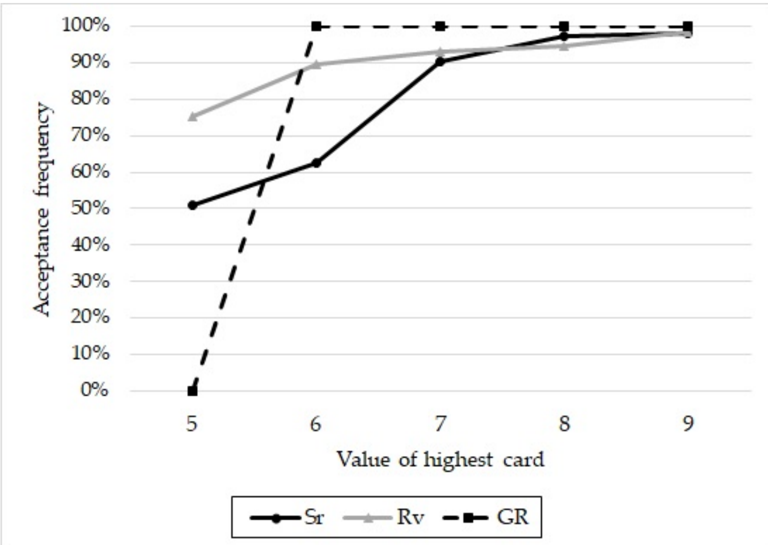


Figure 7: Acceptance frequencies for a given value of the highest card (T=9)

Table 9: Aggregate acceptance frequencies for good and bad hands (T=9)

Type of hand		Freq. GR	Freq. Sr	Freq. Rv	count	p-value
Bad hands	Highest card < 6	0.000	0.173	0.211	365	0.156
	Highest card ≥ 6	1.000	0.721	0.430	86	0.031
	All bad hands	0.191	0.277	0.253	451	0.438
Good hands	Highest card < 6	0.000	0.509	0.754	57	0.031
	Highest card ≥ 6	1.000	0.911	0.948	812	0.234
	All good hands	0.934	0.885	0.936	869	0.055

Note: Counts are for each treatment. P-values refer to the comparison between the Sr and Rv frequencies.

truthful in 85% of the cases, while in Rv this happens only in 53% of cases which is a significantly lower percentage ($p - value = 0.016$). Moreover, consistent with Result 5, senders reveal the higher card systematically more often in Sr (98.56%) than receivers verify the higher report in Rv (82.64%). The difference in the corresponding frequencies is statistically significant ($p - value < 0.001$). Next, for any given verified/revealed value receivers are more skeptical in Sr than in Rv, in line with Result 6. As in the T=11 treatment, due to differences in the verification/revelation strategy, the overall acceptance frequencies of reported good hands (77.59% for Rv and 75.38% for Sr) do not differ significantly between Rv and Sr.

Finally, the GR prediction in the treatments where T=9 gives the receiver an average payoff very close to the optimal one given the senders' behavior. Specifically, following the GR prediction attains more than 99% of receiver's optimal ex post average payoff both in Rv and in Sr. [28]

In summary, when T=9 we find a pattern of results very similar to the case where T=11. Senders' behavior is closer to GR predictions in Sr rather than Rv while receivers are less skeptical in Rv than in Sr for a given observed value. This, however, does not decrease players' average payoffs because in Rv senders deviate in ways that reward a more lenient response from receivers. Nonetheless, the GR strategy is very close to optimal under these parameters as well.

7 CONCLUSION

We have studied games of strategic information transmission between a sender and a receiver in which cheap talk claims are partially backed by evidence. Such games reflect many naturalistic environments like buyer-seller interactions where the buyer is exposed to advertisements or listens to a sales pitch but can also test the products (e.g. downloading samples of software or test-driving cars). Other situations involve policy makers that are pressured by self-interested lobbyists to implement certain legislation but who can also acquire (limited) facts regarding the lobbyists' claims. These situations have been studied extensively in the theoretical literature but have received little attention from experimental research so far.

[28] See Appendix C for the details regarding the receiver's optimal average payoff given the empirical distribution in T=9.

We focused on two settings based on two theoretical models of Glazer and Rubinstein (2004, 2006). These differ in the amount of control the receiver has over the available evidence. In one setting (Rv) the receiver can choose which cheap talk claim to verify, while in the other (Sr) the sender has this choice. We argue that there is a compelling equilibrium prediction for the Sr game in which the receiver achieves his highest equilibrium payoff. Although in Rv there is an equilibrium which gives the same payoff to the receiver, this equilibrium is less compelling. Hence, we expected behavior and outcomes to be closer to the receiver's preferred equilibrium in Sr than in Rv.

We observe some significant differences across games. Specifically, the sender's message strategy is further from the GR predictions in Rv than in Sr and these deviations are advantageous for the receiver. Also, the receiver is less skeptical in the Rv treatment than in the Sr one. This latter finding is consistent with the idea that having more control reduces skepticism: Penczynski and Zhang (2017) find that when buyers can choose the seller to buy from (competition setting) they are less skeptical than when they do not have this choice (monopoly setting). With respect to which environment is better for the receiver, there is no clear winner. We do not observe significant differences in terms of average payoffs between treatments.

In closing, we note that while Glazer and Rubinstein adopt a mechanism design approach in their analysis, we analyze these settings through a non-cooperative game theoretic lens. Nevertheless and somewhat surprisingly, following the theoretically optimal mechanism would give the receiver more than 98% of his best possible payoff given the behavior of the senders in our experiment irrespective of who has verification control.

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APPENDIX

A EQUILIBRIUM EXAMPLES

In order to illustrate the multiplicity of equilibria, in this section we describe a few examples. We focus on those that pin down receiver's equilibrium payoff bounds.

A.1 *Receiver's best equilibrium (Rv and Sr)*

The receiver's best equilibrium is the GR one both in Sr and in Rv, for either parametrization (T=11 or T=9). In the Sr case, this has been described fully in section 3. For the Rv game, sender's message strategy is not unique. Table 10 presents an example for the T=11 case which makes it optimal for the receiver to play according to the GR prediction described in section 3. The highlighted messages represent bad hands which are profitably lying. The red messages represent bad hands lying in a particular way even though there is no benefit. All the other messages represent truthful reports.

Table 10: Example for sender's message strategy in GR equilibrium for Rv (T=11)

9	(2,9)	(2,9)	(3,9)	(4,9)	(5,9)	(6,9)	(7,9)	(8,9)	(9,9)
8	(3,8)	(4,8)	(3,8)	(4,8)	(5,8)	(6,8)	(7,8)	(8,8)	(9,8)
7	(4,7)	(5,7)	(6,7)	(4,7)	(5,7)	(6,7)	(7,7)	(8,7)	(9,7)
6	(7,6)	(6,6)	(5,6)	(4,6)	(5,6)	(6,6)	(7,6)	(8,6)	(9,6)
5	(7,5)	(2,5)	(3,5)	(4,5)	(6,5)	(6,5)	(7,5)	(8,5)	(9,5)
4	(8,4)	(7,4)	(3,4)	(4,4)	(5,4)	(6,6)	(7,4)	(8,4)	(9,4)
3	(8,3)	(2,3)	(3,3)	(4,3)	(5,3)	(6,5)	(7,6)	(8,3)	(9,3)
2	(9,2)	(2,2)	(3,2)	(4,7)	(5,6)	(6,2)	(7,5)	(8,4)	(9,2)
1	(1,1)	(2,9)	(3,8)	(4,8)	(5,7)	(6,7)	(7,4)	(8,3)	(9,2)
orange card/blue card	1	2	3	4	5	6	7	8	9

Given the above message strategy, the receiver checks the highest message and accepts if and only if the value of the observed card coincides with the message and is at least 7. This gives rise to a payoff of $\frac{66}{81}$ for the receiver and $\frac{45}{81}$ for the sender.

A.2 *Receiver's worst equilibrium (Rv)*

The receiver's worst equilibrium in Rv is the babbling one irrespective of T. In a babbling equilibrium, the message is uninformative (e.g. all sender types send each of the possible messages with equal probability, or all sender types send the same message). The receiver does not condition the checking decision on the message (e.g. the receiver always checks the same card, or checks each of the two cards with equal probability). Upon observing the true value of one of the cards, the receiver takes the optimal acceptance decision given that the other card is equally likely to be any value between 1 and 9.

For T = 11, the receiver accepts if and only if the observed card is 6 (since in 5/9 of cases the sum is at least 11) or higher. This equilibrium gives rise to a payoff of $\frac{61}{81}$ for the receiver and $\frac{36}{81}$ for the sender.

For T = 9, the receiver accepts if and only if the observed card is 4 (since in 5/9 of cases the sum is at least 9) or higher. This equilibrium gives rise to a payoff of $\frac{62}{81}$ for the receiver and $\frac{54}{81}$ for the sender.

A.3 *Receiver's worst equilibrium (Sr)*

The receiver's worst equilibrium in Sr depends on T. To find this equilibrium we look for one that gives rise to an outcome in which the receiver makes a number of errors equal to min(no. of good hands, no. of bad hands). This is the maximum number of errors the receiver can make in equilibrium. To see why this is true, start by assuming that the sender plays a pure strategy. Let m be the message and c the revealed card. Given (m, c), the receiver will accept if and only if more good hands than bad hands use (m, c). The number of errors in this case is equal to min(no. of good hands that send (m, c), no. of bad hands that send (m, c)). Then, the total number of errors is the sum of this number over all possible (m, c) that are observed in equilibrium. Because of the properties of the minimum, this cannot be higher than min(total no. of good hands, total no. of bad hands). This argument can be generalized to mixed strategies.

Next, we describe equilibria that attain the receiver's lowest payoff bound satisfying the above property. To keep the examples simple, we assume that the sender sends a random message which is then ignored by the receiver, and we focus on the sender's revelation decision.

When T=11, table 11 depicts the sender's revelation decision leading to a number of errors equal to 36, min(no. of good hands, no. of bad hands). The sender reveals the highest card for bad hands and the lower one for good hands (when the two cards are equal, one is revealed at random). Irrespective of the value of the observed card, this gives rise to a probability of the hand being good conditional on the observed value lower than 0.5. Hence, the receiver best replies by always rejecting. This gives rise to a payoff of $\frac{45}{81}$ for the receiver and 0 for the sender.

Table 11: Sender's revelation decision for receiver's worst equilibrium when T=11

9	9	**2**	**3**	**4**	**5**	**6**	**7**	**8**	9/**9**
8	8	8	**3**	**4**	**5**	**6**	**7**	8/**8**	8
7	7	7	7	**4**	**5**	**6**	7/**7**	7	7
6	6	6	6	6	**5**	6/**6**	6	6	6
5	5	5	5	5	5/**5**	5	5	5	5
4	4	4	4	4/**4**	**5**	**6**	4	4	4
3	3	3	3/**3**	**4**	**5**	**6**	**7**	3	3
2	2	2/**2**	**3**	**4**	**5**	**6**	**7**	**8**	2
1	1/**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
orange card/**blue card**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

Table 12 presents the equivalent revelation decision for the case where T=9. Again, the sender reveals the highest card when the hand is bad and the lowest when the hand is good (mixing with equal probability between the two in case of equality). The receiver best replies by always accepting, a strategy which leads to a total number of errors equal to 28 - the number of bad hands. This gives rise to a payoff of $\frac{53}{81}$ for the receiver and 1 for the sender.

Table 12: Sender's revelation decision for receiver's worst equilibrium when T=9

9	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	9/**9**
8	**1**	**2**	**3**	**4**	**5**	**6**	**7**	8/**8**	8
7	7	**2**	**3**	**4**	**5**	**6**	7/**7**	7	7
6	6	6	**3**	**4**	**5**	6/**6**	6	6	6
5	5	5	5	**4**	5/**5**	5	5	5	5
4	4	4	4	4/**4**	4	4	4	4	4
3	3	3	3/**3**	**4**	**5**	3	3	3	3
2	2	2/**2**	**3**	**4**	**5**	**6**	2	2	2
1	1/**1**	**2**	**3**	**4**	**5**	**6**	**7**	1	1
orange card/**blue card**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

B AVERAGE PAYOFFS PER MATCHING GROUP

Tables 13 and 14 present the average payoffs for each player within each matching group. These represent our independent observations. The GR average payoffs are computed given the actual realization of good and bad hands while assuming that both players follow the GR prediction. Note that the GR prediction differs between the matching groups due to differences in the realized hands.

Table 13: Average payoffs per matching group: T=11

	Receiver			Sender		
Matching group	Rv	Sr	GR prediction	Rv	Sr	GR prediction
1	0.822	0.717	0.833	0.606	0.578	0.628
2	0.722	0.789	0.806	0.528	0.439	0.544
3	0.856	0.744	0.794	0.506	0.506	0.556
4	0.794	0.783	0.817	0.600	0.567	0.567
5	0.744	0.761	0.800	0.528	0.467	0.561
6	0.794	0.822	0.850	0.589	0.506	0.544
7	0.717	0.789	0.817	0.494	0.578	0.506
8	0.806	0.733	0.789	0.478	0.561	0.528

Table 14: Average payoffs per matching group: T=9

	Receiver			Sender		
Matching group	Rv	Sr	GR prediction	Rv	Sr	GR prediction
1	0.860	0.853	0.900	0.693	0.687	0.627
2	0.907	0.820	0.893	0.707	0.660	0.640
3	0.872	0.800	0.889	0.706	0.644	0.667
4	0.872	0.789	0.889	0.711	0.639	0.694
5	0.867	0.839	0.906	0.706	0.633	0.678
6	0.839	0.889	0.894	0.722	0.772	0.700
7	0.907	0.787	0.860	0.660	0.673	0.707
8	0.853	0.860	0.900	0.707	0.713	0.713

C RECEIVER'S BEST RESPONSE GIVEN THE EMPIRICAL DISTRIBUTION WHEN T=9

C.1 *Receiver verifies*

Table 15: Calculating the best response to the empirical distribution for Rv, T=9

Message	Absolute frequency of message	Absolute frequency of good hands conditional on message	Expected payoff from: check highest report and accept if true[29]	Expected payoff from: check lowest report and accept if true[30]	Expected payoff from: check either report and reject[31]	Expected payoff from: check either report & always accept[32]
(7,7)	30	23	0.817	0.817	0.233	0.767
(7,6)	42	37	0.881	0.786	0.119	0.881
(7,5)	43	41	1.000	0.930	0.047	0.953
(7,4)	32	24	0.906	0.844	0.250	0.750
(7,3)	52	28	0.827	0.731	0.462	0.538
(7,2)	70	23	0.843	0.500	0.671	0.329
(6,6)	55	38	0.636	0.636	0.309	0.691
(6,5)	47	34	0.894	0.681	0.277	0.723
(6,4)	47	29	0.851	0.745	0.383	0.617
(6,3)	73	30	0.808	0.603	0.589	0.411
(5,5)	40	16	0.688	0.688	0.600	0.400
(5,4)	125	37	0.664	0.664	0.704	0.296

[29]Computed by counting the instances in which the highest report is untrue and the hand is bad and those where the highest report is true and the hand is good. This is then divided by the frequency of the corresponding message.

[30]Computed by counting the instances in which the lowest report is untrue and the hand is bad and those where the lowest report is true and the hand is good. This is then divided by the frequency of the corresponding message.

[31]Computed by counting the number of bad hands and then dividing by the frequency of the corresponding message.

[32]Computed by counting the number of good hands and then dividing by the frequency of the corresponding message.

Table 15 excludes messages where either of the two reports is 8 or a 9. In these cases, it is optimal to check the higher report and accept if it is true as this strategy gives a probability of a good hand conditional on the report being true equal to 100%. The table also excludes the cases when the reported hand is bad. Conditional on such a report receiver's best decision is to reject since the probability of a good hand is 0%.

The highlighted cells in the table represent receiver's optimal payoff for a given good hand message. Behaving optimally for all senders' messages gives the receiver an average payoff of 0.882. If the receiver were to follow the GR prediction he would earn an expected payoff of 0.878 which is 99.44% of receiver's best payoff.

C.2 *Sender reveals*

Table 16 depicts the cases where it is optimal for the receiver to accept (highlighted cells) and those where it is optimal to reject (non-highlighted cells) depending on the value of the revealed card (y-axis) and that of the unobserved claim (x-axis).

Table 16: Proportion of good hands given revealed value and unobserved claim

		Revealed Value								
		1	2	3	4	5	6	7	8	9
Unobserved Claim	1	0%	0%	0%	0%	0%	0%	0%	100%	100%
	2	0%	0%	0%	0%	0%	0%	83%	100%	100%
	3	0%	0%	0%	0%	0%	80%	75%	100%	100%
	4	0%	0%	NA	0%	35%	52%	67%	100%	100%
	5	0%	0%	0%	5%	38%	74%	95%	100%	100%
	6	NA	NA	0%	0%	33%	84%	97%	100%	100%
	7	0%	0%	6%	0%	0%	100%	100%	100%	100%
	8	0%	0%	0%	0%	100%	100%	100%	100%	100%
	9	0%	17%	0%	NA	NA	100%	NA	NA	100%

Note: Highlighted cells represent the cases where it is optimal for the receiver to accept.

We notice that as long as the two values add up to at least 9, it is almost always optimal to accept if the revealed value is equal to 6 and reject otherwise. This strategy gives the receiver an expected payoff of 0.896. Following the GR prediction gives the receiver 99.8% of his optimal payoff, i.e. 0.895.

D INSTRUCTIONS

D.1 *Rv, T=11*

INSTRUCTIONS

Welcome and thank you for participating in this experiment. Throughout the whole experiment you are kindly asked to remain seated and refrain from communication with the other participants. Mobile phones and other electronic devices should be switched off. If there are any questions please raise your hand and an experimenter will come to answer your questions in private.

Payment: This experiment consists of 30 rounds. In each round you can earn points. At the end of the experiment you will be paid according to your accumulated point-earnings from all rounds. You will be paid in private and in cash with **£0.50 for each point earned**. Additionally, you will receive a **participation fee of £3.**

All your decisions are anonymous, so your identity will be kept secret at all times.

At the beginning of each round you will be randomly matched with another participant (i.e. the person you are paired with will change from round to round). One of you will have the role of Person A and the other the role of Person B. Your role will be assigned at the beginning of the first round and you will keep this role for all 30 rounds.

Each round consists of 2 stages which are described below.

Stage 1: *Person A observes two cards and sends a message*

In this stage, the computer will randomly select two cards, one **orange** and one **blue**, each carrying a value between 1 and 9. Each combination of values on these 2 cards is equally probable. At this stage, only **Person A** will be able to observe these values.

The hand is "**GOOD"** if the sum of the values on the two cards is **at least 11**. The hand is "**BAD**" if the sum of the values is **10 or below**.

This is an example of a BAD hand:

After observing the randomly drawn cards, Person A will send a message to Person B of the following form:

The value of the **orange card** is: ☐

The value of the **blue card** is: ☐

where Person A fills each blank box with a number between 1 and 9.

Stage 2: *Person B selects one of the cards to observe and makes a decision*

After observing Person A's message, Person B will **select one of the two cards** (**orange** or **blue**) and the computer will reveal its value.

After observing the value on the selected card Person B will **decide between "Accept" and "Reject"**.

End of the Round

At the end of the round both Person A and Person B will receive a summary of the round including:

- The cards that were randomly dealt;
- Person A's message;
- Person B's choice regarding which card to observe;
- Person B's decision to accept or reject;
- Person A and Person B's point-earnings for the round.

How your point earnings are determined:

Person A earns 1 point if B accepts and 0 points if B rejects.

Person B earns 1 point if A has a good hand and B accepts or if A has a bad hand and B rejects. Person B earns 0 points otherwise.

This is summarised in the Table below:

	B **Accepts**	B **Rejects**
A has a **GOOD** hand	Person A receives 1 point, Person B receives 1 point	Person A receives 0 points, Person B receives 0 points
A has a **BAD** hand	Person A receives 1 point, Person B receives 0 points	Person A receives 0 points, Person B receives 1 point

Preliminary questions: Before the 30 rounds begin, you will be asked to answer a few questions regarding your understanding of the instructions. The rounds will begin only after all participants have answered these questions correctly.

Final questionnaire: After the 30 rounds, you will be asked to fill in a short questionnaire. You will then be paid your earnings in private and in cash.

D.2 *Sr, T=11*

INSTRUCTIONS

Welcome and thank you for participating in this experiment. Throughout the whole experiment you are kindly asked to remain seated and refrain from communication with the other participants. Mobile phones and other electronic devices should be switched off. If there are any questions please raise your hand and an experimenter will come to answer your questions in private.

Payment: This experiment consists of 30 rounds. In each round you can earn points. At the end of the experiment you will be paid according to your accumulated point-earnings from all rounds. You will be paid in private and in cash with **£0.50 for each point earned**. Additionally, you will receive a **participation fee of £3.**

All your decisions are anonymous, so your identity will be kept secret at all times.

At the beginning of each round you will be randomly matched with another participant (i.e. the person you are paired with will change from round to round). One of you will have the role of Person A and the other the role of Person B. Your role will be assigned at the beginning of the first round and you will keep this role for all 30 rounds.

Each round consists of 3 stages which are described below.

Stage 1*: Person A observes two cards and sends a message*

In this stage, the computer will randomly select two cards, one **orange** and one **blue**, each carrying a value between 1 and 9. Each combination of values on these 2 cards is equally probable. At this stage, only **Person A** will be able to observe these values.

The hand is "**GOOD"** if the sum of the values on the two cards is **at least 11**. The hand is "**BAD**" if the sum of the values is **10 or below**.

This is an example of a BAD hand:

After observing the randomly drawn cards, Person A will send a message to Person B of the following form:

The value of the **orange card** is: [ ]

The value of the **blue card** is: [ ]

where Person A fills each blank box with a number between 1 and 9.

Stage 2: *Person A selects one of the cards for Person B to observe*

After Person B observes Person A's message, Person A will **select one of the two cards** (**orange** or **blue**) for Person B to observe its value in the next stage.

Stage 3: *Person B observes the value of the card and makes a decision*

After observing the value of the selected card, Person B will **decide between "Accept" and "Reject"**.

End of the Round

At the end of the round both Person A and Person B will receive a summary of the round including:

- The cards that were randomly dealt;
- Person A's message;
- Person A's choice regarding which card to be observed by Person B;
- Person B's decision to accept or reject;
- Person A and Person B's point-earnings for the round.

How your point earnings are determined:

Person A earns 1 point if B accepts and 0 points if B rejects.

Person B earns 1 point if A has a good hand and B accepts or if A has a bad hand and B rejects. Person B earns 0 points otherwise.

This is summarised in the Table below:

	B **Accepts**	B **Rejects**
A has a **GOOD** hand	Person A receives 1 point, Person B receives 1 point	Person A receives 0 points, Person B receives 0 points
A has a **BAD** hand	Person A receives 1 point, Person B receives 0 points	Person A receives 0 points, Person B receives 1 point

Preliminary questions: Before the 30 rounds begin, you will be asked to answer a few questions regarding your understanding of the instructions. The rounds will begin only after all participants have answered these questions correctly.

Final questionnaire: After the 30 rounds, you will be asked to fill in a short questionnaire. You will then be paid your earnings in private and in cash.