Endogenous vs. Exogenous Transmission of Information: An Experiment*

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Abstract

Based on Gossner, Hernández and Neyman's (2006) 3-player game (hereafter GHN) we analyze communication efficiency in the lab. In that game, player 1 represents random nature —an i.i.d. procedure—, player 2 is a fully informed player (wiser), and player 3 is the less informed player (agent). The game is repeated and players 2 and 3 get 1 if both actions match nature's actions, and 0 otherwise. We propose an experiment following this game. We implement two treatments: one without chat (NC) and one with chat (C). In the treatment with chat, players may first send messages to each other through an on line chat application, and then play the game. After the chat time, only the wiser player has perfect information on the realized (random) sequence played by nature. The players then play the finitely repeated binary game. In treatment NC, subjects just play the game. In the experiment we observed endogenous communication —treatment NC—as well as exogenous —in treatment C—, both of which result in higher payoffs. Furthermore, when explicit communication is possible we observe a chat effect which can be interpreted as a higher level of efficiency in communication. Strategies used by subjects are in line with GHN strategies.

Keywords: communication, transmission of information, efficiency, experiments.
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1 Introduction

Communication is intrinsic to human behavior. It is the activity of transmitting information by exchanging words, signals, messages, thoughts, and behavior among other forms of interaction. Given the device of information transmission, communication can be classified as exogenous or endogenous. Exogenous communication entails the existence of an external device to support such activities, for instance, sending e-mails, chatting, WhatsApp, etc. Nevertheless, endogenous communication may occur when a natural understanding emerges between individuals who are 'in contact'.

In the broader economy, the fact that communication may reduce inefficiencies between agents is beyond doubt. Many real examples like advertising, a broker's advice to an investor or the information contained in an employee's CV reveal the fact that communication occurs in one way or another. But the most basic type of communication is implicit communication through actions rather than words. In fact, it is the combination of words and actions that makes up the complete communication toolbox. In particular, communication between agents may be exogenously conveyed through explicit messages or, communication may be endogenously transmitted through actual action in the course of business. In this sense, here we deal with exogenous as well as endogenous transmission of information among players that play a pure coordination game.

Experimental studies on explicit transmission of information reveal the importance of aspects such as the pre-play versus post-play communication phases, the incentives to lie when the interests of players are in conflict, whether the messages are open or closed, or even the role played by the cost of communication versus costless information. Our main goal is to measure the efficiency of the communication in an experimental setting. For this purpose, we design an experiment which permits the natural development of the two types of communication: endogenous and exogenous.

1.1 Theoretical model

Based on the theoretical 3-player game of communication from GHN, we implement in the lab a 2-player pure coordination game with a pre-play stage. The game is repeated a finite number of times. During the pre-play stage, the two players have to coordinate their action against nature's actions. The sequence of actions played by nature is revealed to only one player. After that, players play the game. Therefore, exogenous communication may take place only before the game is played, and no explicit messages can be sent after the pre-play has taken place. In an infinite frame, GHN show that such a set up allows for measuring efficiency in communication. In this paper, given the optimal strategy for players in a specific frame, we design an experiment in order to measure the efficiency of communication in the lab.

1.2 The experiment

The experiment consists of two treatments: a baseline (NC) with no chat and a treatment (C) with chat. There are two types of experimental subjects: type 1 and type 2. Type 1 plays the role of the *wiser*, a fully informed player with complete information about the sequence played by nature. Type 2 plays the role of the *agent*, a player with incomplete information about nature's sequence. Type 1 and type 2 play a simultaneous coordination game over 55 rounds.

A total of 180 subjects participated in the experiment, distributed over three independent sessions of 60 participants each, one session for treatment NC and two for treatment C. In treatment C, a session was divided into two sections, both consisting of a pre-play chat stage and then playing the simultaneous game over 55 rounds. Subjects were all grouped into pairs at the beginning of the session, and then each participant was randomly given her permanent role.

The sequences played by nature were randomly generated at the beginning of each section within the session through a random number generator simulating a '0' and '1' binary variable, each outcome with a constant probability of 0.5. Subjects were informed about this fact in the instructions (see Appendix 1). In the experiment, a total of six independent sequences of nature —two sequences per session —were generated.

1.3 Results

We analyze how efficiently players communicate in order to get higher payoffs. Furthermore, we are able to measure the effect of two types of communication. On the one hand, our first result is related to the existence of *endogenous* communication. In the baseline NC without chat, several type 1 players make an intentional mistake to induce a change in type 2's behavior. Several type 2 players, by looking at type 1's actions, make some kind of guess about the future actions of nature. As a result, there are subject-pairs whose members make an attempt to coordinate their actions, thus actually improving their average payoff.

The second result states that *explicit* communication between players improves average payoffs. When allowed to chat in treatment C, players establish a way of decodifying messages that are actually used in the play phase.

The third result relates both sources of communication. In our experimental data we detect a team effect and a chat effect by using one-way analysis of variance. The team effect is identified as the source of endogenous communication, while the chat effect is the consequence of exogenous communication.

The fourth and final result shows that the efficient use of the chat function implies explicit communication leading to better average payoffs. The existence of a chat function allows subjects to face nature's sequence by designing sophisticated communication strategies and, therefore, developing more aware and strategic behavior to get better payoffs. These strategies are in consonance with those presented in GHN. The use of mistakes to inform the future realization of nature's actions is the key ingredient of the optimal strategies in the theoretical paper of GHN. This strategy is naturally implemented by the subjects in the experiment.

To summarize, endogenous and exogenous communication matter and individuals make good use of exogenous communication in the experiment. Exogenous as well as endogenous communication are found, both resulting in higher payoffs. Furthermore, when explicit communication is possible through the chat, subjects get higher payoffs, which can be interpreted as a higher level of efficiency in communication.

1.4 Related literature

Although ours is the first experimental work that explicitly deals with the measurement of efficiency in exogenous/endogenous communication, its natural relation with the literature on communication deserves some attention. The importance of communication through information transmission has been extensively confirmed from both perspectives: theoretical and experimental.

As far as the theoretical references on communication are concerned, since the seminal paper on strategic communication by Crawford and Sobel (1982) in a sender-receiver context, many relevant contributions to the literature on strategic information transmission have focused on different aspects of the general model. Leading extensions of that model are those of Farrell (1987) and Rabin (1994), important references on *cheap talk* models and the role of pre-play communication. Particularly important contributors to the literature on communication are Myerson (1986) and Forges (1986), who were the first in formally establishing the concept of *communication equilibrium* in the literature of Game Theory. Some years later, and in a market context, Radner (1993) studied how communication affects the level of organizational efficiency of a firm. With the aim of keeping this overview brief, we direct the reader to Sobel (2010), who offers an exhaustive review of communication models.

There are many contributions to experimental research on the transmission of information that focus on how communication may help to solve coordination problems. Many articles deal with communication when agents have conflicts of interest rather than aligned preferences. In such cases, contrary to what happens in our framework, players have incentives to lie. The works by Gneezy (2005), Sutter (2009), and Camera et al. (2010) are outstanding references on this approach.

In line with our players' aligned interests, several studies investigate the role of costless (cheap talk) versus costly pre-play communication. Van Huyck et al. (1993), by auctioning off the right to play, used costly (but tacit) information to overcome coordination failure completely. Turning from costly to costless messages, references such as Burton and Sefton (2004) or Blume and Ortmann (2007) find that costless messages with minimal information content, when added to games with Pareto-ranked equilibria, can enable both quick convergence to, and participants' initial coordination on, the Pareto-dominant equilibrium.

In the context of aligned preferences within players, another aspect that has been dealt with in the literature is the fact of allowing communication on a closed rather than an open basis. In Blume and Ortmann (2007) pre-play messages take a closed form like 'I intend to play action X'. More recently, Corgnet et al. (2012) designed an experimental asset market in which subjects could send closed messages, finding that messages can play a significant role in bubble abatement. At the other extreme, Chaudhuri et al. (2005) allow for open-ended communication that they analyze for content, finding that, although subjects do not always focus on efficiency-enhancing communication, cheap talk is efficiency enhancing as the quality of advice given is positively related to the probability of coordination success.

Far from being exhaustive, we have mentioned some of the key references with common framework components. In our set-up, endogenous (always costly) as well as (costless) exogenous communication are possible for subjects who play a coordination game with aligned interests. In such a context, we measure the interrelation between the two kinds of communication as well as the level of efficiency in the communication process, in the sense of achieving higher payoffs.

The rest of the paper is structured as follows. In Section 2 we describe the game on which the experiment is based. We dedicate Section 3 to the experimental design. In Section 4 we describe the steps of the data analysis and highlight the main results. Section 5 concludes the paper. An appendix at the end of the paper includes the instructions given to experimental subjects as well as some tables showing examples of the dialogs that subjects wrote in the sessions of treatment with the chat.

2 Theoretical framework

In this section we describe in detail the game played by subjects in the experiment: A 2-player pure coordination game with asymmetric information with respect to a random phenomenon denoted as *nature*. Nature is represented by two equally probable events labeled as '0' and '1', and this is common knowledge to all players. One player, the *wiser*, has perfect future information about nature, while the other, the *agent*, knows just the probabilities and historical information. Each player's set of actions is $\{0, 1\}$. As far as payoffs are concerned, when actions played by the two players match nature's actions, the payoff for each player is 1. Otherwise, both players get zero. No losses are possible. Therefore, if, for instance, the two players and nature all play '0', then each player gets 1.

Formally, we denote *nature* as player i, the *wiser* as player j and, the *agent* as player k. The payoff matrix of the game is:

$$\begin{array}{ccc}
\begin{array}{c|c|c|}
 & k=0 & k=1 \\ \cline{2-3}
j=0 & 1 & 0 \\ \cline{2-3}
j=1 & 0 & 0 \\ \cline{2-3}
\end{array}
& \qquad &
\begin{array}{c|c|c|}
 & k=0 & k=1 \\ \cline{2-3}
j=0 & 0 & 0 \\ \cline{2-3}
j=1 & 0 & 1 \\ \cline{2-3}
\end{array}
\\[2em]
i=0 & & i=1
\end{array}$$

One main question here is to analyze whether players coordinate the way they play in order to transmit information about nature's play from the wiser to the agent. The wiser aims to share private information with the agent in order to match nature. If both players could tacitly cooperate, then maximum payoffs are guaranteed for the team.

2.1 The repeated game

Sharing information becomes more likely in a repeated game framework. In such a context, players may share information in two different ways. On the one hand, the action taken by the wiser may endogenously convey a message about nature's play. This way the agent may decode the signal before taking her own action. In order to decode the signal, a translator of messages is needed say, a book of coding rules. On the other hand, players may exogenously share information if they were able to exchange opinions or comments between each other. A way of implementing such a possibility is by creating a kind of meeting space in which players are able to 'talk' and set rules that they will take into consideration later in the game. For the two types of information sharing to be possible, we add a cheap-talk first stage to our coordination game through an on-line chat program.

Let us consider the n-repetition version of our game with a cheap-talk first stage and the following information structure: Nature selects a sequence of n actions as the realization of n *i.i.d* random variables with law $(\frac{1}{2}, \frac{1}{2})$. Before the coordination game starts, the wiser is fully informed about the sequence of actions that nature will play. The agent knows just the law from which nature generates her actions. The timing of the game is as follows: first, the wiser and the agent explicitly send messages to each other through an on-line chat during a finite time; second, the wiser is informed about nature's actions; third, nature, wiser and agent play the coordination game described above for a number n of rounds. In each round, the wiser and the agent are aware of the actions taken by the two players and nature in the past.

Through the chat facility, players may fit together the strategies they will implement in the subsequent repeated coordination game. Presumably, the more sophisticated strategies are those containing more information, therefore implying more communication between players and higher payoffs. One can think of the following outcomes:

(1) The wiser and the agent exchange no information and, hence, there is no communication. In such a case, the wiser, with perfect information, may match nature's actions, whereas the agent, with no information, plays an action randomly with the same probability of occurrence $(\frac{1}{2})$. The expected common payoff is $\frac{1}{2}$.

(2) An alternative example of no communication transmissions is when the wiser plays nature's actions in every round and the agent plays either '0' or '1' in all rounds. By statistical properties of the *i.i.d.* process of nature, the expected common payoff is $\frac{1}{2}$.

(3) In the repeated version of the game, introducing communication may result in better expected payoffs. In this case, the wiser may choose to play nature's actual action at even rounds and nature's next action at odd rounds. Alternatively, the agent may play the action played by the wiser in the previous round at even rounds but play randomly at odd stages. The expected common payoff[1] in this case is $\frac{5}{8}$.

From GHN we know that the wiser may efficiently transmit information on line to the agent about nature's play. When the number of repetitions is large enough, the maximum the wiser and the agent can guarantee is the solution of the equation

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[1] Half of the times players match and get a payoff of 1, and half of the times they match with probability $\frac{1}{4}$. Therefore, $\frac{1}{2} \times 1 + \frac{1}{2} \times \frac{1}{4} = \frac{5}{8}$.

$H(x) + (1 - x) \log 3 = 1$ where $H(x)$ is the entropy function.[2]

The next section presents the experimental design and the hypotheses that we want to test.

3 Experimental design and testable hypotheses

The experiment was conducted at the experimental economics lab of the University of Valencia, Spain, (LINEEX). It was programmed using z-Tree (Fischbacher, 2007) and lasted about 45 minutes. Subjects were students/volunteers recruited from the third and fourth years in Economics, International Business, and Business Administration at the University of Valencia. The 180 experimental subjects were distributed across three independent sessions of 60 participants each: one (session 0) for treatment NC, and two sessions (1 and 2) for treatment C.

At the beginning of the session, subjects were randomly assigned to a seat in the lab, and given the written general instructions of the experiment. Before the actual experiment started, subjects performed several tests[3]. Additionally, subjects answered an *ad hoc* test of several questions about the game in order to test whether they understood how the incentives worked in the coordination game.

When the subjects were all grouped into pairs, each participant was randomly given her permanent role in the pair: type 1 or type 2. The participant labeled type 1 played the role of the wiser: the player who is fully informed about nature. The one labeled type 2 played the role of the agent: the player with historical information on the past actions of nature and the wiser. The pair then played a simultaneous game for 55 rounds. The pairs were kept constant throughout the experiment so it is plausible to assume no correlation across the decisions among pairs. At the end of the session subjects were paid in cash according to their performance in the experiment. Additionally, subjects were paid a show-up fee of 5 Euros for their participation. The average payoff was approximately 18 Euros.

The sequences of nature were generated at the beginning of each round by a random number generator simulating a '0' and '1' binary variable with a constant

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[2] Let x be a random variable over a finite binary set with distribution p. The entropy $H(x)$ of x is

$$H(x) = - \sum_{\theta \in \{0,1\}} p(\theta) \log_2 p(\theta)$$

where $0 \log_2 0 = 0$.

[3] In particular, they performed the Cognitive Reflexion Test (CRT) by Frederick (2005), and the Team Work Test (TWT) with twenty-five selected questions. In order to match the subjects in pairs, we used subjects' performance in the TWT to rank students from more to less collaborative.

probability of 0.5. Subjects were informed about the computerized random process as being like tossing a coin. Therefore, there were six different, independent sequences of nature (two sequences per session).

The experiment consisted of two treatments: a baseline NC without chat and a treatment C with chat. With the first treatment we test our first hypothesis:

H1: Inherent communication emerges when players share incentives.

In treatment C, a session was divided into two sections, both consisting of a pre-play chat stage and then playing the simultaneous game over 55 rounds. With treatment C, we aimed to address the second hypothesis:

H2: Wiser and agent as a pair are able to design explicit communication rules in order to match the actions of nature.

A key feature of our experimental design in treatment C is that, before playing the game, there is a pre-play stage of 3 minutes in which subjects are allowed to chat on-line. Participants could send messages to each other in order to share information and experience. Therefore, subjects were able to communicate, to coordinate their actions in order to earn as much as possible. The chat time started simultaneously for all pairs in the session, and even though subjects could close it before the end of the third minute, all pairs would start the game at the same time. Once the chat time finished, the sequence of nature was generated and privately transmitted to player type 1, the 55 rounds of the game started. A record with information about actions played in the past was available on the subjects' computer screen. At the end of each round, subjects were privately informed about their earnings in that specific round.

In order to have subjects with a solid understanding of the experiment, a pilot session of 8 periods was played by all participants before the real experiment started.[4]

4 Empirical analysis and main results

In this section we analyze the experimental data. We first provide a brief description of the sample, then follow with the statistical analysis of data, and finish with econometric analysis explaining the decision making of our experimental subjects. Specifically, we apply a one-way repeated measures ANOVA analysis to determine the importance of the on-line chat in the results.

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[4] Data from the pilot session are not part of the present analysis.

4.1 Communication between the wiser and the agent

A total of 30 subject-pairs constituted a session in our experiment. As already explained, a total of three sessions were run: sessions 0, 1 and 2 comprising, respectively, 32 males and 28 females, 34 males and 26 females, and 27 males and 33 females.[5]

The statistical analysis of the experimental data from treatment NC in which the players could only transmit information through their own actions, reveals our first main result:

Result 1: *Endogenous communication is found in treatment NC. Several subject-pairs make an attempt to coordinate their actions, thus improving their average payoffs.*

Table 1 shows the strategies followed by subjects in session 0. Plays 1 and 2 denote, respectively, the first and second sections of the session in which subjects actually play the game. The table shows the average payoffs earned and the number of pairs implementing each combination of strategies.

Table 1: Strategies performed in treatment NC, with average payoffs

Strategy		Type 1							
		Play 1				Play 2			
		Nature	obs.	1 mistake	obs.	Nature	obs.	1 mistake	obs.
Type 2	Pure	30.67	3	24.50	2	24.40	5	21.50	2
	Guessing	27.80	5	**31.60**	5	24.80	8	**27.60**	5
	Random	27.10	10	25.20	5	23.20	5	22.00	5

Strategies for players of type 1 are of two kinds: *'Nature'* if type 1 always matches nature, or *'1 mistake'* when type 1 makes a mistake, which may be intentional. Strategies for players of type 2 are classified into three categories: *'Pure'* if type 2 almost always plays the same action, *'Guessing'* when type 2 makes some guessing about the future actions of nature by looking at type 1's action, or *'Random'* if type 2 plays randomly. Figures in bold highlight the highest average payoffs, which correspond to the case where type 1 plays *'1 mistake'* and type 2 plays *'Guessing'*.

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[5] Although this gender distribution was not *ex ante* part of our design, analysis of the data reveals no significant gender differences among pairs in any of the sessions.

In the first play, 5 pairs played that specific combination and reached an average payoff of 31.60 ECU. Similarly, in Play 2, the highest average payoff of 27.60 ECU corresponded to the same type of combination of strategies. Presumably, with this strategy, type 1 tries to signal a change in course of action of nature, and type 2 understands types 1's implicit intention in 5 out of 12 rounds.

We therefore confirm our first hypothesis that subjects make an effort to communicate with each other tacitly. When implementing treatment C, we were asking for evidence about efficient exogenous communication. In other words, we expected that pairs use the chat time to define profitable coordination rules. Our data confirm not only the existence of endogenous communication through embodied messages in played actions, but also exogenous communication through explicit coordination rules held in the chat before playing the game. Consequently, by having the opportunity to propose and agree on certain strategies to be played during the game, subjects manage to improve their average payoff. This allows us to propose our second result:

Result 2: *Exogenous communication is found in treatment C. Explicit coordination rules between players improves average payoffs.*

Table 2 reports the descriptive statistics of the number of matches occurring in each treatment. The number of matches of sessions 1 and 2 for treatment C have been aggregated.

Table 2: Statistics on the number of matches, by treatment

Descriptive Statistics	Session 0 NC	Sessions 1-2 C
Obs.	60	120
Max.	33	44
Min.	12	18
Average	26.20	31.87
St.D.	4.01	5.70
CI(mean)	[4.22, 7.12]*	
CI(St.D.)	[0.32, 0.79]	

(∗) Sample Confidence Interval (CI) at 95% for H_0 of equal means

Observe first that the average number of matches is higher in treatment C (31.87) than in treatment NC (26.20). Furthermore, the dispersion in treatment NC (4.01) is significantly lower than the one observed in treatment C (5.70). Therefore, by the two-sample t-test for equal means with different variances, it can be concluded that there is a significant difference of means at the 95% confidence level ($[4.22, 7.12]$) in favor of exogenous communication. Overall, one can affirm that subjects made a profitable use of the explicit communication device by establishing payoff-enhancing strategies.

Remember that subject-pairs in both treatments play the game twice. Furthermore, subjects played against a random nature sequence before each Play. Table 3 shows the descriptive statistics of the number of matches by play within each session. With respect to session 0, the average number of matches is 27.83 out of 55 in Play 1 versus 24.57 in Play 2. In addition, the confidence interval for the equal means hypothesis at 95% is [-4.7824, -1.7508]. This allows us to claim that there is a significant difference in means between Plays 1 and 2 in treatment NC.[6]

Table 3: Statistics of the number of matches in each session, by play

Descriptive Statistic	Session 0 NC		Session 1 C		Session 2 C	
	Play 1	Play 2	Play 1	Play 2	Play 1	Play 2
Max.	33	31	37	44	42	41
Min.	16	12	18	21	21	18
Average	27.83	24.57	28.97	35.23	31.20	32.07
CI(mean)	[-4.7824, -1.7508]*		[3.901, 8.632]		[-1.219, 2.953]	
St.D.	3.39	3.96	4.83	5.38	8.24	5.69
Obs.	30	30	30	30	30	30

(∗) Paired-sample Confidence Interval (CI) at 95% for H_0: equal means

With respect to treatment C, in session 1 a significant improvement is observed in the average number of matches from Play 1 (28.97) to Play 2 (35.23), behind which is the effect of the exogenous communication via chat. Therefore, a chat effect is found in session 1. Although less important and not significant, the sign (i.e., positive implying a favorable effect on communication efficiency and negative implying a detractive effect) of the chat effect holds in session 2, where the average number of matches increases to 31.20 and 32.07 in Plays 1 and 2, respectively.

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[6] The standard deviation statistics are not statistically different (3.39 vs. 3.96). In fact, we do not reject the null hypothesis of equal variances.

The explanation for this difference between sessions 1 and 2 may be that subjects in both sessions made very similar use of the chat in Play 1 and they also played in a similar way. However, the second chat of a session is used differently. In fact, in comparison with session 1, subjects in Play 2 of session 2 wasted their chat time, by failing to develop new profitable strategies. Given the above data, it is necessary to further study in more detail the impact of chats on the behavior of individuals. In the next subsection we study the effect of nature's actions on how individuals make strategic use of communication.

We are interested in testing the effect in Play 2 of having played the game in Play 1, that is, the effect of repetition on the number of matches (dependent variable). Furthermore, since the 'chat-play' structure occurs twice in the sessions of treatment C, we test for a *chat effect* on the explicit communication efficiency. To this end, we apply a one-factor repeated measures ANOVA to each session of our experiment.

On the one hand, we denote as *Play* the repeated intra-subject factor for session 0, and as *Chat* this same factor for sessions 1 and 2. If significant, the intra-subject factor conveys that, on average, subject-pairs change their playing strategy from Play 1 to Play 2. In such a case, subject-pairs would develop different strategies in each Play, either by explicit agreements in the chat —in the case of sessions 1 and 2 —, by spontaneous signaling, or even guessing during the game. We obtain that, on average, subject-pairs' behavior changes from Play 1 to Play 2.

On the other hand, the inter-subject effect is named *Pair*. This effect allows us to test the hypothesis of differences, on average, between the strategies played by different subject-pairs. If significant, this effect captures the difference of strategic communication among pairs.

From this analysis our third result emerges:

Result 3: *Endogenous as well as exogenous communication are found. Average payoffs are positively affected by the pair's actions during the game as well as by the on line chat.*

Table 4 reports the F-test values and the corresponding p-values for ANOVA analysis. First, regarding session 0, both Pair and Play effects are statistically significant at the 5% level. In other words, in the absence of exogenous communication, pairs are able to develop different strategies, which they modify in each play phase. Second, at an aggregated level, in treatment C both the Pair as well as the Chat effect are significant at the 5% level. Notice that the Pair effect may be understood as a source of endogenous communication. Furthermore, the Chat effect is interpreted as evidence of exogenous communication.

Table 4: One-way Analysis of Variance, by treatment

Model	Session 0		Sessions 1-2	
	F	$Pr > F$	F	$Pr > F$
Play/Chat	19.43	0.0001	17.96	0.0001
Pair	2.30	0.0140	1.78	0.0146
Total Effect	2.88	0.0028	2.04	0.0033

We also perform the ANOVA analysis for each session in order to look for differences between sessions 1 and 2 that could be explained by random nature. In Table 5 we find a significant Chat effect for session 1, significant at 1%, but no Pair effect is found. Consequently, on average, subject-pairs in session 1 follow the same strategy, which is different in each play. In session 2, the opposite is found. In other words, no Chat effect but a strong Pair effect, significant at 1%, is observed. Thus, on average, subject-pairs in sessions 1 and 2 develop different strategies.

Table 5: One-way Analysis of Variance, by session

Model	Session 0		Session 1		Session 2	
	F	$Pr > F$	F	$Pr > F$	F	$Pr > F$
Play/Chat	19.43	0.0001	29.36	0.0001	0.72	0.4025
Pair	2.30	0.0140	1.61	0.1041	2.84	0.0032
Total Effect	2.88	0.0028	2.53	0.0072	2.77	0.0037

The next subsection is dedicated to the actions actually played by nature in our experimental sessions, and how, depending on the sequence played by nature, communication between subjects may be a complex strategic process.

4.2 The play of nature

Nature represents the unknown world for economic agents. In our setting, one player, *the wiser*, has perfect knowledge of nature, whereas the other player, *the agent*, who has only historical information. Nature is modeled as an *i.i.d* process that, once realized, the agents may find more or less predictable.

In the experiment, two sequences of length 55 per session were generated. That is, a total of six sequences $\{s_1, \ldots, s_6\}$ were generated by using a random number generator, just before the game started. These sequences, which are realizations of a $(\frac{1}{2}, \frac{1}{2})$ *i.i.d.* variable taking values 0 and 1, represent the random play of nature.

Concerning sequences, an important issue is randomness. In order to avoid any pattern and, consequently, the possibility of trivial communication, the sequences used in the experiment must be random. For instance, if nature's actions are always 0s (or 1s) then it is trivial for subjects to coordinate. Since our aim is to measure the efficiency in the communication process, it is necessary to eliminate the trivial scenarios. Therefore, we test for randomness and, as shown in the next subsections, the six sequences generated in our experiment were random enough to accept the hypothesis of coming from a random process.

4.2.1 Strategic behavior against nature's actions

In general, for a given realization of nature, different coordination rules (strategies) may get the same payoff. On the contrary, a specific rule may result in different payoffs depending on the realization of nature's play. Coordination rules are explicitly agreed among players in some 'physical space', which in the experiment is the chat platform, and are then implemented during the game. There are as many coordination rules designed to communicate nature's play as players are able to imagine. Nevertheless, what makes the difference is the quality of the rule in the sense of how much information is transmitted through a specific rule. We consider low quality rules and high quality rules, which permits us to distinguish between two different communication levels.

The first level consists of strategies with no communication at all, that is, in their strategies, players do not take each other into account. We are able to identify extreme strategies. On the one hand, the worst possible strategy: *both players play random balanced sequences.* As a result, the average number of nature-wiser-agent matches is $\frac{1}{4}$ times the length of the sequence. The average payoff is $\frac{1}{4}n$, where n is the length of sequence, which is exactly 13.75 ECU. On the other hand, smarter subjects use the best possible strategy: *the wiser matches nature, and the agent plays the same action, either 0 or 1.* There are many other strategies with no exchange of information such as, for instance, the one in which the wiser matches nature's sequence and the agent plays 111000, 110011, 101010, and so on and so forth.

The second level of communication conveys strategic behavior, that is *active* players may implement strategies by using some kind of signaling. As already agreed at the chat stage, the wiser may, on purpose, make a mistake, with this mistake acting as an informative signal for the agent. Therefore, a code is established between players, which constitutes exogenous communication in itself. What happens is that the wiser cuts the sequence of nature into pieces of equal or different sizes. The mistake can be interpreted as saying to the agent: ‘change the action’, since the wiser knows it, she says that nature will play this new action a large number of rounds. Therefore any payoff starting on the best possible no communication strategy until the optimal payoff of this game should imply this strategic behavior. The theory provides a bound for communication success when nature plays a $(\frac{1}{2}, \frac{1}{2})$ *i.i.d* sequence. The theoretical optimal block strategy for a 55-length sequence is to divide the whole sequence into 3-length blocks and make an intentional mistake to communicate the majority rule of the next block. Consequently, the theoretical optimal bound[7] is 45.85.

4.2.2 Evidence from the experimental data

In this subsection, we first check whether the realization of the sequences used in the experiment can be considered as coming from a random process. In order to know how random a sequence is, we use the Wald-Wolfowitz runs test for Randomness (WWR) performed under the null hypothesis that the sequence is random. The classical definition of a run, say, of 0s, is a series of one or more 0s, which is followed and preceded either by 1 or by no symbol at all.[8] The test statistic U is defined as the total number of runs of 0s and 1s in the entire sequence.[9]

Table 6 reports the values of the z-test and the corresponding p-values for the six sequences generated in the experiment. The high p-values mean that we can accept the randomness of the sequences with negligible error. Randomness ensures no time patterns in the sequences of nature and, consequently, that the current actions in the course of play cannot be determined in advance. Notice that if a sequence is

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[7] A complete study of this bound is available from the authors upon request.

[8] For instance, in the sequence 0010110000, there are three runs of zeros: 0, 00, and 0000, and two runs of ones: 1, and 11.

[9] The asymptotic sampling distribution of a standardized U is the normal probability function. The mean of U is $(1 + 2n_1 n_0/N)$ and the standard deviation is $\sqrt{\frac{2n_1 n_0(2n_1 n_0 - N)}{N^2(N-1)}}$, n_1 being the number of 1s, n_0 the number of 0s, and $N = n_1 + n_0$. U is standardized, and since U takes only integer values, a continuity correction of 0.5 is introduced. Thus, the z statistics are defined as follows:

$$z_L = \frac{U + 0.5 - 1 - 2n_1 n_0/N}{\sqrt{\frac{2n_1 n_0(2n_1 n_0 - N)}{N^2(N-1)}}}; \quad z_R = \frac{U - 0.5 - 1 - 2n_1 n_0/N}{\sqrt{\frac{2n_1 n_0(2n_1 n_0 - N)}{N^2(N-1)}}}$$

$$z = \begin{cases} -z_L & if \quad (U < 1 + 2n_1 n_0/N) \\ z_R & if \quad (U > 1 + 2n_1 n_0/N) \end{cases}$$

Table 6: Wald-Wolfowitz runs test for Randomness (WWR)

Magnitude	Sequences of nature					
	s_1	s_2	s_3	s_4	s_5	s_6
No of 1s (n_1)	23	**32**	26	**31**	**34**	26
No of 0s (n_0)	**32**	23	**29**	24	21	**29**
No of runs of 1s	12	15	13	12	11	10
No of runs of 0s	13	15	13	13	10	10
U=n_0+n_1	25	30	26	25	21	20
z-test	-0.633	0.485	-0.523	-0.707	-1.577	-2.161
p-value	0.526	0.627	0.602	0.479	0.116	0.029

H_0: The sequence is random (two sided test at the 95% confidence level).

the realization of a uniform binary random variable, the best one can do to match such a sequence is to play either 0 always or 1 always. As the realization of n times the random variable may not be fair, for each specific realization in each section the maximal number of matches is obtained by playing the most favorable action. Figures in bold in Table 6 correspond to the number of matches of the best strategy with no communication in each session.

Next we determine the numerical bounds of communication for the specific realizations of the sequences of nature in our experimental sessions. Notice that the lower bound for no communication strategies and the upper bound for communication strategies depend on the length of sequence only, and they are 13.75 and 45.85, respectively.

Finally, we classify the communication strategies established by subject-pairs from less to more sophisticated. To do this, we conduct qualitative as well as quantitative analysis. In order to perform the qualitative analysis of the chats, we carefully read each conversation held by each subject-pair. Interestingly, we find that pairs use intelligible language, which makes it easy to identify agreed strategies. In the first chat of session 1, most of the pairs define a *pure strategy*, and only a few pairs think of some kind of signaling to match nature as much as possible. Hence, we classify communication strategies in two levels: level 0 (L_0) and level 1 (L_1). The former is related to the already mentioned no communication strategies: 'always 0', 'always 1', 'at random', 'fixed sequence', etc. Table 7 reports the first chat of pair 1 in session 1 as an example of an L_0 strategy. The sentence '*We should always take the same value over 55 rounds*' defines a pure strategy. Strategies L_1

involve agreed changes of actions. For instance, as shown in table 8, subjects in pair 1 agree on an L_1 strategy by stating '*Let's start with 1 and when I see that you change, I will also change*'. Upper levels of communication involving intended mistakes to signal the action to be played next round were found only in 2 out of 30 subject-pairs' strategies. For instance, a pair wrote: '*When I make a mistake, I am saying that the numbers that will follow are my last action*'. Notice that this kind of behavior is the key for implementing optimal strategies à la GHN. In their construction, the wiser and the agent create a code such that the mistakes are used as signals for future nature actions. Therefore, the use of mistakes coincides in both approaches —the theoretical and the experimental —as the proper mechanism to transmit information.

Table 7: Example of L_0 in treatment C (pair 1, session 1, chat 1)

Chat 1	
agent:	Hi
type 1:	Hi
	Should we both take the same option?
agent:	I think, **we should always take the same value over 55 rounds**, shouldn't we?
type 1:	Yes, I think so
agent:	Yes
type 1:	Which one?
agent:	It doesn't matter to me
type 1:	Me neither
agent:	Option 1, then?
type 1:	Ok
agent:	Ok
type 1:	Ok. 55 rounds of 1s.
agent:	Perfect! then 55 rounds with the number 1.
type 1:	To win as much money as possible.
agent:	I hope so. Good luck!!
type 1:	Me too. Good luck !!
agent:	Any time!!
	Bye
type 1:	Bye

The findings in session 1 of treatment C show some discrepancies between the strategies agreed on during the chat and the ones actually played. Although most pairs (24 out of 30) implemented the strategy agreed on in the chat, several subject-pairs were able to redefine it while playing the game in order to reach higher profits.[10]

In Play 1, four out of 30 teams played a more sophisticated strategy than the

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[10] In Appendix 2, Tables 12 to 15 give summaries of the strategies played in treatment C.

Table 8: Example of L_1 in treatment C (pair 1, session 1-chat 2)

Chat 2	
type 1:	Hi
agent:	Hi
type 1:	Before, were you type 1 or 2?
agent:	2
	you?
type 1:	1
	Did you know what your partner chose?
	When the round finished
agent:	Yes, we both wrote the same number
	Is it the same as before?
type 1:	Didn't you see if we matched with the computer?
agent:	Yes, I saw
	I saw we both wrote number 1
type 1:	When you see that I change the number, it is because
	a large number of 0s follows, Ok?
agent:	Ok
type 1:	And when you see that, I am going change
agent:	And when I see that you change, should I change too?
type 1:	We change to 0 because there is a run of 0s
	understood?
agent:	Very well
	And when will I know that 1 is back; because you change again, right?
type 1:	Because there were at least 8 zeros together
agent:	Yes, I saw it
type 1:	And on choosing 1 we didn't match the computer
agent:	Yes
	Let's start with 1 and when I see that you change, I will change too.
type 1:	Ok, we always choose 1 until you see that I change and write 0
	and if I change, we write 1 again.

one agreed on during the chat: in particular, they agreed to an L_0 strategy but played an L_1 one, which involves signaling. Likewise, in Play 2, two pairs played a different level communication strategy from the one agreed to in the chat. It is remarkable that two subject-pairs obtained lower payoffs than those corresponding to the strategy agreed on in the chat. Despite playing the agreed L_1 strategy, their real gains belonged to an L_0 interval due to *over-signaling* and *bad coordination* between players.

As far as session 2 of treatment C is concerned, no discrepancies are found, which means that no subject-pair deviates from the strategy agreed to during the chat.

We now classify the strategies by applying a quantitative approach. First, we define the experimental communication intervals from the actually played strate-

Table 9: Discrepancies between agreed and played strategies (treatment C, session 1)

Pair	Strategy	Description
6	Agreed:	Pure strategy of 1s.
	Played:	By default 1, change to 0 when there is a run.
9	A:	Pure strategy of 0s.
	P:	By default 1, the agent sometimes changes when type 1 changes.
16	A:	Pure strategy of 1s.
	P:	By default 1, change to 0 when there is a run.
24	A:	Pure strategy of 0s.
	P:	Communicate one stage and then a pure strategy.
27	A:	Pure strategy of 0s.
	P:	By default 1, change to 0 when there is a run.
29	A:	Agent proposed a signaling strategy, type 1 did not follow it.
	P:	Pure strategy of 1s.

gies. These intervals are directly related to nature sequences. Let $(x_1, \ldots, x_{55})$ be a sequence of nature. Define the experimental no communication interval $L0$ as $(\min\{\sum_{i=1}^{55} x_i, 55 - \sum_{i=1}^{55} x_i\}, \max\{\sum_{i=1}^{55} x_i, 55 - \sum_{i=1}^{55} x_i\})$. Notice that the lower and the upper bounds depend on nature's actions. In contrast, the optimal communication interval does not depend on these bounds but rather on the length of sequence. The theoretical optimal block strategy for any balanced 55-length sequence is to divide the whole sequence into 3-length blocks and intentionally make a mistake to indicate the most repeated event over the next block. This strategy produces average payoffs within the interval $[36.67, 45.83]$[11].

As previously mentioned, subjects frequently design sophisticated strategies, which produce higher average payoffs than non-communication ones, although hardly optimal, which is not surprising because the design of optimal strategies is not trivial. Therefore, we consider that there exists an attempt to communicate information when players agree a signaling rule in an attempt to match nature's actions. The eventual success of the rule depends on the information transmitted and the sequence played by nature. Define $L1$ as the interval for communication: *the pair changes its joint action by a previous signal from the type 1 player*. It is important to stress

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[11] The theoretical optimal interval is computed as per GHN (2006).

that the interval depends on the final realization of nature and on the strategic use of information. Therefore, the spanning interval may vary for each session and play.

Table 10: Experimental Intervals of Communication

Bounds	Session 0		Session 1				Session 2			
	Play 1	Play 2	Play 1		Play 2		Play 1		Play 2	
	L_0	L_0	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1
Lower	23	23	26	30	24	34	21	33	26	30
Upper	32	32	29	37	31	44	34	42	29	41

$L0$: interval with no communication.

$L1$: interval with communication.

Remember that in session 0 subjects implemented L_0 strategies, whereas in sessions 1 and 2, they could also implement L_1 strategies thanks to the chat. In light of this, it should be mentioned that several subjects in session 0 had an intuition as to the benefit of communication and tried to coordinate with their partners via actions signaling a change of future events of random nature. As stated before, our data show that there are some subject-pairs that implemented almost optimal strategies. They get a payoff varying within the range $[41, 44]$. The examination of experimental intervals of communication provides our fourth result:

Result 4: *Experimental subjects efficiently use the chat to exogenously communicate and reach agreements on earnings.*

Differences between session 1 and 2 are reported in Table 11. The first result observed is that the minimum values registered at level L_0 are less than the corresponding experimental lower bound but bigger than 13.75, which indicates the poor strategic behavior of subject-pairs operating at level L_0. In session 1, Play 1, 19 out of 30 pairs did not transmit any information, which implies that the average number of matches (25.89) lies slightly below $L0 = [26, 29]$. The number of matches of the remaining pairs ranges from 30 to 37, which means an average of 34.27, thus classified within $L1$. Note that in Play 2 of the same session, 21 out of 30 subject-pairs play $L1$ strategies getting an average number of matches of 38.28. In addition, two of them play nearly optimal strategies producing an average of 42.50.

In relation to session 2, some differences emerge. On average, numbers in Play 1 are a bit higher than in Play 2. However, the number of pairs that use strategies L_1 increases from 6 in Play 1 to 13 in Play 2, which can be interpreted as a positive chat effect. Surprisingly, we also realize that, in this session, pairs may have been victims of what we call the *wealth effect.* That is, subjects get high enough payoffs so that, presumably, they do not want to make an additional effort in the second part of the session.

Table 11: Descriptive statistics of the communication levels in treatment C

Number of matches	Session 1				Session 2			
	Play 1		Play 2		Play 1		Play 2	
	L_0	L_1	L_0	L_1	L_0	L_1	L_0	L_1
Max.	30	37	32	44	36	42	36	41
Min.	18	30	21	34	21	33	18	30
Average	25.89	34.27	28.11	38.28	29.61	37.33	28.65	36.54
St.D.	2.51	2.72	3.33	2.22	4.62	2.94	4.37	3.82
Obs.	19	11	9	21	24	6	17	13

5 Final remarks

Communication is fundamental in any aspect of life. In fact, through communication we reveal and receive information that allows us to take decisions according to our preferences. To the best of our knowledge, the present study is the first work on communication applied to economics that studies endogenous as well as exogenous communication in the lab. Endogenous communication is inherent to human behavior. It is the implicit message in the sender's actions, that the receiver gives meaning depending on her own subjective understanding, or experiences in similar circumstances. Exogenous communication involves both external devices or channels to transmit information, and above all a code of communication code, which ensures that the meaning of the message is understood by both sender and receiver.

From the premise that communication always exists in some form, the main purpose of the paper is to investigate how efficient the communication process is when coordination of actions is required in order to obtain higher payoffs (aligned incentives). To differentiate between endogenous and exogenous communication, our experimental design includes two treatments: a baseline in which only endogenous communication is possible, and a treatment which allows each subject-pair to share information and agree on coordination rules during an online chat prior to the game.

Our main findings can be summarized thus. (1) There is endogenous communication. In the baseline, there are several subject-pairs who try to coordinate their actions. Type 1 player with full information signals to her partner through her actions when she makes a mistake. Type 2 player makes some guesses to the meaning of these signals and decides to play her partner's action up to the point of observing a new change. (2) There is exogenous communication. When subjects are allowed to chat, they define communication strategies to transmit information in the course of the game, aimed at enhancing coordination and improving average payoffs. (3) Both endogenous and exogenous communication have an influence on obtaining higher payoffs. We detect a team or inter-subject effect, as well as a chat or intra-subject effect by using one-way analysis of variance. We associate these two effects to endogenous and exogenous communication, respectively. (4) The efficient use of the chat tool implies explicit communication leading to better average payoffs. The existence of a chat facility allows subjects to face the complexity of sequences played by nature by designing more sophisticated communication strategies and, therefore, developing more aware and strategic behavior to get better payoffs. These strategies implemented by subjects who transmit information and get higher payoffs are in line with GHN strategies

This last observation highlights a need for further research. How complexity may affect the way subjects learn and play remains an open question.

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7 Appendix 1: Instructions for Experimental Subjects (translated from Spanish)

You are going to participate in an experimental session that will give you the possibility to earn some money in cash. How much money you will ultimately take will depend on luck and your and others' decisions. Please switch off your mobile phone and leave your things to one side. For your participation in the session you need just the instructions and the computer on your desk. Please raise your hand if you have any questions, and one of us will see to it privately.

In this experiment, you will be paired with another participant, who will not change throughout the session. A pair is composed of two types of participants: 'type 1' and 'type 2'. At the beginning of the session, the computer will randomly assign you a role and display it on your screen. The experiment is divided into two plays of 55 rounds each. At the beginning of each play, the computer will randomly determine, for every round, a value that may be either 0 or 1. This value will be called 'Prize'. In each round, the probability that the Prize is associated to 0 or to 1 is exactly the same: 50% (it is like tossing a coin). Each of value will determine your earnings in each round, according to the following rules.

Each round, your decision making consists of choosing either 0 or 1. In each pair, the two participants simultaneously choose either 0 or 1 taking into account that:

- If the decisions of both participants coincide with the Prize, they both get 1 ECU each in that round.

- If at least one decision within the pair does not coincide with Prize, then both get nothing in that round.

At the beginning of each block, you will have 3 minutes to communicate with your partner through a chat. You can end the chat at any time before the end by clicking on the option 'Exit from the chat'. Every message sent through the chat will be recorded and carefully analyzed by the those conducting the experiment. At the end of each round, your screen will display information concerning the value of the 'Prize' (0 or 1), the decision of your partner (0 or 1) and your own decision in that round.

To be 'type 1' or 'type 2' has consequences:

- If you are 'type 1', at the beginning of each block of 55 rounds, and after using the chat to communicate with your partner, you will be aware of the sequence of values of the Prize that corresponds to that block.

- If you are 'type 2', you will be aware of the value of the Prize at the end of each round.

Moreover, participant 'type 2' knows that participant 'type 1' will be aware of the values of Prize for each block just after the chat time. Type 1 knows that type 2 will have that information at the end of each round.

Earnings

At the end of each block, the participants in the experiment will know the number of winning rounds. At the end of the session, you will be paid your total payoff in cash, that is, the total number of rounds (in the two blocks of 55) in which you won the prize of 1 ECU. The exchange rate between ECUs and Euros is 1 ECU=1/4 Euro.

8 Appendix 2: Chat dialogs in treatment C

Table 12: Agreed and played strategies in treatment C, session 1, play 1

Pair	Chat	Communication Level	Description
1	L0	L0	Pure strategy to 1s.
2	L1	L1	1 by default, type 1 changes to 0 when there is a run of 0s and type 2 changes too.
3	L0	L0	Pure strategy: 25 to 0s and 30 to 1s.
4	L0	L0	Pure strategy: 101010...10.
5	L0	L0	Pure strategy to 1s.
6	L0	L1	They start with 1 and change when they see runs.
7	L0	L0	At random.
8	L0	L0	Type 1 match nature, type 2 plays randomly.
9	L0	L0	Pure strategy to 1s.
10	L1	L1	Majority of 55-length blocks.
11	L1	L1	First 25 are 1s, next 25 are 0s, and 5 remaining randomly.
12	L1	L1	Majority of 55-length blocks.
13	L1	L1	Type 1 makes a signal when there are runs.
14	L1	L1	0 by default, they change when there is a series such as 1111.
15	L1	L1	When there are a lot of 1s or 0s they make a change.
16	L0	L1	Start with 1 and change when there exist runs.
17	L0	L0	A pure strategy: 010101...01.
18	L0	L0	A pure strategy of 1s.
19	L1	L1	2-length blocks.
20	L0	L0	No coordination, they do not follow the same strategy.
21	L0	L0	A pure strategy: 1111100000...1111100000.
22	L0	L0	A pure strategy of 0s.
23	L0	L0	A pure strategy: 1100110011...0011.
24	L0	L1	Communication one stage and then a pure strategy.
25	L0	L0	A pure strategy of 1s.
26	L0	L0	A pure strategy of 1s.
27	L0	L1	Start with 1 and change when there exist runs.
28	L0	L0	A pure strategy: 000111...000111.
29	L0	L0	A pure strategy of 1s.
30	L0	L0	A pure strategy: 1111100000...1111100000.

Table 13: Agreed and played strategies in treatment C, session 1, play 2

Pair	Chat	Commun. Level	Description
1	L1	L1	1 by default, they change to 0 when there exist a lot of 0s.
2	L1	L1	1 by default, they change to 0 when there exist a lot of 0s.
3	L0	L0	A pure strategy: 000111…000111
4	L1	L1	1 by default, they change to 0 when there exist more than three 0s in a row.
5	L1	L1	1 by default, they change to 0 when there exist a lot of 0s.
6	L1	L1	1 by default, they change to 0 when there exist a lot of 0s.
7	L0	L0	Type 1 always matches nature, type 2 changes when type 1 changes.
8	L2	L2	They use mistakes to signal the following action when there exist 3-or-more-length blocks.
9	L0	L1	1 by default, type 2 sometimes changes when type 1 changes.
10	L1	L1	Type 1 changes, then type 2 changes.
11	L1	L1	25 zeros, the rest to 1s.
12	L1	L1	Type 2 takes the action taken by type 1 at the previous stage.
13	L1	L1	Signaling changes when there exist large runs.
14	L1	L1	When type 1 changes to 0, type 2 changes too.
15	L1	L1	Type 2 follows type 1.
16	L1	L1	1 by default, when type 1 changes to 0, type 2 changes too.
17	L1	L1	At the first stage, type 1 communicate the most repeated number and then type 2 follows type 1.

Table 14: (cont.) Agreed and played strategies in treatment C, session 1, play 2

Pair	Chat	Commun. Level	Description
18	L2	L2	At positions 1, 20, and 38, type 1 writes the most repeated number in the row, and type 2 plays it.
19	L1	L1	2-length blocks, one mistake and one match.
20	L0	L0	A pure strategy: 1100 . . . 1100.
21	L0	L0	A pure strategy: 1111100000 . . . 1111100000.
22	L1	L1	Type 1 changes, type 2 changes too.
23	L1	L0	1 by default, type 1 changes and type 2 changes too.
24	L1	L1	Type 1 changes, type 2 changes too.
25	L1	L1	Start with 1, and when type 1 changes, type 2 changes too.
26	L1	L0	1 by default, the change to 0 when there exist a lots, but they do not coordinate well.
27	L1	L1	A value by default, type 1 changes to gain more.
28	L0	L0	A pure strategy: 000111 . . . 000111.
29	L1	L0	A pure strategy: type 1 matches nature, type 2 always plays 1.
30	L0	L0	A pure strategy: 1111100000 . . . 1111100000.

Table 15: Played strategies in treatment C, session 2, play 1

Pair	Communication Level	Description
1	L0	Type 1 matches nature, type 2 plays randomly.
2	L0	A pure strategy of 0s.
3	L0	A pure strategy to 1s.
4	L0	A pure strategy: 0000011111. . . 0000011111.
5	L0	Type 1 matches nature, type 2 plays randomly.
6	L1	Type 2 changes when type 1 changes.
7	L0	A pure strategy of 0s.
8	L0	A pure strategy: 1010. . . 101010.
9	L0	A pure strategy of 0s.
10	L0	A pure strategy: 001, 010, 100, 000.
11	L0	A pure strategy of 0s.
12	L1	0 by default, they change to 1 when type 1 sees 011.
13	L0	Type 1 matches nature, type 2 plays randomly.
14	L1	1 by default, they change to 0 when type 1 sees 00.
15	L0	Type 1 matches nature, type 2 plays randomly.
16	L0	Type 1 matches nature, type 2 plays randomly.
17	L0	Type 1 matches nature, type 2 makes a pure 1100. . . 1100.
18	L0	A pure strategy of 0s.
19	L0	A pure strategy: 0011. . . 0011.
20	L1	Start with 0, type 1 changes to 1, type 2 changes to 1.
21	L0	Type 1 matches nature, type 2 plays 0 all time.
22	L0	A pure strategy of 1s.
23	L1	Type 1 changes to 0 to indicate that 00 follows.
24	L0	A pure strategy: 01010101.
25	L0	Type 1 matches nature, type 2 plays randomly.
26	L0	Type 1 matches nature, type 2 plays a fixed number.
27	L0	A pure strategy of 0s.
28	L0	At random.
29	L1	2-length blocks, one mistake.
30	L0	Type 1 matches nature, type 2 plays 1.

Table 16: Played strategies in treatment C, session 2, play 2

Pair	Commun. level	Description
1	L0	Type 1 matches nature, type 2 plays randomly.
2	L0	A pure strategy: 0000011111…0000011111.
3	L1	Start with 1, type 1 changes to indicate a large round, and type 2 changes.
4	L0	A pure strategy: 0000011111…0000011111.
5	L0	Type 1 matches nature, type 2 plays randomly.
6	L1	Type 2 changes when type 1 changes.
7	L0	Type 1 matches nature, type 2 plays 000111…000111.
8	L0	A pure strategy: 10…10.
9	L0	A pure strategy of 1s.
10	L0	Type 1 matches nature, type 2 plays 000111…000111.
11	L1	Majority for unequal length blocks.
12	L1	Type 1 makes 11 to indicate a change to 1.
13	L0	Type 1 matches nature, type 2 plays randomly.
14	L1	1 by default, type 1 changes to 0, and type 2 changes too.
15	L0	Type 1 matches nature, type 2 plays randomly.
16	L0	Type 1 matches nature, type 2 plays randomly.
17	L0	Type 1 matches nature, type 2 makes a pure 1100…1100.
18	L1	Majority for 55-length block.
19	L1	Type 1 makes a mistake to indicate next action to be played.
20	L1	Start with 0, type 1 changes to 1, type 2 changes to 1.
21	L1	Type 1 changes to indicate a new large round.
22	L1	Type 1 changes to indicate a new large round.
23	L1	Type 1 changes if it follows 11111 or 0000.
24	L0	A pure strategy: 01…01.
25	L0	Type 1 matches nature, type 2 plays randomly.
26	L0	Type 1 matches nature, type 2 plays randomly.
27	L0	A pure strategy of 1s.
28	L1	Type 1 make a mistake for type 2 to change.
29	L1	2-length blocks, one mistake to signal.
30	L0	Type 1 matches nature, type 2 plays randomly.