2013

Cheap Talk with Two Audiences: An Experiment

Mikhail Drugov

Roberto Hérnan-Gonzalez

Praveen Kujal

Marta Troya Martinez

Cheap Talk with Two Audiences: An Experiment

Comments

Working Paper 13-32

Cheap Talk with Two Audiences: An Experiment

Mikhail Drugov, Roberto Hernán-González, Praveen Kujal

and Marta Troya Martinez*

18 DECEMBER 2013

Abstract: In this paper we experimentally test strategic information transmission between one informed and two uninformed agents in a cheap-talk game. We find evidence of the "disciplining" effect of public communication as compared to private; however, it is much weaker than predicted by the theory. Adding a second receiver naturally increases the complexity of strategic thinking when communication is public. Using the level-k model, we exploit the within subject design to show how individuals decrease their level-k in public communication. Surprisingly, we find that individuals become more sophisticated when they communicate privately with two receivers rather than one.

JEL Classification: C72; C92; D83.

Keywords: Cheap Talk, Communication, Experiment, Level-k, Cognitive ability, Cognitive Reflection Test

* Universidad Carlos III de Madrid, University of Warwick and CEPR, mdrugov@eco.uc3m.es; Departamento de Teoría e Historia Económica, Universidad de Granada, roberto.hernangonzalez@gmail.com; Middlesex University Business School, P.Kujal@mdx.ac.uk and Department of Economics, University of Oxford, marta.troyamartinez@economics.ox.ac.uk. We thank participants of the CESS workshop (Oxford), IMEBE 2012 (Castellón), the 7th Nordic Conference on Behavioral and Experimental Economics (Bergen), EEA 2013 (Gothenburg) and particularly Vincent Crawford, Douglas Bernheim, Nagore Iriberri, Pedro Rey Biel, Victoria Prowse and Dmitry Ryvkin for very useful comments. Mikhail Drugov gratefully acknowledges the financial support of the Spanish Ministry of Education and Science under grant ECO2011-30323-C03-03. Roberto Hernán-González and Praveen Kujal gratefully acknowledge the financial support of the Spanish Ministry of Education and Science under grant 2012/00103/001.

1. Introduction

Examples of strategic information transmission from an informed agent to an uninformed one abound and have been studied extensively since the seminal paper by Crawford and Sobel (1982). In a cheap-talk model, a party, called "sender", has private information about the state of the world. He communicates this information to another party, called "receiver", by sending a costless, non-binding and non-verifiable message. The receiver then takes an action. The payoffs of both the sender and the receiver depend on the state and the taken action but not on the message sent.

In many instances, however, there is more than one receiver listening to the "talk". For example, a CEO's talk can be heard by its investors and workers; a politician's speech is heard by voters and by leaders in other countries, a senior bureaucrat talks to politicians with different policy preferences.[1] There are two key features present in all these cases. First, the sender might want to say different things to the two receivers. A CEO may want to convince investors that the company is doing well, while he might wish to convey just the opposite to the workers say, to reduce the wage bill. Voters like populist and nationalistic gestures, while other countries' leaders prefer to deal with a reasonable and cooperative politician. Second, the sender can send messages publicly and/or privately. Public messages are heard by everybody, say, through press releases and public speeches while private messages are destined for a particular receiver only. For example, politicians may say something more belligerent to the public while they may defend a more moderate stance in private.

In this paper, we conduct an experiment on a cheap-talk model where the sender faces two receivers with preferences different from his own and from each other. We are interested in identifying how the incentives for truthful revelation to one receiver are affected by the presence of the other. As mentioned earlier, this is an important setting as it reflects quite a few real-life scenarios.

We build on the recent experiments on the standard cheap-talk model of Cai and Wang (2006) and Wang, Spezio and Camerer (2010) by adding a second receiver to their experimental design. For comparability with the previous experimental work, subjects first play a standard one-receiver cheap-talk game. They then play two-receiver cheap-talk games in the private and in the public modes. In the private mode the sender

[1] See more examples and references in Goltsman and Pavlov (2011).

sends a (private) message to each receiver, while in the public mode the sender sends a single (public) message to both receivers.

Before presenting the results, let us briefly comment on the related theoretical literature. In a seminal paper Crawford and Sobel (1982) showed that despite messages being cheap talk, some information transmission is nevertheless possible provided that the sender and the receiver's preferences are not too apart. As the preferences of the sender and the receiver become closer, more information can be transmitted. Two papers studied cheap talk with two receivers. Farrell and Gibbons (1989) consider two states of the world and two possible messages. The sender either reveals the truth or nothing at all. Depending on the parameters, there are three cases when the public mode is different from the private mode. In the case of a one-sided discipline the sender reveals the truth to only one receiver in the private mode and does the same in the public mode. In the case of subversion, on the contrary, he does not reveal the truth in the public mode. Finally, under mutual discipline, the sender reveals the truth in the public mode but does not do so to either receiver in the private mode. Goltsman and Pavlov (2011) take the continuous-state setup of Crawford and Sobel (1982). They show that, if the sender equally cares about the actions of the two receivers, the public mode is equivalent to the standard one-receiver cheap-talk game with the bias equal to the average bias of the two receivers.

In our experiment we vary the sender bias(es) in such a way that there is a completely informative, an uninformative ("babbling"), and a partially informative equilibrium in each of the three communication modes. In one-receiver mode our results are in line with the previous literature. In particular, as compared to the theoretical most informative equilibrium, there is more information transmitted when the preferences diverge a lot and there is less information transmitted when they are close. We then compare the private and public mode and find evidence of both mutual discipline and one-sided discipline/subversion.[2]

We also identify the behavior of the players using a level-k model. The level-k model of non-equilibrium strategic thinking has been used to rationalize the systematic

[2] In richer settings than the two-state setting of Farrell and Gibbons (1989) the sharp distinction between one-sided discipline and subversion is lost and they effectively become a single case. If the sender has a small or no bias with one receiver and a large one with the second, the communication in the public mode is somewhat in between the individual communications. There is less information transmitted than the sender transmits privately to the first receiver but more than he transmits privately to the second.

deviations of the subjects' behavior from the theoretical predictions.[3] The distribution of levels that we find in the one-receiver mode is similar to that found in Cai and Wang (2006) and Wang et al. (2010). Our within-subject design further allows us to explore the evolution of strategic thinking as we change the complexity of the game. Adding a second receiver and letting the sender communicate privately does not make the game more complex, because the communications with the two receivers are separable from each other, and we expect the distribution of levels to stay unchanged. Surprisingly, we find that subjects increase their level-k on average in the private mode. Our explanation is that in the private mode, where each player looks at the payoff tables of the two other players, it becomes more salient to guess what other players would do and, therefore, to think strategically.[4] It is also possible that subjects learn how to play the game even though no feedback is given (Weber, 2003) and we do not find any evidence of learning within the modes.

In the public mode the game does become significantly more complex, as players now need to take into account the biases of both receivers when sending or interpreting the message. We expect subjects to decrease their level-k on average and that is exactly what we find despite the fact that the public mode is played last, i.e., the subjects have been longer in the game and might have learned more.[5]

Even though cheap-talk models have been extensively studied in the theoretical literature, experimental evidence on these models is fairly limited. Starting with Dickhaut et al. (1995), Cai and Wang (2006), Kawagoe and Takizawa (2009) and Wang et al. (2010) among others confirm the main insight of Crawford and Sobel (1982), that is, the amount of information communicated decreases as the preferences of the sender and the receiver diverge. However, they also find over-communication, i.e., senders reveal more information and receivers trust senders more than predicted by the theory.

[3] See Crawford et al. (2013) for a recent survey (particularly, Section 9) and other papers later in this section.

[4] This finding is somewhat in line with a lot of experimental evidence that players change their strategic behavior depending on the characteristics of other players. The best known example is, arguably, Palacios-Huerta and Volij (2009) who find that the behavior of chess grandmasters in a standard centipede game is dramatically different depending on whether they faced another chess grandmaster or a student. Closer to this paper, subjects are found to decrease their level-k in a beauty contest experiment when playing against a computer (Coricelli and Nagel, 2009 and Agranov et al. 2012) and against subjects with lower ability (Gill and Prowse, 2012 and Agranov et al. 2012). We are not aware of any evidence for cheap-talk games.

[5] The subjects took a Cognitive Reflection Test (Frederick, 2005) at the end of the experiment. The performance in this test positively correlates with the level-k in each mode. Ours is the first experiment to perform this exercise in cheap-talk experiments. See also Gill and Prowse (2012) for the analysis of the relationship between cognitive ability and levels-k in a beauty contest experiment.

The existence of over-communication has been explained using level-k reasoning (Stahl and Wilson (1994), Stahl and Wilson (1995) and Nagel (1995)).[6]

Since completing our experiment we have become aware of a recent paper by Battaglini and Makarov (2012). They run an experiment very close to the model of Farrell and Gibbons (1989), that is, with two states/messages/actions. Their goal, as well as ours, is to study the effects on communication of introducing the second receiver. As in our experiment, their results are broadly consistent with theoretical predictions.

There are multiple differences between their design and ours, however. We have five states (as in Wang et al, 2010) and provide no feedback on outcomes after each period. Our five-state design allows sharper tests of the theory.[7] Importantly, level-k behavior is supposed to reflect the subjects' initial response and, therefore, might be confounded by feedback. Other important differences are that subjects change roles in their experiment while we have fixed roles. Further, we run the private mode which they do not; all our sessions have the modes in the same order while they change the order of the modes in half of the sessions. Finally, using the same design and parameter values as in Wang et al. (2010) enables us to directly compare our results with the previous literature. Overall, multiple differences in the design make our paper and theirs complementary.

The rest of the paper is organized as follows. Section 2 describes the three communication modes, theoretical predictions and our hypotheses. Experimental results are found in Section 4: Section 4.1 describes the information transmission and Section 4.2 reports the analysis of levels-k. Section 5 concludes. Appendix A contains screenshots, experimental instructions and the understanding tests.

2. Three Communication Modes and Hypotheses

Our experimental design is based on Wang et al. (2010). We take their parameter

[6] This non-equilibrium model of strategic thinking assumes that the population is partitioned into types that differ in their depth of reasoning. A level-0 type is non-strategic which, in cheap-talk games, means a truth-telling sender and a completely trusting receiver (Crawford, 2003). A higher level-k sender best responds to the belief that the receiver has level k-1, while a level-k receiver best responds to the belief that the sender is of the same level.

[7] The consequence of a two-state space is that the identification of levels-k is not very clear as level-0 should play the same as level-2. Another inconvenience is that the results of Goltsman and Pavlov (2011) cannot be directly tested, since they predict that what matters to the sender is the average bias of the receivers.

specification of a standard cheap-talk game (with one receiver) and add a second receiver. At the beginning of each round, the sender is informed about the true state of the world, *s*, which is uniformly distributed on *{1,2,3,4,5}*, and about bias(es), that is, the differences in preferences that he has with the receiver(s). The receivers know the biases but do not know the realization of the state. The sender then sends a private or public message m ∈ {1,2,3,4,5} to each receiver.[8] After observing the message *m*, (each) receiver takes an action a ∈ {1,2,3,4,5}. The utility of the receiver is $U_R = 110 - 20|s-a|^{1.4}$. The receiver thus wants his action to be as close to the state as possible. The utility of the sender depends on the particular communication mode.

2.1 One-receiver mode

In this mode, the utility of the sender is $U_S = 110 - 20|s-a+b|^{1.4}$, where *b* is the sender's bias. The sender thus prefers the receiver to take an action equal to the state plus the bias. As in Wang et al. (2010), we use the following biases: 0 (20% of rounds), 1 (40% of rounds) and 2 (40% of rounds). When the bias is 0, the sender should perfectly reveal the state and the receiver should believe him and take the action that matches the message.[9] When the bias is 2, the opposite is true and only the babbling equilibrium exists, that is, the sender does not transmit any information to the receiver and, therefore, the receiver disregards the message and chooses *a=3* based on his prior beliefs. Finally, when the bias is 1 there is some but not perfect information transmission. Wang et al. (2010) focused on the equilibrium in which the sender reveals whether the state is 1 or higher. The sender should then choose action 1 when seeing message 1, and action 3 or 4 otherwise.[10]

2.2 Private and public modes

With two receivers, the utility of the sender is

[8] Following previous experiments on cheap talk, we assume that subjects use messages in their natural language meaning. This is based on two reasons: first, Blume et al. (2001) find that equilibrium messages tend to be consistent with their natural language meanings, and second, the communication protocol is highly structured.

[9] As is standard in cheap-talk literature, our focus is on the most informative equilibrium.

[10] We also consider "non-robust" equilibria with partitions [1, 2], [3, 4, 5] and [1], [2, 3], [4, 5] (the sender is indifferent in "border" states), but find no evidence that they are played.

$$U_S = \frac{1}{2}\left(110 - 20\left|s - a_1 + b_1\right|^{1.4} + 110 - 20\left|s - a_2 + b_2\right|^{1.4}\right),$$

where a_i and b_i, $i=1,2$, are the action of receiver i and the sender's bias with respect to receiver i.

The following are the configurations of sender biases in both modes: (2, 2), (0, 2), (2, 0), (-2, 2) and (2, -2) for 20% of rounds each. We chose these biases so that in the public mode the average bias is 0, 1 and 2 as in the one-receiver mode since it is average bias that determines the equilibrium, as shown by Goltsman and Pavlov (2011).

Theoretically, the equilibrium play in the private mode is the same as in the one-receiver mode. The sender should send the message to each receiver, taking into account only his bias with that particular receiver, and each receiver should pay attention only to the sender's bias with respect to him and his message. As a result, when the bias is either 2 or -2 with respect to a receiver, there is only the babbling equilibrium in communication with that receiver, while when the bias is 0 there is the truth-telling equilibrium.

In the public mode the sender should behave as if he were facing one receiver with bias equal to the average of the two biases. Thus, when biases are (0,2), the average bias is 1 and the sender reveals the state only partially (as in the one-receiver mode). When the biases are (-2, 2), the average bias is 0 and the sender tells the truth in all the states. Obviously, when the bias combination is (2, 2) only the babbling equilibrium survives and we should observe the same outcome in the three modes.[11]

2.3 Hypotheses

We are now ready to summarize our hypotheses.

Hypothesis 1: *Information Transmission.*

(ι) No communication. Both the private and the public modes are identical when the sender has the same bias with the two receivers, (2, 2).

(ιι) Mutual discipline. When the receivers' preferences differ from those of the sender in opposite directions (-2, 2), the sender misleads the two receivers

[11] In the language of Farrell and Gibbons (1989), the case (-2,2) is "mutual discipline", (2,2) is "no communication" and (0,2) is "one-sided discipline"/"subversion".

in the opposite directions in the private mode. In the public mode, there is mutual discipline and the sender reveals the true state of the world.

(iii) *One-sided discipline / subversion.* When the receiver preferences differ from the sender's in the same direction but to a different extent, (0, 2), in the private mode the sender communicates truthfully with the receiver of bias 0 and does not communicate with the one of bias 2. In the public mode the quality of communication is intermediate and can be either closer to one-sided discipline or subversion.

There are two competing theories that explain over-communication in cheap-talk experiments: cognitive difficulty of deception (as the level-k model assumes) and guilt (Gneezy (2005), Charness and Dufwenberg (2006)). Wang et al. (2010) use eye-tracking to measure how much subjects' pupils dilate while deciding on which message to send. They find that senders' pupils dilate more (immediately before and after the message is sent) when their deception is larger in magnitude. Since pupils dilate both under stress and cognitive difficulty, this evidence is consistent with both theories.[12] In the following hypothesis we conjecture that adding the second receiver increases the feeling of guilt if the sender were to deceive the receivers. This would then suggest that we should get less lying due to the feeling of guilt (and not due to the complexity of the problem).

Hypothesis 2. *Guilt.* When the biases are (2,2), senders lie less both in the private and public mode than in the one-receiver mode with bias 2 if guilt plays a dominant role.

As is standard in the literature, we check whether the level-k model is successful in explaining out-of-equilibrium behavior. The private mode does not really add complexity to the game so we anticipate that the subjects will play according to the same level-k as in the one-receiver mode (and in the previous literature). However, making the sender communicate publicly increases the complexity of the game significantly as the subjects now need to take into account both biases when sending and interpreting the message. Accordingly, we expect that the subjects decrease their level-k.

[12] Although they find that the lookup patterns suggest a specific (level-k) reasoning process that has a particular level of cognitive difficulty.

Hypothesis 3. *Levels-k.*

(ι) Subjects play according to the same level-k in the one-receiver and private modes.

(ιι) Subjects decrease their level-k in the public mode as compared to the private mode.

3. Experimental design

We ran twelve sessions with 168 subjects (56 senders and 112 receivers) in November of 2011 at a major Spanish University. Subjects were recruited for a 2½ hour experiment. The payment consisted of an attendance fee, plus a performance part that was computed using the subjects' payoffs in all the rounds. The average subject payment was 18.60€, including the attendance fee 5€.

All the sessions were made up of three modes. First, subjects played the one-receiver mode for 10 rounds; they then played the private mode for 20 rounds and, finally, they played the public mode for 20 rounds. Before starting the one-receiver and the private modes, subjects were given instructions with detailed explanations about the one-receiver and two-receiver games, respectively. After reading the instructions, subjects took a test to ensure that they understood the instructions and the layout of the payoff matrices.[13]

No feedback was given during the experiment.[14] Roles were kept fixed and subjects were randomly matched in each round. States were randomly generated in each round; a pre-specified composition of different biases in each mode was used.

4. Results

4.1 Information transmission

The experimental literature has measured information transmission in terms of correlations. The correlation between the states and the messages shows the informativeness of the sender's messages. The correlation between the messages and the

[13] See Appendix A1 for screenshots, Appendix A2 for instructions and Appendix A3 for understanding tests.

[14] The only exception is the two understanding tests in which the subjects could pass to the next question only by answering the previous one correctly.

actions measures how "trusting" the receiver is. Overall, the information transmission is measured by the correlation between the states and the actions. We start by analyzing the results from the one-receiver mode, see Table 1. Our results are in line with Wang et al. (2010). We observe slightly less overall information transmission when the bias is 2 (only the babbling equilibrium exists) but still significantly different from 0 which is what the theory predicts.

Table 1: One-receiver mode+				
Bias	r(S,M)	r(M,A)	r(S,A)	Predicted r(S,A)
0	0.88 [0.94]	0.84 [0.94]	0.72** [0.88]	1
1	0.53 [0.51]	0.58 [0.61]	0.33** [0.35]	0.71
2	0.29 [0.23]	0.42 [0.63]	0.17** [0.28]	0

* (**) – statistically different from zero at 5% (1%)

+ Non-eyed tracked correlations from Wang et al. (2010) in squared brackets

We now compare the correlations of the one-receiver mode, when the bias is 2, with the correlations of the two-receiver modes with the biases (2, 2) in Table 2. *Hypothesis 1(i)* says the correlations should be the same in all three modes. Our results are in line with the theory, in that the correlation between the state (S) and the action (A) in the one-receiver mode is not statistically different from the one in the private mode (*p-value 0.3*). The same is true for the comparison between the private and public modes (*p-value 0.13*). Our results support *Hypothesis 1(i)*.

Interestingly, communication in the public mode is in line with the theory as the correlation is not significantly different from zero (it is significantly different from the one in the one-receiver mode (*p-value = 0.01*)). The change in the information transmitted between the two modes is driven by the senders, i.e., the correlations between the messages and actions are almost the same in both modes, while the correlation between states and messages decreases significantly in the public mode. One possibility is that, even though the players receive no feedback, the senders learn to play more in line with equilibrium as they go through the different modes.[15]

We observe less instead of more communication. This suggests that deception may occur from cognitive difficulty (rather than from guilt). This is in line with how Wang

[15] This is in line with what we find in the analysis of levels-k, see Section 4.2.

et al. (2010) interpret the look-up patterns. Our results thus do not support *Hypothesis 2*.

Table 2: Mode equivalence				
Biases (2,2)	r(S,M)	r(M,A)	r(S,A)	Predicted r(S,A)
Private mode	0.26	0.38	0.11**	0
Public mode	0.20	0.43	0.01	0
One-receiver mode (b=2)	0.29	0.42	0.17**	0

*(**) – statistically different from zero at 5% (1%)

We now turn to *Hypothesis 1(ii)*. According to the theoretical prediction, when the biases are (-2,2), the sender does not transmit any information to either receiver in the private mode. In the public mode there is "mutual discipline" and the sender sends a message as if he were facing a single receiver with the bias equal to the average of -2 and 2, i.e., 0. Thus, the sender should reveal the truth. The results of our experiment are displayed in Table 3. We observe that the total information transmission in the private mode is as predicted by the theory. We observe little information transmission and the correlations are not significantly different from zero. Furthermore, mutual discipline is observed in the public mode; however, it is much weaker than predicted by the theory, the correlation being 0.32 while the theoretical prediction is 1. Surprisingly, we observe much less information transmission in the public mode than in the theoretically equivalent one-receiver mode with bias 0.[16] This suggests that subjects fail to fully understand the mutual discipline effect.

Table 3: Mutual Discipline				
Biases (2,-2)	r(S,M)	r(M,A)	r(S,A)	Predicted r(S,A)
Private mode, b=2	0.23	0.27	0.04	0
Private mode, b=-2	0.21	0.47	0.03	0
Public mode	0.54	0.57	0.32**	1
One-receiver mode (b=0)	0.88	0.84	0.72**	1

*(**) – statistically different from zero at 5% (1%)

Finally, we turn to *Hypothesis 1(iii)* regarding the case of one-sided discipline /

[16] They are significantly different with a p-value < 0.001.

subversion in Table 4. The correlation between states and actions for the private mode (0.15 for the receiver with bias 2 and 0.75 for the one with bias 0) are in line with what we find in the one-receiver mode in Table 1 (with biases 2 and 0, respectively). As predicted by the theory, the sender communicates more truthfully with the receiver of bias 0 than with the one of bias 2. In the public mode, the quality of the communication is intermediate (0.53) and less than predicted by the theory (0.71). Surprisingly, we observe more communication than in the theoretically equivalent one-receiver mode with bias equal to 1.[17]

Table 4: One-sided discipline/Subversion				
Biases (0,2)	r(S,M)	r(M,A)	r(S,A)	Predicted r(S,A)
Private mode, b=2	0.23	0.44	0.15**	0
Private mode, b=0	0.87	0.86	0.75**	1
Public mode	0.74	0.72	0.53**	0.71
One-receiver mode (b=1)	0.53	0.58	0.33**	0.71

*(**) – statistically different from zero at 5% (1%)

The comparison between the public and the one-receiver mode allows us to test the prediction in Goltsman and Pavlov (2011). Their result predicts that under public communication a sender only takes into account the average bias of the receivers and acts as if there were a unique receiver with this "effective" bias. We find that the behavior of the senders is different. The senders under-communicate relative to the communication in the one-receiver mode when the "effective" bias is 0 and 2.[18] In contrast, when the average bias is 1, the senders over-communicate with respect to the one-receiver mode.

One possible explanation for this non-monotonic behavior is the presence of bias 0 with one of the receivers. This only happens when the average bias is 1.[19] In this case it is possible that the sender thinks that he cannot convince the receiver with bias 2 and puts an effort into at least convincing the one with bias 0. The sender effectively places a larger weight on the receiver with bias 0; the receivers correctly anticipate it and, as a result, there is more information transmission.

[17] They are significantly different with a p-value < 0.001.
[18] See Tables 3 and 2, respectively.
[19] In the other two cases the biases of the receivers are either 2 or -2.

4.2 Level-k analysis

In order to assign a level-k to subjects, we follow the same procedure as in Cai and Wang (2006). We assign a certain level-k if (1) the subject's behavior is consistent with this level-k in at least 60% of choices and (2), if the subject's behavior is consistent with other levels-k in fewer cases. In case of a tie between two or more levels-k, we assign the lower level-k.

Tables 5 and 6 and Figures 1 and 2 present the level-k classification for senders and receivers, respectively. The level-k model performs fairly well in identifying subjects in all modes and roles. Sophisticated and equilibrium types are also identified.[20]

Table 5: Senders' level-k classification

Level/Mode	One-receiver	Private	Public	Cai and Wang (2006)
Level 0	7%	2%	18%	6%
Level 1	25%	9%	21%	25%
Level 2	30%	48%	14%	31%
Sophisticated	0%	2%	0%	13%
Equilibrium	7%	0%	0%	0%
Non-identified	30%	39%	46%	25%
Total	**100%**	**100%**	**100%**	**100%**

Table 6: Receivers' level-k classification

Level/Mode	One-receiver	Private	Public	Cai and Wang (2006)
Level 0	14%	11%	22%	9%
Level 1	30%	11%	21%	9%
Level 2	10%	3%	2%	34%
Sophisticated	13%	5%	10%	28%
Equilibrium	4%	16%	3%	0%

[20] A sophisticated-type sender (receiver) maximizes his payoff given the empirical distribution of the receivers' (senders') types. An equilibrium-type player plays according to the theoretical (most informative) equilibrium.

Non-identified	29%	54%	43%	19%
Total	**100%**	**100%**	**100%**	**100%**

In order to test *Hypothesis 3* (subjects play according to the same level-k in the one-receiver and private modes but decrease it in the public mode), we first run the non-parametric Wilcoxon signed-rank test.[21, 22] However, a lot of observations are lost since only those subjects who are identified with a certain level in both compared modes can be used. We then run regressions with the dummy variables for the modes.

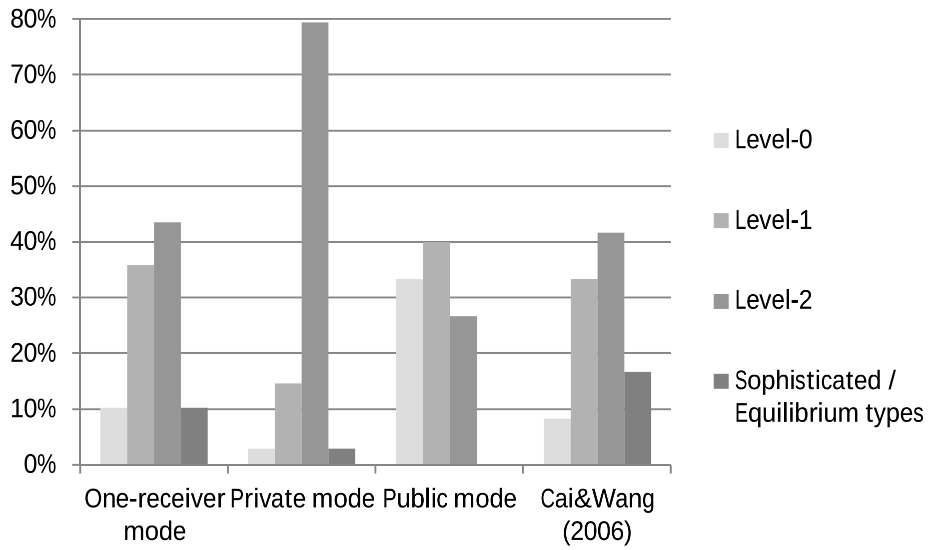


Figure 1: The distributions of the senders' levels-k in the three modes.

[21] In what follows, we group sophisticated and equilibrium type players in one, the highest reasoning level, type.

[22] More standard Kolmogorov-Smirnov and Wilcoxon–Mann–Whitney tests cannot be used because they assume independent samples. Also, the Kolmogorov-Smirnov test requires continuous distributions.

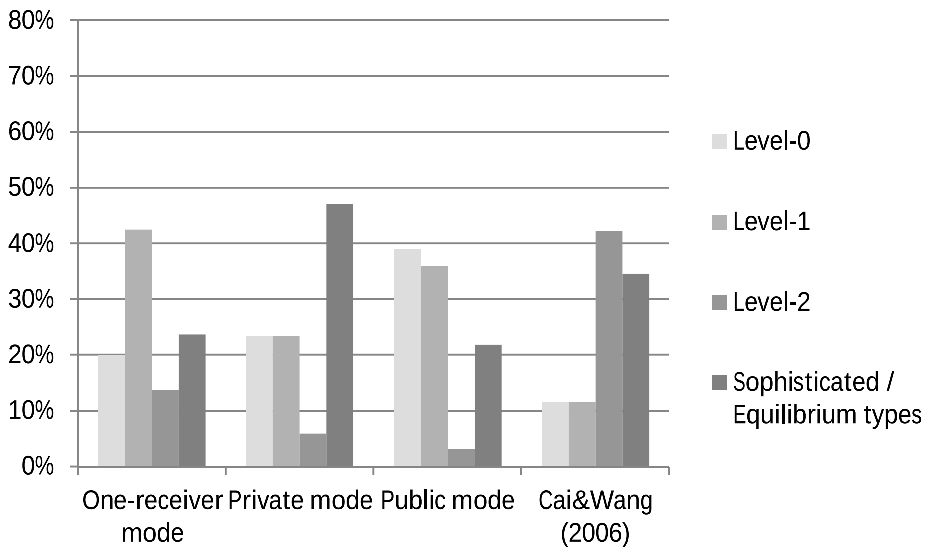


Figure 2: The distributions of the receivers' levels-k in the three modes.

Hypothesis 3(i) predicts that the levels-k do not change between the one-receiver and private modes. Surprisingly, we find that the distribution of levels in the private mode shifts to the right as compared to the one-receiver mode. Facing two other players instead of one seems to help the players to "think in the opponent's shoes". As a result, the subjects' level of strategic thinking goes up. Costa-Gomes and Weizsacker (2008) find that asking the players about the beliefs of the opponent's play does not increase the level of sophistication of the players asked. For example, when a player thought that the opponent was going to play according to a level 1, he was not playing according to a level 2 but rather like a level 1. Our results suggest that introducing another player in the game is more successful in increasing the player's level of sophistication.

Among senders, 28 or 43.5% were identified in both one-receiver and private modes. A majority of the senders (17 or 61%) were classified with the same level-k, 8 senders (29%) were classified as a higher level-k in the private mode than in the one-receiver mode, and 3 senders (11%) were classified as a lower level-k in the private mode. The Wilcoxon signed-rank test *(p-value 0.106)* suggests that senders did improve in the private mode compared to the one-receiver mode, although no feedback was given and theoretically there are no differences between these two modes.

Among receivers, 45 or 40% were identified in both one-receiver and private modes. A half, 22 or 49%, of the receivers were classified with the same level-k in the one-receiver and private modes; 18 or 40% were classified as a higher level-k in the private mode as compared to the one-receiver mode, and 5 or 11% were classified as a lower level-k in the private mode. The Wilcoxon signed-rank test reports an increase in receivers' levels-k in the private mode *(p-value 0.006).*

In Table 7 we present the regression results of the effect of modes on the level-k. The base mode is the private mode. For both senders and receivers, the dummy for the one-receiver mode is statistically significant and negative. Thus, the level-k is on average higher in the private mode then in the private mode.[23] Therefore, *Hypothesis 3(i)* is rejected for senders and receivers alike.

Table 7: The effect of modes, performance on the CRT and demographic variables on the level-k

VARIABLES	(1) Senders	(2) Receivers
One-receiver mode	-0.300**	-0.415**
	(0.032)	(0.017)
Public mode	-0.887***	-0.747***
	(0.000)	(0.000)
CRT	0.321*	0.708***
	(0.086)	(0.001)
Understanding test	-0.00186	0.0276
	(0.961)	(0.320)
Age	-0.0141	-0.0411***
	(0.552)	(0.001)
Male	0.412**	-0.182
	(0.029)	(0.384)
Constant	1.716***	2.338***
	(0.001)	(0.000)
Observations	103	192
R-squared	0.318	0.151

Robust p-values in parentheses. *, ** and *** denote significance at the 10%, 5% and 1% levels. Standard errors are clustered at the subject level. CRT is a dummy variable that takes value 1 if the subject has answered at least one CRT question correctly. "Understanding test" is the number of mistakes in the understanding test.

Hypothesis 3(ii) states that, due to the added complexity, subjects decrease their level of strategic thinking in the public mode. We find evidence that this is the case. Among 23 senders identified in both private and public modes, none increased the level in the public mode as compared to the private one. 14 (or 61%) decreased the level while 9 (or 39%) stayed at the same level. The corresponding Wilcoxon signed-rank test confirms

[23] In Appendix B we present the ordered logit specification of the same regression with qualitatively similar results. We prefer the standard OLS specification reported here because ordered logit imposes more structure on the data and its coefficients are harder to interpret.

this result (*p-value <0.001*). A similar picture holds for the receivers. Among 35 receivers identified in both private and public modes, only one receiver increased the level-k. 12 or 34% decreased the level while 22 or 55% did not change it. The *p-value* from the corresponding Wilcoxon signed-rank test is *0.002*.

We also see from Table 7 that the dummy variable for the public mode is significant and negative for both senders and receivers. Thus, a lower level-k is played on average in the public mode as compared to the private mode.

Thus, *Hypothesis 3(ii)* is confirmed for both senders and receivers. While it seems intuitive that subjects should play according to a lower level-k in a more complex game, our experiment is the first one to confirm this in the same game, to the best of our knowledge. Comparing different experiments in terms of complexity can be difficult as it is not clear how this is to be measured. In our experiment the public mode is undoubtedly more complex than the private one and yet it is similar enough to make a comparison meaningful.

Cognitive Reflection Test

At the end of the experiment the subjects took a Cognitive Reflection Test (Frederick, 2005) which is a short test containing three questions. The questions are designed in such a way that the common intuitive response is incorrect, but the correct answer can be found with some deliberation. In this sense, the CRT measures cognitive reflectiveness or impulsiveness versus elaborate and deliberative thought.

We see from Table 7 that the performance in this test positively correlates with the level-k in each mode; though, only for receivers the coefficient is significant. Ours is the first experiment to perform this exercise in a cheap-talk experiment. [24,25]

5. Conclusion

In this paper we experimentally tested the two-receiver cheap-talk model, building on the models of Farrell and Gibbons (1989) and Goltsman and Pavlov (2011). Using the design and specification of a standard (one-receiver) cheap-talk experiment by Wang et al. (2010) as the first mode, we are able to check the consistency of our experiment with

[24] See Brañas-Garza et al. (2012) for a beauty contest experiment where subjects with a better performance on the CRT make lower guesses.

[25] Interestingly, the performance on the understanding test does not affect the level-k (see Table 7) but does affect the probability of being classified as any level (see Table B2 in Appendix B).

the previous literature and, having established it, be sure that our results are not driven by some unusual design features.

We find that subjects behave in a way which is broadly consistent with the theoretical predictions. In particular, talking to two receivers with opposing preferences improves communication due to the so-called “mutual discipline” effect. When the preferences of one receiver are aligned with the sender, while the preferences of the other differ greatly, talking publicly produces communication at an intermediate level as compared to private communication; this corresponds to the one-sided discipline / subversion case.

We then turned to the level-k analysis of the subjects' behavior. We found that facing an additional player increases the level of reasoning, i.e., in the private mode with two receivers, the levels-k are higher than in the one-receiver mode. Comparing private and public modes, we found that the subjects decreased their level-k. Our explanation is that the public mode is more complex and, therefore, achieving the same level-k is more cognitively difficult. Finally, we found that the performance on the Cognitive Reflection Test (Frederick, 2005) positively correlates with the level-k which is in line with several recent papers looking at the connection between cognitive ability and levels-k.

References

Agranov, M., Potamites, E., Schotter, A., and C. Tergiman (2012): “Beliefs and endogenous cognitive levels: An experimental study,” *Games and Economic Behavior*, 75(2), 449-463.

Battaglini, M., and U. Makarov (2012): “Cheap Talk with Multiple Audiences: An Experimental Analysis,” Princeton University, mimeo.

Blume, A., D. V. DeJong, Y.-G. Kim, and G. B. Sprinkle (2001): “Evolution of Communication with Partial Common Interest,” *Games and Economic Behavior*, 37(1), 79-120.

Brañas-Garza, P., García-Muñoz, T., and R. Hernán González (2012): “Cognitive effort in the Beauty Contest Game,” *Journal of Economic Behavior & Organization*, 83(2), 254-260.

Cai, H., and J. T.-Y.Wang (2006): “Overcommunication in strategic information transmission games,” *Games and Economic Behavior*, 56(1), 7-36.

Charness, G. and M. Dufwenberg (2006): “Promises and Partnership,” *Econometrica*, 74(6), 1579-1601.

Coricelli, G. and R. Nagel (2009): “Neural correlates of depth of strategic reasoning in medial prefrontal cortex,” *Proceedings of the National Academy of Sciences (PNAS)*, 106(23), 9163-9168.

Costa-Gomes, M., V. P. Crawford, and B. Broseta (2001): “Cognition and Behavior in Normal-Form Games: An Experimental Study,” *Econometrica*, 69(5), 1193-1235.

Costa-Gomes, M. A., and V. P. Crawford (2006): “Cognition and Behavior in Two-Person Guessing Games: An Experimental Study,” *American Economic Review*, 96(5), 1737-1768.

Costa-Gomes, M. A., and G. Weizsacker (2008): “Stated Beliefs and Play in Normal-Form Games,” *Review of Economic Studies*, 75, 729-762.

Crawford, V. P. (2003): Lying for Strategic Advantage: Rational and Boundedly Rational Misrepresentation of Intentions,” *American Economic Review*, 93(1), 133-149.

Crawford, V. P., M. A. Costa-Gomes, and N. Iriberri (2013): "Structural Models of Nonequilibrium Strategic Thinking: Theory, Evidence, and Applications," *Journal of Economic Literature*, 51(1), 5-62**.**

Crawford, V. P., and J. Sobel (1982): “Strategic Information Transmission,” *Econometrica*, 50(6), 1431-1451.

Dickhaut, J. W., McCabe, K. A. and A. Mukherji (1995): “An Experimental Study of Strategic Information Transmission”, *Economic Theory*, 6(3), 389-403.

Farrell, J., and R. Gibbons (1989): “Cheap Talk with Two Audiences,” *American Economic Review*, 79(5), 1214-1223.

Frederick, S. (2005): “Cognitive Reflection and Decision Making”, *Journal of Economic Perspectives*, 19(4): 25–42.

Gill, D., and V. Prowse (2012): “Cognitive Ability and Learning to Play Equilibrium: A Level-k Analysis”, *Oxford Department of Economics Discussion Paper 641.*

Gneezy, Uri (2005): “Deception: The Role of Consequences,” *American Economic Review*, 95(1), 384-94.

Goltsman, M., and G. Pavlov (2011): “How to talk to multiple audiences,” *Games and Economic Behavior*, 72(1), 100-122.

Kawagoe, T., and H. Takizawa (2009): “Equilibrium Refinement vs. Level-k Analysis: An Experimental Study of Cheap-Talk Games with Private Information,” *Games and*

Economic Behavior, 66(1), 238-255.

Nagel, R. (1995): “Unraveling in Guessing Games: An Experimental Study,” *American Economic Review*, 85(5), 1313-1326.

Palacios-Huerta, I., and O. Volij (2009): "Field Centipedes," *American Economic Review*, 99(4), 1619-35.

Stahl, D. O. I., and P. W. Wilson (1994): “Experimental evidence on players models of other players,” *Journal of Economic Behavior and Organization*, 25(3), 309-327.

Stahl, D. O. I., and P. W. Wilson (1995): “On Players’ Models of Other Players: Theory and Experimental Evidence,” *Games and Economic Behavior*, 10(1), 218-254.

Wang, J. T.-y., M. Spezio, and C. F. Camerer (2010): “Pinocchio’s Pupil: Using Eyetracking and Pupil Dilation to Understand Truth Telling and Deception in Sender-Receiver Games,” *American Economic Review*, 100(3), 984-1007.

Weber, R (2003): “’Learning’ with no Feedback in a Competitive Guessing Game,” *Games and Economic Behavior*, 44(1), 134-144.

Appendix A

A.1 Screenshots

Figure 1: Sender Screen

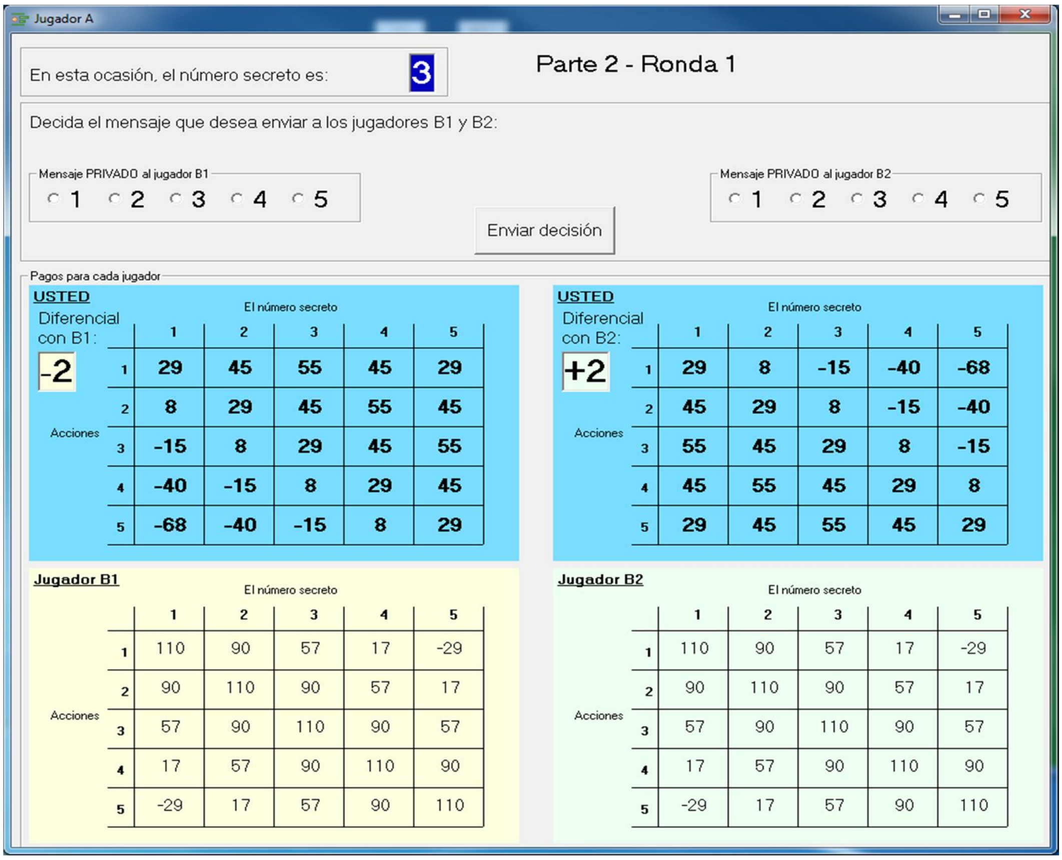


Figure 1 shows a typical sender's screen for the private mode. In this particular case, the state of the world ("número secreto") is 3 and it appears in the top left of the screen. The sender needs to decide which private message ("mensaje privado") to send to receivers 1 and 2, by respectively choosing a number from each of the left and right top panels. The two top (blue) matrices represent the sender's payoffs, depending on the actions taken by receivers 1 and 2, respectively. Next to each of these matrices, there is the bias ("diferencial") that the sender has with this particular receiver. Finally, the bottom matrices are the payoffs of receivers 1 and 2, respectively. The sender's screen in the public mode looks the same, the only difference being that he can send just one message that will be observed by both receivers.

Figure 2: Receiver Screen

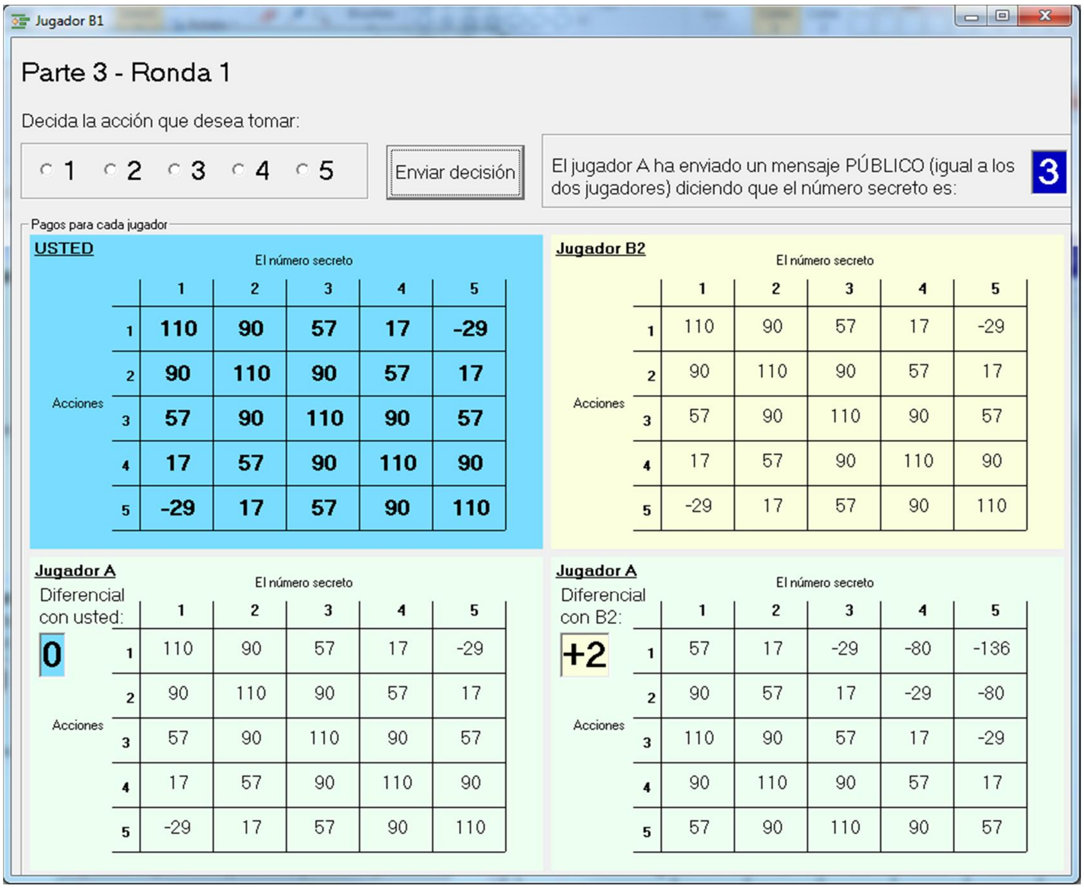


Figure 2 shows a typical screen for a receiver in the public mode. In this particular screen, the public message sent by the sender is 3 and is in the top right corner. In the left top corner, the receiver decides which action ("acción") to take by selecting one of the five options. The payoffs of this receiver (B1) are in the top left (blue) matrix. The payoffs of the other receiver (B2) are in the top right matrix. Finally, the payoffs of the sender with respect to the receivers B1 and B2 are in the bottom left and right matrices, respectively. The bias that the sender has with each receiver is next to his payoff matrix corresponding to that receiver. The receiver's screen in the private mode looks the same, the only difference being that the message is said to be private.

A.2 Instructions

<u>Introduction</u>:

Welcome! This is a study of decision-making. The funds for this project have been provided by a public funding agency. If you follow these instructions, and make decisions carefully, you could earn a considerable amount of money in addition to the attendance fee of 5 euros. You will be paid in cash at the end of today's experiment.

<u>Experimental Instructions</u>:

The experiment in which you are participating consists of 3 parts. Part 1 has 10 rounds, while parts 2 and 3 each have 20 rounds. In each round of Part 1, you will be randomly matched with one other participant and in Parts 2 and 3 with two other participants. At the end of Part 3, you will be asked to fill out a questionnaire and will be paid the total amount you have accumulated during the course of the entire experiment.

During the experiment all the earnings are denominated in ECU (experimental currency unit). Your earnings in euros are determined by the ECU/$ exchange rate: 350 ECU = 1 euro.

You will be informed about your role (A or B) at the beginning of the experiment. You will have the same role for the entire duration of the experiment.

<u>Part 1:</u>

In this part, player A is randomly matched with another player, B1.

In each round, the computer randomly chooses a secret number that can be 1,2,3,4 or 5 and all these numbers are equally likely. The secret number is displayed only on player A's screen and it is the same secret number for players A and B1.

After seeing the number, player A will send the message to player B1 with whom he/she is matched: "Player A sent you the message saying that the secret number is X".

After receiving the message from player A, player B1 will choose an action. Specifically, player B1 can choose one of the following actions: 1, 2, 3, 4 or 5.

Earnings of both players depend on the secret number and player B1's action.

<u>Earnings are determined in the following manner:</u>

Player B1's earnings are higher when his/her action is closer to the secret number. Player A's earnings are higher when the action of player B1's is closer to the secret number **plus the preference difference** (represented by a number). The preference difference is either 0, 1 or 2, and will be determined by the computer in each round. <u>The preference difference will be displayed and announced to everyone at the beginning of each round.</u>

<u>An example</u>: If the preference difference is 2 and the secret number is 3, player B1's earnings are higher if his or her action is closer to 3. However, player A's earnings are higher when player B1's action is closer to 3 + 2 = 5.

<u>To summarize, in each round the computer will display the secret number only on player A's screen.</u> The secret number will not be revealed to player B1. Both players will be informed about the preference difference. Player B1 will receive a message "Player A sent you the message saying that the secret number is X" from player A and will then choose an action. The earnings will be determined according to the actual value of the secret number and player B1's action.

If the explanation above is not clear, please raise your hand and the experimenter will answer your questions.

Please answer now a few questions to ensure that you understand the instructions.

Part 2:

In this part, player A is randomly matched with two other players, B1 and B2.
In each round, the computer randomly chooses a secret number that can be 1,2,3,4 or 5 and all these numbers are equally likely. The secret number is displayed only on player A's screen and it is the same secret number for players A, B1 and B2.

After seeing the secret number, player A sends a separate **private message** to each of the two players, B1 and B2, with whom he or she is matched "Player A sent you a PRIVATE message (only for you) saying that the secret number is X".

Players B1 and B2, after receiving the respective messages from player A, will choose an action. Specifically, players B1 B2 can choose one of the following actions: 1, 2, 3, 4 or 5.

Earnings of all the players depend on the secret number and actions of players B1 and B2.

Now player A has two different **preference differences:** one with B1 and one with B2. The preference differences can take values -2, 0, or 2. Furthermore, the preference differences may not be the same for players B1 and B2. The preference differences will be displayed and announced to all players in the beginning of each round.

Earnings are determined in the following manner:

As in Part 1, player B1's and B2's earnings are higher when their own action is closer to the secret number, while player A's earnings are higher when players B1's and B2's actions are closer to the secret number **plus the preference differences** that player A has with B1 and B2, respectively.

Example 2: If A's **preference difference with B1 is 2** and the **secret number is 3**, player B1's earnings are higher if his or her action is closer to 3. However, **player A's earnings are higher when B1's action is closer to 3 + 2 = 5**. A's **preference difference with B2 be -2**. In this case player B2's earnings are higher if his or her action is closer to 3 (the secret number). However, **player A's earnings are higher when player B2's action is closer to 3 + (-2) = 1.**

To summarize, in each round the computer will display the secret number only on player A's screen. All the players will be informed about preference differences. Players B1 and B2 will each receive separate private messages from player A "Player A sent you a PRIVATE message (only for you) saying that the secret number is X". Players B1 and B2 will then each choose an action. The earnings are determined according to the actual value of the secret number and B1's and B2's actions.

If the explanation above is not clear, please raise your hand and the experimenter will answer your questions.
Please answer now a few questions to ensure that you understand the instructions.

Part 3:

In this part, player A is randomly matched with two other players, B1 and B2.

In each round, the computer randomly chooses a secret number that can be 1,2,3,4 or 5 and all these numbers are equally likely. The secret number is displayed only on player A's screen and it is the same secret number for players A, B1 and B2.

The only difference with Part 2 is that player A now sends a **public message** (the same) to players B1 and B2 "Player A sent you a PUBLIC message (the same to both players) saying that the secret number is X".

Players B1 and B2, after receiving the respective messages from player A, will choose an action. Specifically, players B1 B2 can choose one of the following actions: 1, 2, 3, 4 or 5.

Earnings of all the players depend on the secret number and actions of players B1 and B2.

As in Part 2, player A has two different **preference differences:** one with B1 and one with B2. The preference differences can take values -2, 0, or 2. Furthermore, the preference differences may not be the same for players B1 and B2. The preference differences will be displayed and announced to all players in the beginning of each round.

The earnings will be determined exactly in the same way as in Part 2.

Recall that player B1's and B2's earnings are higher when their action is closer to the secret number, while player A's earnings are higher when players B1 and B2 actions are closer to the secret number **plus the respective preference difference**.

To summarize, in each round, the computer will display the secret number only on player A's screen. All the players will be informed about preference differences. Players B1 and B2 will receive a common message "Player A sent you a PUBLIC message (the same to both players) saying that the secret number is X" from player A, and then each choose an action. The earnings are determined according to the actual value of the secret number and B1's and B2's actions.

If the explanation above is not clear, please raise your hand and the experimenter will answer your questions.

Thank you for your participation.

A.3 Understanding test

You will now start an understanding test. You must answer each question correctly before being allowed to continue to the next question.

<u>Questions regarding Part 1 of the experiment:</u>

Please look at the example of earning tables below for a case of preference difference equal to +1.

Jugador A

Diferencial con B1: **+1**

El número secreto

Acciones	1	2	3	4	5
1	94	53	21	-33	-84
2	114	86	53	21	-25
3	94	114	94	53	13
4	61	94	106	94	61
5	13	53	86	114	86

Jugador B1

El número secreto

Acciones	1	2	3	4	5
1	106	94	53	21	-33
2	94	106	94	53	13
3	61	94	114	94	61
4	13	53	86	106	94
5	-25	21	53	86	114

Suppose that the secret number is 2.

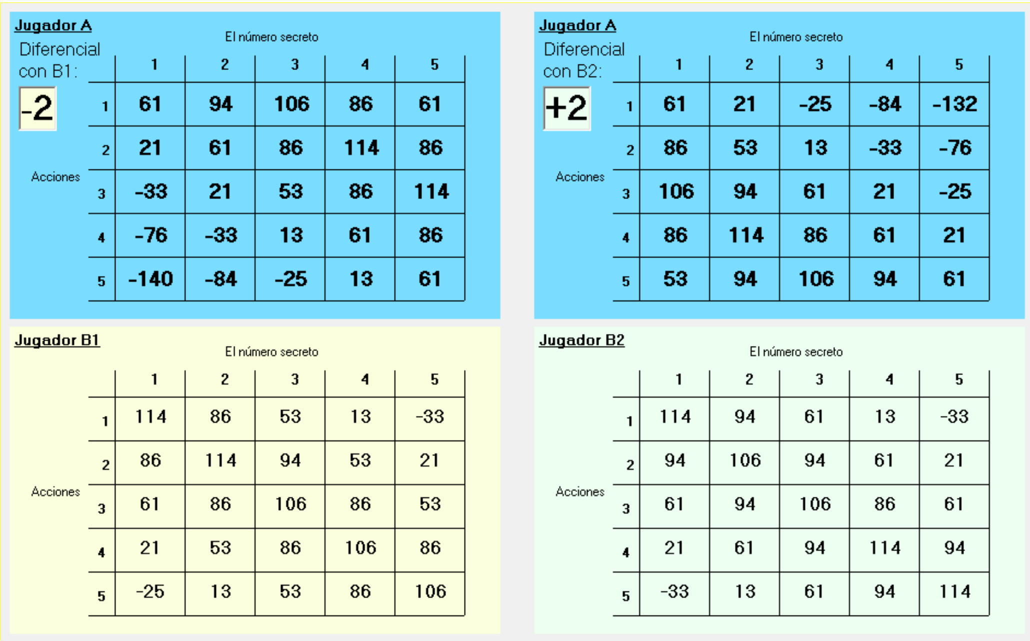
Which action is it optimal for player B to undertake? [ANSWER: 2]
Which action does player A want player B to undertake? [ANSWER: 3]

Suppose now that the secret number is 5.

Which action is it optimal for player B to undertake? [ANSWER: 5]
Which action does player A want player B to undertake? [ANSWER: 5]

<u>Questions regarding the part of the experiment with two players B1 and B2 (parts 2 and 3):</u>

Please look at the example of earning tables below for a case of preference difference equal to -2 for player B1 and equal to +2 for player B2.



Jugador A

Diferencial con B1: -2

Acciones \ El número secreto	1	2	3	4	5
1	61	94	106	86	61
2	21	61	86	114	86
3	-33	21	53	86	114
4	-76	-33	13	61	86
5	-140	-84	-25	13	61

Jugador A

Diferencial con B2: +2

Acciones \ El número secreto	1	2	3	4	5
1	61	21	-25	-84	-132
2	86	53	13	-33	-76
3	106	94	61	21	-25
4	86	114	86	61	21
5	53	94	106	94	61

Jugador B1

Acciones \ El número secreto	1	2	3	4	5
1	114	86	53	13	-33
2	86	114	94	53	21
3	61	86	106	86	53
4	21	53	86	106	86
5	-25	13	53	86	106

Jugador B2

Acciones \ El número secreto	1	2	3	4	5
1	114	94	61	13	-33
2	94	106	94	61	21
3	61	94	106	86	61
4	21	61	94	114	94
5	-33	13	61	94	114

Suppose that the secret number is 3.

Which action is it optimal for player B1 to undertake? [ANSWER: 3]
Which action is it optimal for player B2 to undertake? [ANSWER: 3]
Which action does player A want player B1 to undertake? [ANSWER: 1]
Which action does player A want player B2 to undertake? [ANSWER: 5]

You have completed the understanding test.

Appendix B

Table B1: The effect of modes, performance on the CRT and demographic variables on the level-k (ordered logit specification) (marginal effects are reported)

VARIABLES	(1) Senders	(2) Receivers
One-receiver mode	-1.030**	-0.687**
	(0.029)	(0.031)
Public mode	-2.540***	-1.351***
	(0.000)	(0.000)
CRT	0.959*	1.357***
	(0.096)	(0.001)
Understanding test	0.00634	0.0535
	(0.955)	(0.229)
Age	-0.0371	-0.0847**
	(0.618)	(0.028)
Male	1.130**	-0.216

	(0.031)	(0.585)
cut1		
Constant	-2.988**	-2.900***
	(0.048)	(0.006)
cut2		
Constant	-0.922	-1.140
	(0.553)	(0.281)
cut3		
Constant	2.880*	-0.727
	(0.053)	(0.483)
Observations	103	192

Robust p-values in parentheses. *, ** and *** denote significance at the 10%, 5% and 1% levels. Standard errors are clustered at the subject level. CRT is a dummy variable that takes value 1 if the subject has answered at least one CRT question correctly. "Understanding test" is the number of mistakes in the understanding test.

Table B2: The effect of modes, performance on the CRT and demographic variables on the probability of being identified with any type (logit specification) (marginal effects are reported)

VARIABLES	(1) Senders	(2) Receivers
One-receiver mode	0.427	1.075***
	(0.222)	(0.000)
Public mode	-0.314	0.455*
	(0.351)	(0.070)
CRT	-0.0432	0.369
	(0.923)	(0.237)
Understanding test	-0.170***	-0.0892**
	(0.004)	(0.049)
Age	0.0234	-0.00355
	(0.664)	(0.938)
Male	0.430	-0.132
	(0.337)	(0.689)
Constant	0.192	0.118
	(0.876)	(0.908)
Observations	168	330

Robust p-values in parentheses. *, ** and *** denote significance at the 10%, 5% and 1% levels. Standard errors are clustered at the subject level. CRT is a dummy variable that takes value 1 if the subject has answered at least one CRT question correctly. "Understanding test" is the number of mistakes in the understanding test.