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Information transmission under an experimental approach

DOCTORAL DISSERTATION

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To my family

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Chapter 1: New evidence on efficency in Spanish stock futures market

The aim of this first chapter is to provide new evidence on efficiency in the Spanish stock futures market during the period 2001-2010. An autocorrelation analysis is conducted on equal-weighted index portfolios, volume-weighted index portfolios and individual futures contracts, revealing the existence of negative autocorrelation in the short term of one week. In order to exploit arbitrage benefits coming from that time series pattern, a set of trading strategies *á la Conrad and Kaul* is constructed for each weekday. The empirical evidence shows that such arbitrage opportunities do not obtain statistically significant returns. Thus, it allows to conclude the fulfillment of the weak efficiency hypothesis.

El objetivo de este primer capítulo es presentar nueva evidencia sobre la eficiencia del mercado español de futuros sobre acciones durante el período 2001-2010. Para ello, nos servimos del análisis de correlación realizado sobre carteras índices igualmente ponderadas y ponderadas por volumen, así también sobre contratos de futuros individuales. Este análisis revela la existencia de autocorrelación negativa en el corto plazo de una semana. Para explotar el beneficio del arbitraje procedente del patrón de fuente temporal, construimos un conjunto de estrategias de negociación *á la Conrad and Kaul* para cada día de la semana. La evidencia empírica muestra que tales oportunidades de arbitraje no producen rentabilidades estadísticamente significativas. De manera que el presente estudio nos permite concluir el cumplimiento de la hipótesis de eficiencia débil.

Chapter 2: An experimental online matching pennies game

This second chapter is devoted to Communication theory from an economic viewpoint. In particular, we analyze the theory by Gossner, Hernández and Neyman (2006) on the optimal use of communication resources. To our knowledge, we are first in to contrast that theory in the setting of experimental economics laboratory. Like in their article, random nature decides on an —i.i.d. procedure—, the wiser is a fully informed player, and the agent is a less than the wiser informed player. Players get 1 when their actions match nature's actions, and 0 otherwise. We test in the lab a finitely repeated version of this game. Our main concern is to question the model's robustness to explain the subjects' behavior in a lab environment, emphasizing the transmission of information among players with aligned incentives. The work presented in this chapter contributes to characterize the optimal structure of the equilibrium strategies of the set up under consideration. Also, we establish the length of the sequence of the experimental game for which the players' optimal strategy is the majority rule, considering a minimal length of 3. Experimental findings give support to the theoretical results in Gossner, Hernández and Neyman (2006).

Este segundo capítulo está dedicado a la Teoría de la comunicación desde un punto de vista económico. En particular, analizamos la teoría propuesta por Gossner, Hernández and Neyman (2006) sobre el uso óptimo de los recursos de comunicación. En lo que nosotros conocemos, este es el primer estudio dedicado a contrastar dicha teoría en el entorno de un laboratorio de economía experimental. Como en el artículo original, la naturaleza aleatoria sigue un —proceso i.i.d —, el sabio es un jugador completamente informado y el agente es un jugador imperfectamente informado. Los jugadores ganan 1 cuando las sus acciones coinciden con las acciones de la naturaleza y 0 en otro caso. Nosotros testamos en el laboratorio una versión repetida de este juego. Nuestro principal interés es cuestionar la robustez del modelo para explicar el comportamiento de los sujetos en un laboratorio, enfatizando la transmisión de información entre los jugadores con objetivos alineados. El trabajo presentado en este capítulo contribuye a caracterizar la estructura óptima de las estrategias de equilibrio en el contexto considerado. También, establecemos la longitud de la secuencia del juego experimental para el cual la estrategia óptima de los jugadores es jugar la acción mayoritaria —majority rule —, considerando una longitud mínima de 3 etapas del juego repetido. La evidencia experimental soporta los resultados teóricos de Gossner, Hernández y Neyman (2006).

Chapter 3: Words and actions as communication devices

This third chapter is thought as an application of Gossner, Hernández and Neyman's (2006) model. We explore the role of communication from two different sources: tacit communication and explicit communication. Tacit communication emerges from the players' non-verbal behavior in the course of a repeated game, whereas explicit communication is established in an ad-hoc pre-play phase or chat-phase. GHN's model offers an useful framework to analyze those two sources of communication. Thus, two treatments are implemented, one without chat (NC) and one with chat (C) in which players may first send messages and then play the game. Experimental data show some tacit communication in treatment NC, although it is difficult without some previous conventions. When players have the possibility to send messages through chat, we find payoffs that can only be reached when communication, both tacit and explicit, takes place. Using different criteria, we show that there is explicit communication *á la GHN* by using signaling mistakes.

Este tercer capítulo consiste en una aplicación del modelo de Gossner, Hernández y Neyman (2006). Analizamos el papel de la comunicación prodecente de dos fuentes diferentes: comunicación tácita y comunicación explícita. La comunicación tácita emerge del comportamiento no verbal de los jugadores en el curso de un juego repetido, mientras que la comunicación explícita se produce en una fase previa al juego mediante un chat online. El modelo de Gossner, Hernández y Neyman (2006) ofrece una estructura útil para analizar estas dos fuentes de comunicación. A tal fin, implementamos dos tratamientos, uno sin chat (NC) y otro con chat (C) en el cual los jugadores primero envían mensaje y luego juegan el juego repetido. Los datos experimentales muestran algo de comunicación tácita en el tratamiento NC, aunque entenderse es difícil sin alguna convención previa. Cuando los jugadores tienen la posibilidad de enviar mensajes através del chat, consiguen pagos que sólo pueden ser alcanzados con ambos tipos de comunicación. tácita y explícita. Adicionalmente, empleando diferentes criterios de clasificación de los pagos conseguidos por los jugadores, mostramos que existe comunicación explícita *á la Gossner, Hernández y Neyman* utilizando un mecanismo de comunicación basado en la señalización mediante errores.

Chapter 1

New evidence on efficiency in Spanish stock futures market

1.1 Introduction

The term *overreaction* applied to financial asset prices was first introduced by DeBondt and Thaler (1985). In essence, it implies some kind of mispricing in excess by investors in financial markets. These authors implemented a plain trading rule known as contrarian strategy. It is based on making up a portfolio composed by assets (stocks) which have been previously classified as winners or losers. If the overreaction hypothesis is true then higher (lower) past return assets should experiment a reduction (increase) of their future return. Thus, a portfolio buying past losers and selling past winners should yield a positive mean return. DeBondt and Thaler found the contrarian strategy was profitable in the long-term (3-5 years). Likewise, Jegadeesh (1990) and Lehmann (1988) presented evidence on profitable contrarian strategies in the very short-term (1 week and 1 month). However, in the intermediate-term, it appears that investors underreact to news, which may make profitable the momentum strategy: buying past winners and selling past losers. These two empirical evidences are linking with negative (positive) serial correlation exhibited by asset prices. Lo and MacKinlay (1988), concerned about the potential sources of short-term contrarian profits, analysed US weekly stock prices, by a decomposition process in order to determine a lead-lag effect or an overreaction to firm specific information as a primary source of such profits. Their findings indicate that the first effect generates more than 50 percent of profits and the last has a minor importance.

The controversy continues with the study by Jegadeesh and Titman (1995). By employing an alternative methodology on stocks traded in New York and American Stock Exchanges, they determine that the profitability of contrarian strategies comes mostly from an overreaction to firm specific information. A similar conclusion on the momentum strategy is reached by studies developed in the Spanish Stock Market. Forner and Marhuenda (2006) analyse the sources of profits yield by Jegadeesh and Titman (1993) momentum strategy implemented on Spanish stocks during the period 1965-2000. The strategies are built up for periods of formation and holding ranging from 3 to 12 months length. This work highlights the existence of momentum phenomenon in the Spanish stock market, by explaining the under-reaction of stock prices to the specific components in returns. In Forner and Marhuenda (2003), the authors find that the 12-month momentum strategy and the 5-year contrarian strategy yield significant positive returns, even after adjustments for risk have been made. Other explanations of short-term contrarian profits are: measurement errors such as those induced by bid-ask bounce, firm size effects, time varying market risk, seasonality effects, trading volume, and transaction costs.

Although there is growing empirical evidence of profitable short-term strategies on stock markets, only few studies lead this concern to futures markets. Lin et al. (1999) examine the existence of weekday patterns in short-term contrarian profits in futures markets. The sample used consists of currency, financial and commodity futures contracts. They find that, on average, contrarian profits are the largest on Friday, followed by those on Wednesday, and the smallest on Monday. On a similar line, Wang and Yu (2004) examined the profitability of contrarian strategy based on weekly returns of 24 futures contracts traded on United States Markets. Currency, financial, agricultural and commodity futures contracts are included in the sample. This work shows the negative serial dependence in returns of individual futures contracts as the only source of contrarian benefits. The contrarian strategy remains profitable even after adjusting for transaction costs. Kang (2005) analysed the profitability of contrarian strategy in the context of international index futures markets. The sample period 1993-2002 was divided into pre-Euro period and post-Euro period. In the latter, return reversals and excess profits seem more prevalent. Using daily futures prices, daily returns were calculated for periods of formation and holding from 1 to 5 days. The longer the formation period and holding period are, the more profitable the contrarian strategy is. The study concludes that the return reversals frequently occurred on Fridays, whereas excess profits tended to happen on Tuesdays and Thursdays. Corredor et al. (2006) compared the profitability of Jegadeesh and Titman (1993) momentum strategy based on monthly returns of Spanish stocks with a non-traditional momentum strategy using stock futures contracts whose underlying asset was previously classified as past winner or loser by the classical strategy. This study concluded that there were not profitable momentum strategies after adjusting for risk and transaction costs in the Spanish Derivative Market during period 2001-2004. Miffre and Rallis (2007) investigated the presence of short-term continuation and long-term reversal in commodity futures prices. The authors found that contrarian strategies did not work, whereas the momentum strategies were highly profitable.

In this chapter, we extend the existing literature on trading strategies in Spanish markets by examining the profitability of one-week contrarian and momentum strategies defined on stock futures contracts traded on the Spanish Derivative Market over the period 2001-2010. As far as we know, this is the first study on contrarian strategies based on weekly data in the aforementioned market. By using daily settlement prices and trading volume available from the market data source, we construct weekly series for trading portfolios and index portfolios. Portfolios are named "weekday portfolios" from Monday to Friday. As Wang and Yu (2004), we apply Lo and MacKinlay (1990) methodology. It allows us to decompose strategy profits and distinguish two main sources: time-serial pattern and cross-sectional pattern, and whereby we draw inference about market efficiency. In addition, in order to investigate the random walk hypothesis we conduct variance ratio tests on index portfolio returns series. Findings from this study show poor empirical evidence in favor of contrarian and momentum strategies for one-week horizon. In relation to the results of the variance ratio test, they depend on index portfolios used to summarize the market's behavior. In fact, the effect of introducing trading volume in the portfolio construction is the appearance of significant first-order autocorrelations, which is against the random walk hypothesis. The momentum (contrarian) trading strategy relies on the existence of profitable arbitrage portfolios, i.e. zero-cost and zero-risk portfolios. However, this second condition is not required to the zero-cost portfolio constructed following the aforementioned methodology. Since there is risk in such trading portfolios, a reward to risk performance measure is necessary. Furthermore, this work offers a comparison between several measures: (Adjusted) Sharpe ratio and other recent tailor-made performance measures, which take into account the investor's attitude towards risk and extreme events.

The chapter is organized as follows. Section 2 is devoted to present data, methods and main results. Conclusions are summarized in Section 3. The appendix includes formulae for autocorrelation tests and portfolio performance ratios.

1.2 Data and methods

In this section, we make a brief description of the Spanish Stock Futures Market (hereafter MEFF). We explain the data sources and the index portfolio construction procedure. Some descriptive statistics are computed for each index portfolio and we explain the variance ratio test.

1.2.1 Data

The first five futures contracts on Spanish stocks were launched in January 2001, four new ones in May 2002, three more in March 2004, and in January 2007, MEFF expanded the number of futures contracts to all the underlying stocks in the IBEX 35, and Prisa.

Currently, the Spanish underlying assets traded in MEFF are the following:Abengoa, Abertis, Acciona, Acerinox, Acs cons y serv, Aena, Amadeus, Antena3tv, Arcelormittal, Banco Popular, Banco Sabadell, Banesto, Bankia, Bankinter, BBVA, BME, CaixaBank, Dia, Ebro Foods, Enagas, Endesa, Fomento Const, Gamesa, Gas natural, Grifols, Grupo Ferrovial, IAG, Iberdrola, Iberdrola Renovables, Inditex, Indra, Mapfre, Mediaset, NH Hoteles, Obrascon Huarte, Red Eléctrica Esp, Repsol-YPF, Sacyr Vallehermoso, Santander, Técnicas Reunidas, Telefónica, and Viscofan.

The contract standard size is 100 shares. However, due to corporate actions, some stock futures contracts temporarily have a different size from the standard on some expiration data. Each contract traded at any time has at least 4 expiration months in the March-June-September-December cycle, plus 2 extra months, close to but not coincident with the current quarter expiration. The date of expiration (last trading day) is the third Friday of the expiration month. The price quotation is in Euro per share (to two decimal points), with minimum fluctuation of 1 cent of Euro.

The contracts are settled by the physical delivery of the shares or by cash according to the difference compared to the Reference Price[1], as the holder prefers. The trading hours are from 9:00 a.m to 17:35 p.m hours.

In September 2007, forty new stock futures contracts were launched by MEFF. They were defined on foreign stocks traded in the major European exchanges: Euronext (22 shares), Deutsche Börse (11 shares), Borsa Italiana (6 shares) and OMX (1 share). The foreign underlying assets are the following: Aegon NV, Air Liquide, Alcatel SA, Allianz AG, Assicurazioni Generali SpA, AXA SA, BASF AG, Bayer AG, BNP Paribas, Carrefour SA, Cie de Saint-Gobain, Crédit Agricole SA, DaimlerChrysler AG, Deutsche Bank AG, Deutsche Telekom AG, E.ON AG, Enel SpA, ENI SpA, Fortis, France Telecom SA, Groupe Danone, ING Groep NV, Koninklijke Philips Electronics NV, L'Oreal SA, LVMH Moet Hennessy Louis Vuitton SA, Münchener Rückversicherungs AG, Nokia OYJ, Renault SA, RWE AG, Sanofi-Aventis, SANPAOLO IMI SpA, SAP AG, Siemens AG, Société Generale, Suez SA, Telecom Italia SpA, Total SA, UniCredito Italiano SpA, Unilever NV, Vivendi.

While the single stock futures traded on MEFF since 2001 are settled by physical delivery or by cash, the aforementioned new contracts are only cash settled, according to a reference price. The rest of the characteristics remain the same. Currently, there is no trading on these contracts.

The database of stock futures contracts is provided from MEFF. It consist of daily settlement, high and low prices, and trading volume for the 10-year period from January 2001 to December 2010. For each weekday from Monday to Friday, a series of data is constructed for each of the stock futures contracts. The settlement day's data are removed to avoid any settlement effect.

The second database is made up from spot interest rates for one-month T-bills

[1] The closing price of the stock on the date of expiration.

provided from Spanish Central Bank. Weekly risk-free interest rate is computed as a rate equivalent to the monthly one.

To study the existence of autocorrelation in the stock futures contracts market, we construct two index portfolios: an equal-weighted index portfolio and a volume-weighted index portfolio, with at least twelve weekly quotation to avoid any survive bias. Index portfolio price and return time series are constructed for each weekday portfolio.

1.2.2 Descriptive statistics

Table 1.1 reports some statistics on weekly returns of stock futures index portfolios for each weekday. Regarding the five equal-weighted index portfolios, looking at Panel A is found that Thursday portfolio earns the maximum mean return of 1.37% and a median return of 0.05%, whereas Monday portfolio does the minimum mean return of 0.13% and a median return of 0.34%. The second best mean return is to Wednesdays (0.62%), however its median return is negative (-0.2%). For Friday portfolio both mean and median are positive and lower than those of Thursday's. In terms of standard deviation, Monday (Thursday) returns exhibit less (more) variability than the rest of weekday returns. Regarding the shape of the empirical distribution of returns, skewness and kurtosis is respectively more than 0 and 3, in most cases, which indicates the existence of positive asymmetry and leptokurtosis[2]. In addition, the sign test on median is performed under the null hypothesis of parameter value equals zero. That null hypothesis can not be rejected at conventional levels. Considering volume in portfolio construction, it has consequences in terms of return and variability. Panel B shows that the standard deviation of returns is around twice the above case.Thursday portfolios exhibit the highest mean return (0.7%), followed by Friday, Tuesday, Wednesday and

[2] According to Jarque-Bera test, the rejection of normality hypothesis at 5% level is acceptable for all weekday portfolios.

Monday. These two last return exhibit negative mean values. Anyway, the sign test on median return does not allow us to reject the null hypothesis of median equals zero.

Table 1.1: Descriptive statistics of index portfolio weekly returns

Panel A: Equal-weighted index portfolios					
	Monday	Tuesday	Wednesday	Thursday	Friday
Mean return	0.0013	0.0045	0.0062	0.0137	0.0021
Median	0.0034	-0.0032	-0.0020	0.0005	0.0055
Standard Deviation(SD)	0.0759	0.1392	0.1404	0.1960	0.0798
Median Absolute Deviation (MAD)	0.0549	0.0716	0.0694	0.0711	0.0569
Min.	-0.3100	-0.6770	-0.6896	-0.4823	-0.2784
Max.	0.3024	1.4774	1.721	2.8766	0.3157
Kurtosis	5.3751	42.6252	66.4527	147.6566	5.6210
Skewness	-0.0901	3.4660	5.1003	10.5638	0.1220
Sign test	0.8092	-0.7761	-0.4381	0.0000	1.3973
	(0.41)	(0.43)	(0.66)	(1.00)	(0.16)
Panel B: Volume-weighted index portfolios					
Mean return	-0.0019	0.0032	-0.0003	0.0077	0.0048
Median	-0.0002	-0.0017	0.0007	0.0060	0.0059
Standard Deviation (SD)	0.1824	0.2710	0.2415	0.2352	0.2355
Median Absolute Deviation (MAD)	0.1236	0.1527	0.1443	0.1540	0.1402
Min.	-0.9342	-1.5920	-1.1991	-0.8778	-1.1155
Max.	1.1911	1.3274	1.3850	1.0709	1.7406
Kurtosis	9.7409	12.9810	11.3706	6.7359	19.3102
Skewness	0.4025	0.2026	0.2679	0.4507	1.5525
Sign test	0.0000	-0.2910	0.2434	0.6677	0.8151
	(1.00)	(0.77)	(0.80)	(0.50)	(0.41)
Obs.	391	425	422	323	295

Portfolio return series computed as $r_t = logP_t - logP_{t-1}$ and $P_t = \sum_{t=1}^{N} P_{it}w_{it}$. For equal-weighted index portfolios weights are defined as $w_{it} = 1/N$, and for volume-weighted portfolios as $w_{it} = V_{it}/\sum_{t=1}^{N} V_{it}$. V_{it} is the number of contract i traded on date t.Prices are settlement prices on weekly basis from MEFF database. The sample period begins January 2001 and ends December 2010. Portfolios include assets with a minimum of observations in the sample, at least 12 weekly prices. Figures in parenthesis are p-values.

Table 1.2 shows first-order autocorrelations coefficients and Ljung-Box statistics for index portfolios and individual contracts. Regarding index portfolios, both statistics reject the lack of autocorrelation in all series, except for Friday equal-weighted portfolio. The significant first-order autocorrelations are mostly negative. According to Lo and Mackinlay (1990) decomposition, negative first-order autocovariance in the equal-weighted portfolio (benchmark portfolio) return has a positive (negative) effect on the momentum (contrarian) strategy profits. On the contrary, negative average first-order autocovariance in individual contracts return has a negative (positive) effect on momentum (contrarian) strategy. Table 1.2, Panel C shows the average autocorrelations of the individual contracts alongside the corresponding standard deviations. Mostly the sign of the average values is negative, which indicates negative time serial dependence, on average. The average values are lower than those of portfolios in Panel A and B.

It deserves mentioning that both autocorrelation tests are performed under the hypothesis of identical and independent distributed disturbances. By relaxing this hypothesis, the autocorrelation coming from this source of idiosyncratic risk might be recognized. In order to overcome this limitation, the variance ratio test is performed.

Table 1.2: Autocorrelations and Q-test for portfolios and individual contracts weekly returns

Panel A: Autocorrelations and Q-test for equal-weighted index portfolio						
		Monday	Tuesday	Wednesday	Thursday	Friday
ρ_1		**-0.1036**	**-0.3168**	**-0.4150**	**-0.5338**	0.0272
ρ_2		-0.0031	**0.2551**	-0.0018	**0.2041**	-0.0385
ρ_3		**0.1065**	**-0.2531**	0.0897	-0.0516	0.0339
ρ_4		-0.0639	**0.1126**	**-0.2381**	**-0.2629**	-0.0205
Q_1		4.2718**	43.3803*	73.9079*	94.0669*	0.2234
Q_2		4.2757	71.5748*	73.9094*	107.8645*	0.6696
Q_3		8.8158**	99.3984*	77.3786*	108.7493*	1.0171
Q_4		10.4572**	104.9186*	101.8813*	131.7720*	1.1450
Panel B: Autocorrelations and Q-test for volume-weighted index portfolio						
ρ_1		**-0.4399**	**-0.3950**	**-0.2654**	**-0.3653**	**-0.3443**
ρ_2		**0.1269**	**0.2414**	0.0281	0.0367	**-0.1511**
ρ_3		**-0.2189**	**-0.1852**	**-0.2178**	-0.0326	**0.1211**
ρ_4		**0.1884**	0.0583	0.0155	**-0.3010**	0.1044
Q_1		77.0202*	67.4022*	30.2377*	44.0535*	35.5700*
Q_2		83.4484*	92.6478*	30.5787*	44.5000*	42.4462*
Q_3		102.6266*	107.5469*	51.0393*	44.8539*	46.8801*
Q_4		116.8678*	109.0295*	51.1439*	75.0433*	50.1894*
Panel C: Autocorrelations for individual futures contracts						
ρ_1	Mean	-0.0981	-0.0625	-0.0835	-0.0611	-0.0928
	SD	0.1958	0.1932	0.2076	0.2095	0.2101
ρ_2		-0.0904	-0.0608	-0.042	-0.042	-0.0557
		0.1814	0.1847	0.1881	0.2062	0.2157
ρ_3		0.0309	-0.0303	-0.0579	-0.0595	-0.065
		0.2176	0.1716	0.2044	0.2041	0.2142
ρ_4		-0.0802	-0.0557	-0.0555	-0.0396	-0.0127
		0.1776	0.1814	0.1933	0.1918	0.2022

Autocorrelation coefficients higher than twice their standard errors are in bold.
* $p - value < 0.01$, ** $p - value < 0.05$.

1.2.3 Variance ratio test

In this subsection, we provide evidence of weekly return serial correlation in the two index portfolios defined above and individual contracts, mainly by means of Variance Ratio test (hereafter VR). The use of VR is justified by Poterba and Summers (1988) and Lo and MacKinlay (1989). The VR test is performed for all 'weekday portfolios' and for individual assets in the sample.

We consider an overall test size $\alpha\%$ and several pre-specified q-period VRs. The rejection of an individual test is enough to reject the overall test and to conclude that the weekday return does not follow a random walk. We select periods of 2 and 4 weeks. For a significant level α of 5%, the corresponding value in the standard normal distribution is 1.959. Therefore, in order to reject the null hypothesis, it is enough to find one value of $z_H(q)$ greater than 1.959.

Table 1.3 reports the VR tests for index portfolios and individual contracts. In Panel A, most VR values are different from 1, which would indicate time serial dependence if the null hypothesis could be rejected. For q equals 2, the random walk hypothesis can be rejected at the level of 5% in the cases of Wednesday, Thursday and Friday returns. The effect of volume on time serial dependence is really significant, since it is in favor of the rejection of random walk without exceptions (Panel B). Thus, one could think of considering volume information in trading strategies as a key variable. Panel C shows the mean and standard deviation of VRs of the individual contracts. Although weaker, the average first-order autocorrelation of individual contracts is still kept negative ($VR(2)-1$) for all weekday returns.

1.2.4 Profitability of trading strategies

The methodology used to construct trading portfolios that rely on time series dependance is described in this section. It follows Lo and Mackinlay (1990) and Jegadeesh

Table 1.3: Variance Ratios for index portfolios and individual future contracts weekly returns

Panel A: Variance ratios for equal-weighted index portfolios						
VR(q)		Monday	Tuesday	Wednesday	Thursday	Friday
2		1.0167	0.6618***	0.4467**	0.3996**	0.8705**
4		0.9618	0.5657	0.3400***	0.2730	0.7286
Panel B: Variance ratios for volume-weighted index portfolios						
2		0.6917**	0.5471*	0.6097*	0.6115**	0.7594**
4		0.5777**	0.7381**	0.3561*	0.3655**	0.4657**
Panel C: Variance Ratios for individual futures contracts						
2	Mean	0.9477	0.9872	0.9571	0.9920	0.9580
	SD	0.2551	0.2617	0.2485	0.2527	0.2543
4		0.9272	1.0309	0.9424	0.9863	0.9708
		0.4476	0.4805	0.4036	0.4522	0.4578

* $p-value < 0.01$, **$p-value < 0.05$, ***$p-value < 0.1$.

and Titman (1995). Using a weekly futures prices database, we obtain futures contracts returns for each formation and holding period on a weekly basis. The choice of one week term is consistent with previous studies on stock return reversals.

The weekly return is calculated as the relative difference of settlement prices: $R_t = (P_t - P_{t-1})/P_{t-1}$. Let N be a changing number of contracts in week t over T periods. Each week, a portfolio is made up with these N contracts, and the weight of the contract i (w_{it}) is calculated according to the following expression:

$$w_{it-1} = \frac{1}{N_{t-1}}(R_{it-1} - R_{mt-1}) \tag{1.1}$$

R_{mt-1} defined as an equal-weighted average of returns on the N_{t-1} contracts in week $t-1$.

When the return of the contract i overperforms the average return it is called a *winner* contract, otherwise it is called a *loser* contract. Furthermore, larger weights are given to extreme winners and losers. A trading strategy named *momentum* is defined as buying past winner and selling past loser and it relies on the persistence of difference in (1.1) over future holding periods. The opposite strategy named *contrarian* does rely on the reversal of that difference, therefore the weight of each contract would be $-w_{it-1}$, that is, buying past losers and selling past winners.

In the Spanish Stock Futures Market during the period 2001-2010, we construct weekly trading strategy sets *á la Conrad and Kaul* (1998): a large position in past winners and a short position in past losers. Thus, the sign of the return of the portfolio tells us which kind of strategy is the profitable one. By construction, the large positions are compensated by the short ones giving as a result a zero-cost portfolio: $\sum_i^{N_{t-1}} w_{it-1} = 0$. Consequently, the investor does not compromise his own money. So, the total amount invested/financed is given by: $I_{t-1} = \frac{1}{2}\sum_i |w_{it-1}|$. Therefore, the performance of the portfolio over the subsequent holding period will be measured as $\pi_t = \sum_i^{N_{it-1}} w_{it-1} R_{it}$ or also as $\pi_t^r = \pi_t / I_{t-1}$.

Table 1.4 reports some descriptive statistics for trading portfolios profits (Panel A) and returns (Panel B). Regarding portfolio profits (estimates are multiplied by 1000), all weekday portfolios exhibit negative mean profits, except for Thursday portfolios, which suggests that the contrarian strategy (sell past winners and buy past losers) is mostly profitable. The highest mean profit corresponds to Wednesday contrarian portfolio (0.0391). It is also the riskiest in terms of standard deviation (0.5329). The second best contrarian portfolio, in profit mean terms, is Monday portfolio (0.0240, 0.4537). All series largely departure from the normality hypothesis. According to the sign test, portfolio profits are not statistically significant at conventional levels.

In order to reach a better assessment of the economic results, weekly returns are computed. As shown in Table 1.4, Panel B, Monday, Tuesday and Wednesday portfolios exhibit negative mean returns. Therefore, the profitable strategy is the contrarian one. The normality hypothesis is rejected for all series. According to sign test the null hypothesis (median equals zero) can not be rejected for any portfolio. The lowest $p-value$ is shown by Wednesday portfolio, whose contrarian strategy yields a median profit of 0.0103 and a median return of 0.15% at the level of 11%

Table 1.4: Descriptive statistics for trading portfolios

Panel A: Trading portfolio profits					
	Monday	Tuesday	Wednesday	Thursday	Friday
Mean	-0.0240	-0.0201	-0.0391	0.0103	-0.0144
Median	0.0073	-0.0033	-0.0103	0.0056	0.0040
Standard Deviation (SD)	0.4537	0.4775	0.5329	0.3165	0.4128
Median Absolute Deviation (MAD)	0.2393	0.2337	0.2581	0.1795	0.2147
Min.	-3.5326	-3.5669	-3.3505	-1.8240	-2.6569
Max.	2.9422	3.1323	2.7527	1.4112	1.8541
Kurtosis	21.3180	27.5638	16.4098	11.5753	15.6164
Skewness	-0.9475	-1.5603	-0.9680	0.0499	-1.4207
Sign test	0.8540	-1.1241	-1.5820	0.2313	0.3137
p-value	(0.39)	(0.26)	(0.11)	(0.81)	(0.75)
Panel B: Trading portfolio returns					
Mean	-0.0005	-0.0014	-0.0011	0.0023	0.0016
Median	0.0013	-0.0011	-0.0015	0.0007	0.0007
Standard Deviation (SD)	0.0297	0.0331	0.0342	0.0259	0.0270
Median Absolute Deviation (MAD)	0.0212	0.0216	0.0217	0.0177	0.0190
Min.	-0.1375	-0.2641	-0.1703	-0.0830	-0.0780
Max.	0.1304	0.1275	0.2241	0.1641	0.1360
Kurtosis	6.2532	14.7552	11.4688	9.8644	6.4287
Skewness	-0.2007	-1.5834	0.4785	1.3589	0.6955
Sign test	0.8540	-1.1241	-1.5820	0.2313	0.3137
p-value	(0.39)	(0.26)	(0.11)	(0.81)	(0.75)
Obs.	351	383	384	299	254

1.2.5 Decomposition of trading profits

Following Lehmann (1990) and Lo and Mackinlay (1990),[3] the portfolio's expected profits $E(_t)$ can be decomposed into two main components: *i.* The predictability-profitability index (P), which is related to the autocovariance of returns and, hence, to the time-series predictability in asset returns. *ii.* The cross-sectional dispersion in mean returns of assets (σ^2). That decomposition is shown as follows:

$$\begin{aligned} E(\pi_t) &= -Cov(R_{mt}, R_{mt-1}) + \frac{1}{N_{t-1}}\sum_{i}^{N_{it-1}} Cov(R_{it}, R_{it-1}) + \frac{1}{N_{t-1}}\sum_{i}^{N_{it-1}} (\mu_{it} - \mu_{mt-1})^2 \\ &= -C + O + \sigma^2(\mu) \\ &= P + \sigma^2(\mu) \end{aligned}$$

[3] Lo and MacKinlay (1990) defined the predictability index to deemphasize the role of the cross-sectional dispersion (σ^2) since it has a small effect on profits to trading strategies that use weekly returns.

where μ_{it} is the unconditional mean of security i for the interval $\{t-1, t\}$, and μ_{mt} is the single-period unconditional mean return of the equal-weighted portfolio at time t: $\mu_{mt} = \sum_i^{N_t} \mu_{it}/N_t$. The above decomposition is obtained under the assumption of mean stationary of individual security returns: $\mu_{it} = \mu_i \; \forall \; (i,t)$.

As already shown, the predictability-profitability index is the addition of two components: the average of first-order autocovariances of all individual securities into the portfolio, and the negative of the first-order autocovariance of the equal-weighted portfolio.

That decomposition of profits allows us to understand to what extent the profits result from serial dependence in individual asset returns, and draw the inference about market efficiency. In conclusion, expected profits in this kind of trading strategies emerge from two sources:

- The cross-sectional dispersion of the unconditional mean returns (σ^2), which has a positive (negative) effect on the momentum (contrarian) strategy.
- The first-order autocovariances of the individual securities and the equal-weighted portfolio (benchmark portfolio), which respectively have a positive (negative) and negative (positive) effect on the momentum (contrarian) strategy.

On one hand, if a market underreacts (overreacts) to new information, the autocovariance of the individual security returns will be positive (negative), which will contribute positively (negatively) to the momentum strategy and, in turn, negatively (positively) to the contrarian strategy. On the other hand, the effect of the autocovariance of the equal-weighted portfolio is the opposite one, that is to say, when its sign is negative (positive), it increases the profit of the momentum (contrarian) strategy.

Wang (2004) finds that the sole source of contrarian profits in futures markets is the negative serial dependence in individual futures returns. Unlike what happens in the equity market, where the positive first-order autocovariance in benchmark portfolio return explains a large portion of the total contrarian profits in equity markets -Lo and MacKinlay (1990), Conrad,Gultekin and Kaul (1997)-.

Our findings in Spanish Stock Futures Market are consistent with those reached by previous studies in future markets. As Table 1.5 shows, the results reveal that, whatever weekday strategy is, the average individual autocovariance (O) is negative and statistically significant. Thus, it affects negatively (positively) the momentum (contrarian) strategy. Likewise, the first-order autocovariance of the equal-weighted portfolio returns (C) is also negative, which supports the momentum strategy, but not the contrarian one. Therefore, the sign of the predictability-profitability index ($P = -C + O$) is negative, which indicates a predominance of negative autocovariances in the return of the individual assets. Consequently, the overreaction hypothesis is plausible. The second aforementioned component explains a large portion of the total contrarian profits in the futures market, hence the main source of contrarian profits in the futures market lies on individual time-serial properties, as highlighted by Wang (2004). The component σ^2 only overcomes the other two components in the case of the Thursday strategies. Anyway, no strategy exhibits statistically significant profits, which supports the weak efficiency hypothesis. As known, the existence of autocorrelation is not equivalent to the existence of profitable arbitrage opportunities.

Table 1.5: The decomposition of average profits to trading strategies

	$E(\pi_t)$	C	O	$\sigma^2[\mu]$	$\%C$	$\%O$	$\%\sigma^2[\mu]$
Monday	-0.0240	-0.2218^*	-0.482^*	0.2368^*	-922%	2007%	-985%
Tuesday	-0.0201	-0.0715	-0.3168^*	0.2251^*	-355%	1575%	-1119%
Wednesday	-0.0391	-0.1752^*	-0.43845^*	0.2241^*	-448%	1121%	-573%
Thursday	0.0102	-0.0866^*	-0.2759^*	0.1996^*	847%	-2700%	1953%
Friday	-0.0144	-0.2446^*	-0.4646^*	0.2056^*	-1699%	3227%	-1428%

(*) $p - value < 0.01$ according to t-test.

1.2.6 Portfolio performance measures

In this subsection a number of performance ratios are computed. The Sharpe ratio (Sharpe (1966)) is a commonly used measure of portfolio performance, interpreted as a reward-to-risk ratio. It relies on the second moment of distribution (i.e. standard deviation) as risk measure, and it is properly used when return distributions are normal or investors' preferences are quadratic. Otherwise, the Sharpe ratio can lead to fallacious conclusions when returns exhibit heavy tails or asymmetry. Konno and Yamazaki (1991) defined a ratio more robust to outliers than the Sharpe ratio, by substituting the standard deviation by the mean absolute deviation. More recently, Zakamouline and Koekebakker (2009) derived a formula for the Sharpe ratio adjusted for skewness, considering the investor's relative preference to the skewness of distribution. The Adjusted for Skewness Sharpe Ratio (ASSR) preserves the standard Sharpe ratio for zero skewness.

Currently, there exists literature on performance evaluation taking into account higher moments of distribution by using alternative measures of reward and risk. The ones known as tailor-made performance ratios are used as performance measures that fit the investor's preferences. Sortino and Satchell (2001) substitute the standard deviation with the left partial moment of order 2, Farinelli and Tibiletti (2003) and Farinelli and Tibiletti (2008) take as reward the right order p ($p > 0$) and as risk measure the left order q ($q > 0$), and the (Generalized) Rachev ratio (Biglova et al. (2004) and Rachev et al. (2008)) which draws attention to extreme events. The last measures the expected value of profit and loss, given that the Value-at-risk (VaR) has been exceeded. It awards extreme returns adjusted for extreme losses. Traditional VaR calculations assume that returns follow a normal distribution. In the following, we compute these ratios for trading and index portfolios[4].

[4]See appendix 3 for a full description of performance ratios.

Table 1.6 shows that Sharpe Ratio, Adjusted Sharpe Ratio and Mean Absolute Deviation Ratio produce the same ranking 13 out of 15 times. In particular, 14 out of 15 times the best portfolio is the volume-weighted index portfolio, and the momentum portfolio is 9 out of 15 times the worst portfolio.

Farinelli-Tibiletti Ratio measures the mean gains relative to mean losses. Except for Thursday portfolio, the ratio takes values less than 1, which indicates that average losses overcome average gains. The volume-weighted portfolio behaves the best according to this ratio, taking the first position 3 out of 5 times. On contrary, the momentum portfolio behaves the worst 3 out of 5 times. When extreme gains and losses (VaR Ratio) are considered, the volume-weighted portfolio is the first of the ranking 4 out of 5 times, with values higher than 1. Contrarian portfolios behave better than momentum portfolios, except for Thursday portfolio.

(Generalized) Rachev Ratios consider the expected extreme gains and losses. The Rachev Ratio is equal to the Generalized Rachev Ratio defined for moderate investors ($\gamma = 1, \delta = 1$). Figures in panel H are computations of the Rachev Ratio for conservative investors ($\gamma = 1.5, \delta = 2$), hence comparisons are not possible between panel G and H. They match the best weekday portfolios mostly.

Table 1.6: Portfolio performance ratios

	Monday	Rank	Tuesday	Rank	Wednesday	Rank	Thursday	Rank	Friday	Rank
Panel A: Sharpe Ratio										
equal-weighted	0.0507	2	0.0755	2	0.0744	2	0.0680	2	0.0613	2
volume-weighted	0.0727	1	0.1220	1	0.1026	1	0.1344	1	0.1011	1
momentum	-0.0278	4	-0.0521	4	-0.0418	4	0.0760	3	0.0432	3
contrarian	0.0054	3	0.0328	3	0.0230	3	-0.1014	4	-0.0688	4
Panel B: Mean Absolute Deviation Ratio										
equal-weighted	0.0703	2	0.2045	2	0.2455	2	0.4484	1	0.0870	2
volume-weighted	0.1192	1	0.2488	1	0.1961	1	0.2216	2	0.2439	1
momentum	-0.0389	4	-0.0800	4	-0.0659	4	0.1111	3	0.0614	3
contrarian	0.0075	3	0.0504	3	0.0363	3	-0.1483	4	-0.0977	4
Panel C: Adjusted Sharpe Ratio (b3 = 1)										
equal-weighted	0.0509	2	0.0849	2	0.0863	2	0.0801	2	0.0617	2
volume-weighted	0.0760	1	0.1322	1	0.1099	1	0.1417	1	0.1144	1
momentum	-0.0278	4	-0.0528	4	-0.0416	4	0.0773	3	0.0434	3
contrarian	0.0054	3	0.0331	3	0.0230	3	-0.1037	4	-0.0693	4
Panel D: VaR Ratio (a = b = 0.05)										
equal-weighted	1.2651	1	1.0947	2	1.1996	2	1.2079	2	1.0990	2
volume-weighted	1.1973	2	1.4220	1	1.3990	1	1.7514	1	1.2487	1
momentum	0.8575	4	0.9168	4	0.9245	4	1.1874	3	0.9544	4
contrarian	1.1446	3	1.0669	3	1.0560	3	0.8055	4	1.0080	3
Panel E: Sortino-Satchell Ratio (q = 2)										
equal-weighted	0.0781	2	0.2451	2	0.3140	1	1.2234	1	0.0969	2
volume-weighted	0.1427	1	0.3301	1	0.2447	2	0.2982	2	0.3289	1
momentum	-0.0375	4	-0.0652	4	-0.0589	4	0.1307	3	0.0674	3
contrarian	0.0079	3	0.0537	3	0.0323	3	-0.1225	4	-0.0883	4
Panel F: Farinelli-Tibiletti Ratio (p = 1, q = 2)										
equal-weighted	0.5946	2	0.7063	2	0.7796	1	1.7281	1	0.6070	2
volume-weighted	0.6657	1	0.7984	1	0.7291	2	0.8048	2	0.8221	1
momentum	0.4619	4	0.3758	4	0.4197	4	0.6520	3	0.5824	3
contrarian	0.5276	3	0.5600	3	0.4623	3	0.3508	4	0.4075	4
Panel G: Rachev Ratio or Generalized Rachev Ratio ($\alpha = \beta = 0.05$, $\gamma = 1$, $\delta = 1$)										
equal-weighted	1.1846	2	2.2671	2	2.5920	1	8.9912	1	1.2640	2
volume-weighted	1.7073	1	2.6518	1	2.2303	2	2.2822	2	2.5577	1
momentum	0.8720	4	0.7212	4	0.9554	4	1.4967	3	1.2632	3
contrarian	1.1262	3	1.3624	3	1.0304	3	0.6510	4	0.7728	4
Panel H: Generalized Rachev Ratio ($\alpha = \beta = 0.05$, $\gamma = 1.5$, $\delta = 2$)										
equal-weighted	1.1690	2	2.7503	2	3.4544	1	15.6779	1	1.2771	3
volume-weighted	1.8384	1	2.7745	1	2.3576	2	2.3182	2	3.1291	1
momentum	0.8640	4	0.6563	4	0.9626	3	1.5176	3	1.2865	2
contrarian	1.0725	3	1.3814	3	0.9380	4	0.6018	4	0.7327	4

1.3 Conclusions

The study conducted in this chapter has three parts. The first one answers the question related to the existence of autocorrelation patterns in the returns series of stock futures contracts traded in the Spanish Stock Futures Market. Negative first-order autocorrelations are mostly found in the weekday returns series for the two index portfolios. The variance ratios of the equal-weighted index portfolios allow us to reject the random walk hypothesis on all returns series except for Monday's. When the volume-weighted index portfolio is used, the rejection of the null hypothesis at 5% level is acceptable for all weekday returns. Therefore, it might be concluded that there exists negative first-order autocorrelation in the Spanish Derivative Market over the sample period. The second part analyzes the Conrad and Kaul (1998) strategy in order to contrast the existence of profitable arbitrage portfolios. Overall, in the Spanish Stock Futures Market it is not possible to get any return by constructing zero-cost portfolios on a weekly basis, which supports the weak efficiency hypothesis. Although these arbitrage portfolios are zero-cost portfolios, they are risky. Therefore, some reward-to-risk measures are needed to evaluate their performance. The third part ends this study ranking the trading portfolios and index portfolios according to the Sharpe ratio and other tailor-made performance ratios. As a general result, the arbitrage portfolios behave worse than the index portfolios.

References

Biglova, A., Ortobelli, S., Rachev, S. T., and Stoyanov, S. (2004). Different approaches to risk estimation in portfolio theory. *The Journal of Portfolio Management*, 31(1):103–112.

Corredor, P., Muga, L., and Santamaria, R. (2006). The profitability of momentum strategies using stock futures contracts in small markets. *Applied Financial Economics Letters*, 2(3):173–177.

DeBondt, W. F. and Thaler, R. (1985). Does the stock market overreact? *The Journal of finance*, 40(3):793–805.

Farinelli, S. and Tibiletti, L. (2003). Sharpe thinking with asymmetrical preferences. Technical report, Technical Report presented at European Bond Commission.

Farinelli, S. and Tibiletti, L. (2008). Sharpe thinking in asset ranking with one-sided measures. *European Journal of Operational Research*, 185(3):1542–1547.

Forner, C. and Marhuenda, J. (2003). Contrarian and momentum strategies in the spanish stock market. *European Financial Management*, 9(1):67–88.

Forner, C. and Marhuenda, J. (2006). Análisis del origen de los beneficios del momentum en el mercado de valores español. *investigaciones económicas*, 30(3):401–439.

Jegadeesh, N. (1990). Evidence of predictable behavior of security returns. *Journal of Finance*, pages 881–898.

Jegadeesh, N. and Titman, S. (1995). Overreaction, delayed reaction, and contrarian profits. *Review of Financial Studies*, 8(4):973–993.

Kang, J. (2005). Short-term contrarian and momentum profits in index futures contracts traded in the us and non-us futures markets. Technical report, Nanyang Business School NTU Singapore.

Konno, H. and Yamazaki, H. (1991). Mean-absolute deviation portfolio optimization model and its applications to tokyo stock market. *Management science*, 37(5):519–531.

Lehmann, B. N. (1988). Fads, martingales, and market efficiency. Technical report, National Bureau of Economic Research.

Lin, J. B., Onochie, J. I., and Wolf, A. S. (1999). Weekday variations in short-term contrarian profits in futures markets. *Review of Financial Economics*, 8(2):139–148.

Lo, A. W. and MacKinlay, A. C. (1988). Stock market prices do not follow random walks: Evidence from a simple specification test. *Review of financial studies*, 1(1):41–66.

Lo, A. W. and MacKinlay, A. C. (1990). When are contrarian profits due to stock market overreaction? *Review of Financial studies*, 3(2):175–205.

Miffre, J. and Rallis, G. (2007). Momentum strategies in commodity futures markets. *Journal of Banking & Finance*, 31(6):1863–1886.

Rachev, S., Ortobelli, S., Stoyanov, S., Fabozzi, F. J., and Biglova, A. (2008). Desirable properties of an ideal risk measure in portfolio theory. *International Journal of Theoretical and Applied Finance*, 11(01):19–54.

Sharpe, W. F. (1966). Mutual fund performance. *Journal of business*, pages 119–138.

Sortino, F. A. and Satchell, S. (2001). *Managing downside risk in financial markets*. Butterworth-Heinemann.

Wang, C. and Yu, M. (2004). Trading activity and price reversals in futures markets. *Journal of Banking & Finance*, 28(6):1337–1361.

Zakamouline, V. and Koekebakker, S. (2009). Portfolio performance evaluation with generalized sharpe ratios: Beyond the mean and variance. *Journal of Banking & Finance*, 33(7):1242–1254.

1.4 Appendix 1: Autocorrelation and Ljung-Box tests

Under the random walk hypothesis, the autocorrelation and Ljung-Box tests assume that the disturbance terms e_t are independent and identically distributed (i.i.d.). These two tests are respectively defined as follows:

$$\widehat{\rho_k} = \frac{n\sum_{t=k+1}^{n}(R_t - \bar{R})(R_{t-k} - \bar{R})}{(n-k)\sum_{t=1}^{n}(R_t - \bar{R})^2} \underset{d}{\rightarrow} N\Big(0, \frac{1}{\sqrt{n}}\Big) \quad as \quad n \rightarrow \infty \tag{1.2}$$

Ljung-Box Q-test is developed under no serial correlation null hypothesis: H_0 : $\rho_1 = \rho_2 = \cdots = \rho_q = 0$.

$$Q_q = n(n+2)\sum_{k=1}^{q}\frac{\widehat{\rho}^2(k)}{n-k} \quad \rightarrow \quad \chi_q^2 \tag{1.3}$$

1.5 Appendix 2: Variance ratio test

Lo and MacKinlay (1988) state that the variance ratio can be used as an alternative test of the random walk hypothesis, which is based on the fact that the variance of random walk increments in finite sample increases linearly with the sampling interval. For example, the variance of weekly sample series must be five times as large as the variance of daily data.

Let p_t be the natural logarithm of a price series. Under the random walk hypothesis, p_t follows the form: $p_t = \alpha + p_{t-1} + e_t$.

And the variance of its q-differenced series $(p_t - p_{t-q})$ would be q times the variance of its first-differenced series $(p_t - p_{t-1})$. Therefore, given $nq + 1$ observations of the price series $p_0, p_1, \cdots, p_{nq}$ where q is any integer greater than 1, the variance ratio of q-differenced series is defined as:

$$VR(q) = \frac{\sigma_b^2(q)}{\sigma_a^2} \tag{1.4}$$

being $\sigma_b^2(q)$ an unbiased estimator of the variance of the q-differenced series and σ_a^2 an unbiased estimator of the variance of the first-differenced series.

$$\sigma_b^2(q) = \frac{1}{m}\sum_{t=q}^{nq}(p_t - p_{t-q} - q\mu)^2 \tag{1.5}$$

where

$$m = q(nq + 1 - q)(1 - \frac{q}{nq}) \tag{1.6}$$

$$\mu = \frac{1}{nq}(p_{nq} - p_0) \tag{1.7}$$

and

$$\sigma_a^2 = \frac{1}{nq-1}\sum_{t=1}^{nq}(p_t - p_{t-1} - \mu)^2 \tag{1.8}$$

The statistic test proposed by Lo and MacKinlay adjusts for disturbance's heteroscedasticity and is asymptotically normally distributed with zero mean and a standard deviation of 1.

$$z_H(q) = \frac{\sqrt{nq}(VR(q) - 1)}{\sqrt{\phi(q)}} \to N(0,1) \tag{1.9}$$

$$\phi(q) = \sum_{j=1}^{q-1}\Big(\frac{2(q-j)}{q}\Big)^2\delta(j) \tag{1.10}$$

$$\delta(j) = \frac{nq\sum_{t=j+1}^{nq}(p_t - p_{t-1} - \mu)^2(p_{t-j} - p_{t-j-1} - \mu)^2}{\Big(\sum_{t=j+1}^{nq}(p_t - p_{t-1} - \mu)^2\Big)^2} \tag{1.11}$$

1.6 Appendix 3: Performance ratios

The classical Sharpe ratio

$$\Phi_{Sharpe} = \frac{E(R_P - R_F)}{\sigma(R_P - R_F)} \tag{1.12}$$

where σ denotes the standard deviation and R_F is the risk free interest rate. Using the standard deviation as a measure of risk means that upside and downside deviations to the benchmark are equally weighted. Therefore, this ratio is a good match for investors with a moderate investment style whose main concern is controlling the stability of returns around the benchmark. Its use may be questionable, however, if the investment style is more aggressive and focused on the tradeoff between large favourable/unfavourable deviations from the benchmark.

Mean absolute deviation Sharpe ratio

$$\Phi_{MAD} = \frac{E(R_P - R_F)}{mad(R_P - R_F)} \tag{1.13}$$

Adjusted for skewness Sharpe ratio

$$\Phi_{AjustedSharpe} = \Phi_{Sharpe}\sqrt{1 + b_3 \frac{Skew}{3}\Phi_{Sharpe}} \tag{1.14}$$

$$Skew = \frac{E[(x - E(x))^3]}{E[(x - E(c))^2]^{\frac{3}{2}}} \tag{1.15}$$

b_3 is the investor's relative preference to the skewness of distribution. $b_3 = 1$ for constant absolute risk aversion utility functions.

Value-at-Risk (VaR) ratio

$$VaR = \frac{VaR_\alpha(-X)}{VaR_\beta(X)} \tag{1.16}$$

$$VaR_q(X) = -inf\{x|P(X \leq x) > q\} \tag{1.17}$$

The Sortino-Satchell ratio

$$\Phi_{Sortino-Satchell} = \frac{E(R_P - R_F)}{\sqrt[q]{E[min(R_P - R_F, 0)^q]}} \quad , q > 0 \tag{1.18}$$

This ratio substitutes the standard deviation as a measure of risk with the left partial moment of order q; therefore, the only penalizing volatility is the harmful one below the benchmark (R_F). Note that for $q = 2$, risk measure is excess return semi-variance.

The Farinelli-Tibiletti ratio

$$\Phi_{Farinelli-Tibeletti} = \frac{\sqrt[p]{E[max(R_P - R_F, 0)^p]}}{\sqrt[q]{E[min(R_P - R_F, 0)^q]}} \quad , p, q > 0 \tag{1.19}$$

The parameters p and q can be balanced to match the agent's attitude toward the consequences of overperforming or underperforming. It is known that the higher p and q, the higher the agent's preferences for like and dislike of extreme events, respectively. If the agent's main concern is that he might miss the target, without any particular regard to the amount, then a small value for the left order is appropriate. However, if small deviations below the benchmark are relatively harmless compared to large deviations, then a large value for the left order is recommended. The right order p is chosen analogously and should capture the relative appreciation for outcomes above the benchmark[5].

[5]For defensive investors $p = 0.5, q = 2$, for conservative investors $p = 1.5, q = 2$, and for moderate investors $p = 1, q = 1$ (Usta and Kantar, 2011).

The Rachev ratio

$$\Phi_{Rachev} = \frac{CVaR_{\alpha}[R_F - R_P]}{CVaR_{\beta}[R_P - R_F]} \tag{1.20}$$

Conditional Value-at-Risk is defined, under the assumptions of continuous distributions, as: $-E[X|X \leq VaR_{\alpha}(X)]$, with α, $\beta \in (0,1)$. The lower α, β are, the more the focus is concentrated on the extreme tails, hence more aggressive ratios are computed.

The Generalized Rachev ratio

$$\Phi_{GeneralizedRachev} = \frac{CVaR_{\alpha,\gamma}[R_F - R_P]}{CVaR_{\beta,\delta}[R_P - R_F]} \tag{1.21}$$

where $CVaR_{(\alpha,\gamma)}(X) = (E[max(-X,0)^{\gamma}| - X > VaR_{\alpha}(X)])^{\gamma^*}$ and $\gamma^* = min(1, 1/\gamma)$. Note that the parameters γ, δ are similar to the parameters p, q in the Farinelli-Tibiletti ratio.

Chapter 2

An experimental online matching pennies game

Knowledge is power. Information is power. The secreting or hoarding of knowledge or information may be an act of tyranny camouflaged as humility.

-Robin Morgan

2.1 Introduction

Strategic information transmission is a process that plays a crucial role in many situations in which agents' decisions depend on the disclosured information. In fact, the lack of information is one of main drawbacks to reach agreements. Hence, sharing information is a pivotal point that allows for more profitable agreements. Furthermore, there exists a trade-off between revealed information and profit, which is due to strategic concerns. In Crawford and Sobel's (1982) words, *revealing all information to the opponent is not usually the most advantageous policy.* As Blume and Ortmann (2007) highligth costless messages help overcome strategic uncertainty, problems equilibrium selection, and coordination failure.

As a benchmark structure, information transmission consists of two agents, a sender and a receiver, a message in a common language and a transmission channel. In particular, the sender is an agent with private information who sends a message revealing that information to the receiver, who takes a decision affecting both agents accordingly.

The present work concerns strategic information transmission among two players with asymmetric information. Some of our setting's features are in common with Crawford and Sobel (1982) (henceforth CS) framework: 1) Information is transmitted in an one-sided communication channel. 2) The sender is a fully informed player who has complete and perfect information about the world. While the receiver is an uninformed player who has information about the random process and history of the world. 3) Sharing information is itself a costless activity for the sender. 4) The receiver's decision has an effect on both players' payoffs. Special features in this study are related to the communication protocol in use: 5) The sender and receiver form a team with aligned interest. 6) Repeated interactions are via an online platform. 7) They communicate in binary language ('0' or '1'). 8) Messages are encrypted in the sender's action sequence. 9) The receiver decodes messages according to the team's codebook to find out his action sequence. 10) No constraints are imposed upon strategies the team may include in the codebook.

Let us illustrate our communication framework. Consider that the information about the world is represented as a random 16-length sequence, and consider, for instance, the following sequence: 1110001010101100. Before any interaction within the team, that sequence is fully revealed to the sender, who will transmit it to the receiver according to a communication strategy belonging to the message-action plan codebook. One can think of strategies based on the old principle of 'divide and rule'. Thus, on that sequence, one can define a two-length block strategy, four-length block strategy, eight-length block strategy, etc. A block strategy works as follows: in a block k, the receiver plays an action sequence that is revealed from a message transmitted into the sender's action sequence in the previous block $k-1$. In the block k, the sender plays an action sequence and inform the receiver about the action sequence to be played in the next block $k+1$. The sender and the receiver play simultaneously at each stage of a block. Despite having aligned incentives, the sender does not reveal all information he knows about the world because this information transmission protocol is based on mismatches. Therefore, the receiver will never know the world's complete sequence. In this sense, a full revealing equilibrium is not possible. How much information is transmitted depends on the team's strategy. Taking a 3-length block strategy there are five blocks of three stages and one (the first) with only one stage: 1|110|001|010|101|100. En each block, the sender uses a signaling stage for emitting the receiver's action in the next block, that action is the world's most repeated action in the next block. That signaling stage take place when the world and the receiver do not match. That strategy is known as *majority rule* and gives the agent's action sequence: $*$|111|000|000|111|000. The sender's actions that convey informative content for the receiver are in bold: **1**|11**0**|00**0**|0**1**0|1**0**1|100.

The above communication setup is based on the model by Gossner et al. (2006) (henceforth GHN). They design optimal strategies of communication between two players using a binary information source and modeling the uncertainty coming from the nature as a third player behaving as an independent identical distributed random variable. Players are characterized by the level of available information: *the wiser* has private information on the future state of the nature, which is known with certainty; while *the agent* has public information about the history of nature's past states. The situation is repeated infinitely. The role of the strategic interaction is crucial because the gains of players are mutually conditional. There is a positive gain when both players match the nature. Therefore, the wiser has an incentive to share information in order to improve his own gains. Thus, the coordination of actions is possible and even is a strictly dominant strategy for both players. The authors offer as a main result the construction of optimal strategies based on communication blocks.

Our work is first aimed at providing a theoretical characterization of optimal block strategies when players interact for a finite number of periods. Second, a lab experiment is implemented to contrast the robustness of the model on subjects' behavior under controlled conditions. And, third, we estimate the theoretical model by logit models.

From the analysis of experimental data emerge five main results: 1) Subjects were able to design communication-enhancing strategies, which were grouped in three levels of communication. *i.* Communication at low level corresponds with a babbling equilibrium where the receiver (the agent) ignores or misunderstands the sender's (the wiser) message, therefore, information transmission does not become in communication. *ii.* A medium level strategy is characterized by both the sender and the receiver respectively make an effort to emit and decode messages in common agreement, which means that the players were able to established their own communication code. *iii.* The richest communication codes were clustered into the third level, achieving payoffs close to the optimal payoff predicted by the theoretical model. Restricted to third communication level, the results 2 and 3 are offered: 2) On average, the receiver's behavior that is represented by the proportion of times that his play matches that of the world (nature) was really close to the proportion of $\frac{2}{3}$ corresponding to the optimal strategy: majority rule for 3-stage blocks. 3) The sender's optimal behavior is partially verified by nonparametric statistics. The results 4 and 5 are related to the estimation of the theoretical model corresponding to explain respectively the sender's and receiver's probability equation. 4) The agent's action is significantly explained by the nature's and the wiser's actions. 5) A little of mis-signaling is found in the sender's play due to whether errors or matches in excess.

It is easy to find examples involving strategic information transmission in a sender-receiver game framework. One of the pionnering works is due to Crawford and Sobel (1982), who study an one-sided communication model between an informed sender and an uninformed receiver and show how interest conflict has a negative effect on the flow of information. For instance, in the setting of a firm, an employee may be asked for private and unverifiable information that his manager would need to make a decision that affects them both according to their preferences. Kartik (2005) illustrates this example taking the case of a sales agent who must forecast demand for the forthcoming year in his geographic territory to his manager. The manager may use this information for various decisions, one of which involves setting the target quota for this sales agent, and she would therefore like the best forecast available. The sales agent knows more than the manager on this matter, because of his familiarity with the territory. For any given demand forecast, the agent prefers a slightly lower quota than what the manager would like to set (this would aid his ex-post performance measures), but does not want the quota to be set overly low either (this would make him expendable should layoffs be necessary)[1].

A rich field of application of these communication games are *committees*. In particular, an application in policy science arises in the US House of Representatives (Gilligan and Krehbiel (1989), Krishna and Morgan (2001)). Typically a specialized committee -analogous to an informed expert- sends a bill to the floor of the House -the decision maker. How it may be amended depends on the legislative rule. Under the closed rule the floor is limited in its ability to amend the bill while under the open rule the floor may freely amend the bill. Thus, operating under a closed rule is similar to

[1]A similar example is offered by Watson (1996). In a firm, an employee may gather information in the course of business that his manager would like to use in making decisions. In that the employee has private information that is of value to the manager, it is in the manager's interest to motivate the employee to disclose what he knows. The employee may be asked to simple report his information to the manager, with his report being unverifiable. However, if the employee does not share the preferences of the manager, then it may not be rational for the employee to tell the truth.

delegation while and open rule is similar to Crawford and Sobel's model.

Recent applications to operations management are related to the provision of real-time information by a firm to its customers in both the service and retail sectors (Allon and Bassamboo (2011) and Allon et al. (2011)). Service providers use delay announcements to inform customer about anticipated service delays, whereas retailers provide the customers with information about the inventory level and the likelihood of being out of stock. Often, this information cannot be credibly verified by the customer. The question on how the information the firm shares with its customers influences their buying behavior is a complex one, and its answer depends both on the dynamics of the underlying operations and on the customer behavior.

The rest of the chapter is structured as follows. Section 2.2 offers a review of related literature in the field of strategic information transmission. In Section 2.3 we describe the GHN model on which the experiment is based. Sections 2.4 and 2.5 are devoted to theoretical solution and optimal strategies, respectively. We dedicate Section 2.6 to the experimental design. In Section 2.7 we describe the steps of the data analysis and highlight the main results. Section 2.8 concludes the study.

2.2 Related literature

The strategic transmission of private information plays an important role in many areas of economics and political science[2]. Most theoretical papers on unmediated communication can be classified into the two following categories. A first approach is known as games of persuasion or verifiable discloure, since it is assumed that information is verifiable and agents can conceal information but not lie (Grossman (1981) and Milgrom (1981)). The second approach is named as games of cheap talk, where information is unverifiable and agents can lie without direct costs.

[2] See Sobel (2011) for a review.

The large strand of cheap talk literature[3] was initiated by the seminal work due to Crawford and Sobel (1982). Primary related to the theory of bargaining, in the CS model of strategic communication, a better-informed sender sends a possibly noisy signal based on his private information to an uninformed receiver, who then takes an action that determines the welfare of both. The authors show how when there is some but not complete common interest, imprecise talk may be necessary and sufficient to sustain credibility. This credibility constraint are necessary for equilibrium communication. Under milder conditions on the primitives used in CS, Agastya et al. (2014b) recently completed the earlier analysis by establishing that almost full revelation obtains as the two players' preferences get arbitrarily close to each other.

The issue of when private information is acquired by the sender is addressed in the model by Green and Stokey (2007)[4]. In that paper, it is assumed that the sender knows his private information after making his choice of strategy. Additionally, the agents' preferences are given and are studied the effects of improvements in the available information on agents' welfares at equilibrium, whereas in the CS model information is given and it is studied how agents use it differently when their preferences become more similar. GHN's (2006) model shares with Green and Stokey (2007) the assumption on agents' preferences which are given -moreover they are the same ones- and the assumption on information which is also given with the CS model.

Without incentives to cheat, the sender transmits information to the receiver in the GHN (2006) environment. This feature of an honest sender and a naive receiver is analyzed by Chen (2011) who studies perturbed communication games with an honest sender -he tells the truth- and a naive receiver -he follows messages as if truthful. The characterization of message-monotone equilibria in these games allows to explain several important aspects of strategic communication such as sender exaggeration,

[3]See Farrell and Rabin (1996) for a survey.
[4]This paper was originally circulated in 1980 and 1981.

receiver skepticism and message clustering. In addition, the strategic receiver may respond to more aggressive claims with more moderate actions. In the limit, when the probabilities of non-strategic players approach zero two results are highligthed: the limit equilibrium correspond to a most-informative equilibrium of the CS game, and only the top messages are sent.

A key cornerstone of GHN's (2006) model is the randomness, that is modeled as a binary, uniform random variable representing the state of the world. This uncertainty is privately unveiled to the sender but not to the receiver. Although within a different uncertainty framework, Agastya et al. (2014a) analyze a modified CS game where the sender has expertise on some but not all the payoff-relevant factors. This uncertainty can either improve or worsen the quality of transmitted information, which depends on the effective bias. For symmetrically distributed uncertainty or quadratic loss functions, the authors highlight three results: the quality of information transmission is independent of the riskiness of that uncertainty, it may be suboptimal to allocate authority to the informed player, and despite players' preferences being arbitrarily close, it is impossible to hold that the receiver prefers delegation over authority or vice versa.

Information transmission does not have a direct cost either in the CS model or in GHN (2006). However, in the latter there is an implicit cost when information is online transmitted. That implicit cost comes from the trade-off between the costs and benefits of information transmission. A direct costly communication model is offered by Sobel (2012), who studies the case of both sender and receiver undertake a costly acquisition of communication capacity. It is also pointed out that models of costly communication with aligned preferences can have parallel results to models of costless communication where preferences are not aligned. In particular, for any communication costs or differences in preferences, full communication is not possible and failure to communicate is always possible, decreasing the quality of communication. Somewhat similar previous works investigate the effect of including both costly and costless messages in the original CS model are Austen-Smith and Banks (2000) and Kartik (2009).

As aforementioned, the complexity of the world is represented by a discrete random variable in the GHN (2006) paper. Linked to this issue, Hertel and Smith (2013) introduced in the CS setup discrete and costly communication. The paper's underlying idea is that words are scarce and costly. The sender can communicate only through the use of discrete messages which are ordered by cost. The state space is richer than the message space, since the state space is uncountably infinite and there are a finite number of messages. Thus, the model captures realism because it is impossible to communicate the complexity of the real world: the precision of communication may be enhanced by expending more costly effort, only. In addition, the size of language endogenously emerges due to the costs of communication. When the preferences between players are not aligned an increase in communication costs can improve communication.

In GHN (2006), there exists a codebook that allows for communication between agents. Therefore, once that codebook is established information is easily transmitted from senders to receivers through an online platform available. Thus, that codebook can be seen as an necessary mediator in the information transmission process.

By introducing mediators in the communication process, Ivanov (2010) modifies the CS model to investigate mediated communication between an informed expert (the sender) and an uninformed principal (the receiver) through a strategic mediator. This last collects information from the expert and gives recommendations to the principal according to her own objectives. The expert's and the mediator's preferences are parameterized by their inherent biases relative to that of the principal. The principal takes a choice over potential mediators with different preferences. The author demonstrates that, for any bias in the expert's preferences, there exists a strategic mediator that provides the highest expected payoff to the principal, as if the players had communicated through an optimal non-strategic mediator. The bias of the optimal mediator is characterized and shown opposite to the expert's one. In contrast, if the mediator's bias is between those of the other players, then mediation cannot improve upon direct talk between the expert and the principal.[5]

Thinking of an overall setting, communication is a dynamic process; information transmission is fully completed in several stages. Two recent papers by Golosov et al. (2014) and Ivanov (2015) try with dynamic information transmission in an multi-stage version of CS model over a finite horizon environment. The first paper emphasizes that full information revelation is possible, under certain conditions. By conditioning future information release on past actions improves incentives for information revelation. In the second paper, the receiver makes a decision after a finite number of periods of interaction. In each interaction, the receiver determines a test about the unknown state and the sender emits a message about the outcome of the test. As a main result, the relative payoff efficiency of multi-stage interaction compared to a single-stage game increases without a bound as the bias in preferences tends to zero. The GHN (2006) paper also analyzes communication process on repeated game framework, constructing optimal strategies based on blocks of stages over an infinite horizon.

We follow to review some experiments on cheap talk games, the literature has been also proliferated. The first review of experiments on communication games is due to Crawford (1998). This paper includes experiments with a cheap-talk pre-play phase as well as with communication throughout the game. A second and more recent related survey is by Devetag and Ortmann (2007) on coordination failure in the laboratory.[6]

[5]Ambrus et al. (2013) investigate some situations where communication is only possible through a chain of intermediators. All agents involved in the communication are assumed strategic and they want to influence the action chosen by the final receiver. The set of pure strategy equilibrium outcomes is monotonic in the bias of each intermediator and, as a result, intermediation cannot improve information transmission. However, these conclusions do not hold for mixed strategy equilibria. The authors provide a partial characterization of mixed equilibria, and an economically relevant sufficient condition for every equilibrium to be outcome-equivalent to a pure equilibrium and for the simple characterization and comparative statics results to hold for the set of all equilibria.

[6]The authors explain coordination failure in the laboratory and make a critical review of experi-

One of the first papers on communication in a laboratory is that of Cooper et al. (1989), where are reported experimental results on the role of pre-play communication in a one-shot, symmetric, battle of the sexes game. They studied the effects of three communication structures: one-way communication with one round of messages and two-way communication with one round as well as three rounds of messages. Compared with no communication game, communication significantly increased the frequency of equilibrium play. It was found that one-way communication was most effective in resolving the coordination problem. In a second paper, Cooper et al. (1992) evaluated the cheap talk effect in the settings of two communication structures (one-way and two-way communication) and two types of coordination games (one with a cooperative strategy and a second in which one strategy is less risky). The experimental evidence concluded that one-way communication increases play of the Pareto-dominant equilibrium in the game with a cooperative strategy. Regardless of strategy, two-way communication always leads to the Pareto-dominant Nash equilibrium.

Charness and Grosskopf (2004) analyze which components migth make cheap talk effective in the setting of coordination game. In particular, they design an experiment based on a two-player game to test whether information provision about the other player's action, and whether costless one-way messages before actions are taken have some influence on coordination. They find that information provision about the other person's play only enhances coordination when messages are allowed.

Through an experimental approach, Blume and Ortmann (2007) investigate the effects of costless pre-play communication in symmetric coordination games of the stag hung variety. They find that with repeated interaction cheap talk preceding games with Pareto-ranked equilibria can substancially facilitate player's coordination on the Pareto-dominant equilibrium.

mental studies on coordination games with Pareto-ranked equilibria.

In the setting of a prisoner's dilemma, Rand et al. (2015) examine coordination in repeated interactions where intended actions are implemented with noise but intentions are directly observable. Observing intentions leads to more cooperation, especially if these observations support a cooperative equilibrium that would not otherwise be present, and it also leads subjects to use simpler lower memory strategies.

The Hertel and Smith (2013) model on costly and discrete communication is contrasted in a laboratory by Duffy et al. (2014). These authors find that the size of the language endogenously emerges as a function of the costs of communication: higher communication costs are associated with a smaller language. They find that the sender's payoffs, relative to equilibrium payoffs, are decreasing in cost, whereas the receiver's payoffs, relative to equilibrium payoffs, are increasing in Moreover, over-communication is also found.

Following the Battaglini (2002) multidimensional cheap talk model, Lai et al. (2011) design an experimental where two senders transmit information to a receiver over a 2×2 state space. The experimental findings confirm that more information can be extracted with two senders in a multidimensional setting. The amount of information transmitted depends on whether dimensional interests are aligned between a sender and the receiver, the sizes of the message spaces, and the specification of out-of-equilibrium beliefs.

In the setting of public-goods games, Oprea et al. (2014) investigate the nature of continuous time strategic interaction. In one set of treatments, four subjects make contribution decisions in continuous time during a 10-min interval, whereas in another set they make decisions at 10 discrete points of time during the same interval. The effect of continuous time has no relevance in public-goods games compared to simpler social dilemmas. Furthermore, the data suggest coordination problems as a cause. When added a rich communication protocol, these coordination problems largely disappear and the median subject contributes completely to the public good with no sign of decay over time. In addition, the same communication protocol is less than half as effective in discrete time, at the median.

To finish this section, we review a few papers that are related to the Matching Pennies (MP henceforth) game, on which GHN's (2006) model is based. MP game has received a lot of attention from researchers on experimental economics. The classical version of the game consists of a two-player one shot game. Each player places a covered coin on a table, then both players show it simultaneously. One player wins when the two coins match (two heads or two tails), otherwise it is the other player who wins.

Camerer and Karjalainen (1994) investigated the psychology of timing in an experiment on MP game. They found that if the first mover is the player who does not want to match, he will probably try to outguess what the second mover will do later. However if he moves second, will likely choose the chance randomizing device, hedging his bet. Mookherjee and Sopher (1994) investigated the hypothesis that past experience could affect current strategy, in an experimental finitely repeated MP game, with asymmetric information on the opponent's past actions. Eliaz and Rubinstein (2011) studied framing effects in repeated MP games. The players were labeled as guesser/even (he wants to match) and misleader/odd (he does not want to match). It was found that the first one had an advantage.

In a three-person MP game, McCabe et al. (2000) tested the hypothesis that subjects play the mixed strategy Nash equilibrium without the need of using sophisticated bayesian learning. Chiappori et al. (2002) studied mixed strategies in a real application with the structure of the MP game: a penalty kicks in soccer. Replacing a player by a computer, Shachat and Swarthout (2004) applied an asymmetric MP repeated game in an experiment on mixed strategies deviating from Nash equilibrium, concluding that subjects are able to detect and exploit this kind of strategies, on average.

In the study of Fox and Weber (2002) on the concept of comparative ignorance (Fox and Tversky (1995)) as a state of mind of the decision maker, the authors used an MP game to show that players in a competitive game were sensitive to their counterpart's relative competence, but not when they played a coordination game with the same mixed strategy Nash equilibrum.

The MP game has also been used in neuroscience to study activity in the prefrontal cortex (Barraclough et al. (2004)). In a similar line, Cohen and Ranganath (2007) applied the MP game to study if subjects adapted their decision behavior to reinforcement in a competitive environment. Vickery et al. (2011) replicated the experiments of Barraclough et al. (2004) among others. Participants played either MP or rock-paper-scissors games against computerized opponents while being scanned using functional magnetic resonance imaging(fMRI). The experiment showed as a new result that neural signals related to reinforcement and punishment are broadly distributed throughout the entire human brain.

2.3 The model

In this section we present the model by Gossner, Hernández and Neyman (2006) (GHN hereafter), which is based on a 3-players game called Online Matching Pennies. Using a repeated game structure, the authors study how one fully informed player, said the wiser, can efficiently transmit online information to another less informed player called the agent. That information is related to the play of player 1: the random nature.

2.3.1 The one-shot game

On the basic structure of the one-shot game, the three players choose an action 0 or 1. If all of them take the same action, both players, the wiser and the agent receive a payoff equals 1 and nothing otherwise. Players 1, 2 and 3 are denoted by i, j and k respectively. The payoff function for both players 2 and 3 is the following:

$$g(i,j,k) = \begin{cases} 1 & if \quad i = j = k \\ 0 & otherwise \end{cases} \tag{2.1}$$

It can also be represented in matrix way:

	$k=0$	$k=1$
$j=0$	1	0
$j=1$	0	0

$i=0$

	$k=0$	$k=1$
$j=0$	0	0
$j=1$	0	1

$i=1$

2.3.2 The repeated game

Consider the original Matching Pennies is repeated infinitely. The fully informed player and the partially informed player have the same payoff function, so they could form a team to increase their gains. The nature (player 1) plays a sequence of actions $X \in \{0,1\}^{\mathbb{N}}$ following a law known by the other two players. The wiser (player 2) has knowledge in advance of the future actions of the nature. While the actions of the agent (player 3) depends on the history of the nature's and the wiser's actions. Formally, the strategies for the wiser and the agent are defined as follows:

- A (pure) strategy for the wiser is a sequence $(Y_t)_t$ of mappings $Y_t : \{0,1\}^{\mathbb{N}} \times \{0,1\}^{t-1} \times \{0,1\}^{t-1} \rightarrow \{0,1\}$, where Y_t describes the behavior at stage t.

- A (pure) strategy for the agent is a sequence $(Z_t)_t$ of mappings $Z_t : \{0,1\}^{t-1} \times \{0,1\}^{t-1} \times \{0,1\}^{t-1} \rightarrow \{0,1\}$, where Z_t describes the behavior at stage t.

It is assumed that the sequence $(i_t)_t$ of states of nature is independent and identically distributed of stage law $(\frac{1}{2}, \frac{1}{2})$. A pair of strategies (Y, Z) induces sequences of random variables $(j_t)_t$ and $(k_t)_t$ given by $j_t = Y_t((i_n)_n, (j_1, \ldots, j_{t-1}), (k_1, \ldots, k_{t-1}))$ and $k_t = Z_t((i_1, \ldots, i_{t-1}), (j_1, \ldots, j_{t-1}), (k_1, \ldots, k_{t-1}))$. Notice that the wiser's action at the stage t depends eventually only on the whole sequence of nature $(i_n)_n$ and the agent's also depends on the wiser's past action sequence $(j_{t-1})_{t-1}$.

Thus, given a sequence of nature $X \in \{0,1\}^{\mathbb{N}}$ and a pair of strategies (Y, Z) for the team, the induced sequences of actions $(j_n)_n$ and $(k_n)_n$ of the wiser and the agent are given by the following relations: $(j_n)_n = Y(X)$, $(k_n)_n = Z(X, Y)$. Any probability P on $\{0,1\}^{\mathbb{N}}$ together with strategies (Y, Z) induces a joint probability distribution $P_{Y,Z}$ on the set of sequences (i_t, j_t, k_t) in the space $(\{0,1\} \times \{0,1\} \times \{0,1\})^{\mathbb{N}}$.

In situations under uncertainty, players may share information to reduce inefficiencies. Such situations last a finite time. Therefore, results obtained under infinite time assumption may not be easily applied. Our main concern is whether such techniques can be applied in a finite context. In such case, our second concern is to characterize optimal strategies with asymmetric information.

2.4 Theoretical solution

This section is devoted to obtain the theoretical solution from an optimization problem where players want to maximize their average payoff. As we have already mentioned, the wiser uses some stages to indicate information to the agent. Such stages she makes mistakes on purpose. The ratio of mistakes produced by the wiser and the agent is related to the realized expected payoff per stage in the long-run.

The main result reached by GHN (2006) is the characterization of the solution that the team can guarantee by using optimal strategies when they use the long-run average expected payoff as criterium payoff. The strategies are defined over n-length blocks in such a way that for any sequence of nature $(X_n)_n$, the proportion of stages for which the agent's action matches the nature's $Z_t = X_t$ is denoted by $q \in [0, 1]$ and the proportion of stages for which the wiser's action matches the nature's $Y_t = X_t$ conditional on $Z_t = X_t$ is $p \in [0, 1]$. Then, the proportion of stages in which $Y_t = Z_t = X_t$ is close to $p \cdot q$.

Call x the average long-run payoff computed as $x = p \cdot q$. During each block, the agent has to interpret the message sent by the wiser during the previous block in order to choose a sequence $(Z_n)_n$ of actions or action plan. The wiser chooses a sequence $(Y_n)_n$ of actions or message such that:

- The number of times the three sequences match is equal to $\lfloor q \cdot p \cdot n \rfloor = \lfloor x \cdot n \rfloor$.
- Conditional on the agent does not match nature, neither does the wiser about a half of times $\lfloor \frac{1-q}{2} n \rfloor$.

The following tree depicts the possible outcomes from a stage:

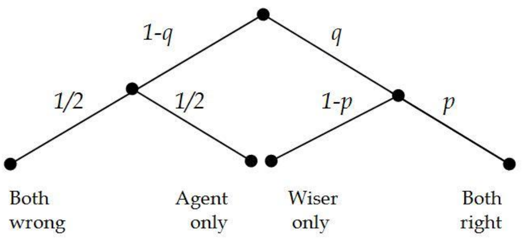


Figure 2.1: Decision tree.

2.4.1 The optimization problem

The problem of the team is to determine q and p to reach the maximal expected payoff, under the information constraint: the amount of information available for the team should overcome the information of nature.

The amount of information is measured by the entropy function, being the entropy of nature defined as the entropy of a random variable X:

$$H(X) = -\sum_{x \in X} P_x \log_2 P_x$$

And the joint entropy of team is:

$$H(Z,Y) = - \sum_{z,y \ \in \ Z \bigcap Y} P_{zy} \log_2 P_{zy}$$

Also in terms of conditional entropy :

$$H(Z,Y) = H(Z) + H(Y|Z)$$

The information conveyed into the tree above is calculated as the joint entropy:

$$H(p,q) = H(q) + H(p|q) = H(q) + qH(p) + (1-q)H(1/2) \tag{2.2}$$

The optimization problem to be solved is as follows:

$$\begin{array}{ll} \max_{q,p} & x = q \cdot p \\ subject \quad to & \\ & H(q) + qH(p) + (1-q)H(1/2) \geq h \end{array}$$

where h denotes the entropy per stage, its value depends on the random process of the nature[7].

[7]If the nature follows a random i.i.d. $(\frac{1}{2}, \frac{1}{2})$, then the value of h is equal to the entropy of nature:

$$\begin{array}{rcl} H(X) & = & P(0)\log_2 \frac{1}{P(0)} \quad + \quad P(1)\log_2 \frac{1}{P(1)} \\ & = & \frac{1}{2}\log_2 \frac{1}{1/2} \quad + \quad \frac{1}{2}\log_2 \frac{1}{1/2} \quad = \log_2 2 = 1 \end{array}$$

The corresponding Lagrangian problem is:

$$\mathcal{L} = q \cdot p + \lambda[H(q) + q(H(p) - 1) + 1 - h]$$

The first order conditions say:

$$\frac{\partial \mathcal{L}}{\partial q} = p + \lambda[H'(q) + H(p) - 1] = 0 \tag{2.3}$$

$$\frac{\partial \mathcal{L}}{\partial p} = q + \lambda q H'(p) = 0 \tag{2.4}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = H(q) + q(H(p) - 1) + 1 - h = 0 \tag{2.5}$$

From (2.3)and (2.4) p is written in terms of q:

$$p = \frac{3q - 1}{2q} \tag{2.6}$$

In addition, p and q can be written in terms of expected payoff x:

$$p(x) = \tfrac{3x}{2x+1}, \quad 1 - p(x) = \tfrac{1-x}{2x+1}$$

$$q(x) = \tfrac{2x+1}{3}, \quad 1 - q(x) = \tfrac{2(1-x)}{3}$$

Given $p(x)$ and $q(x)$, the constraint of the above optimization problem remains as follows:[8]

$$h = H(x) + (1 - x)\log_2 3 \tag{2.7}$$

[8]The value of the entropy function for $0 < x < 1$ is $H(x) = -x \log_2 x - (1 - x) \log_2(1 - x)$, and for $x = 0$ and $x = 1$ is $H(0) = H(1) = 0$.

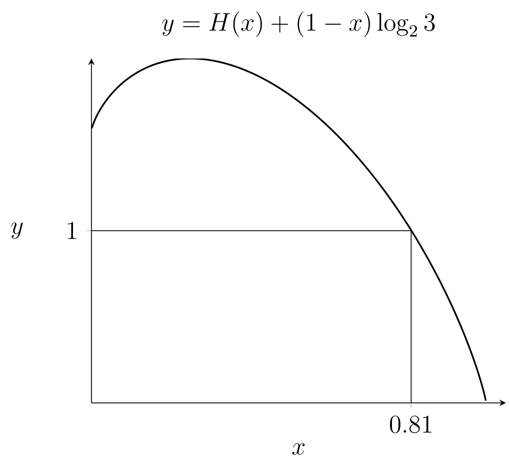


Figure 2.2: Payoff-information constraint.

Thus, the joint entropy $H(p, q)$ is expressed in terms of expected payoff by $H(x)+(1-x)\log_2 3$. The constraint saturates when the information gathered by the team equals the information from the nature h. The optimal expected payoff is given as the solution of the equation 2.7. Since the nature's entropy is $h = 1$, then the solution for x is close to 0.81. As shown in the figure below, the lower the nature's entropy is, the higher the optimal expected payoff is.

2.5 Optimal strategies

This section is divided in three parts: The first one recalls the wiser's and agent's strategy sets from a large horizon (possible infinite) point of view. A map from the wiser's message set to the agent's action plan set is defined following GHN (2006). It continues generalizing the previous results for finite length sequences, and finishes with an instance for a finite nature's sequence of length 55, which is the length of the sequence used in the experiment presented at section 2.6.

2.5.1 Theoretical study

Let's recall the strategies for the wiser and the agent. For a sequence of length n, a message is a sequence of actions $Y_k = (Y_n)_n$ that the wiser plays during a block k of n stages to inform the agent about the sequence of actions $Z_{k+1} = (Z_n)_n$ that the latter should play in the next block $k+1$ of n stages to reach the target payoff.

In order to construct the message Y_k at the current block k, the wiser takes into the account future information about the nature's actions X_{k+1}, and knowing also the nature's and the agent's current actions: X_k and Z_k. Therefore, given the sequences of actions X_k and Z_k in a block k, there exists a message map $m_{X_k Z_k}$ from the set of all n-length sequences to the set of messages $M(X_k, Z_k)$ that applied on X_{k+1} transmits the message $Y_k = m_{X_k Z_k}(X_{k+1})$.

Once received the message is decoded by the agent to find out her next sequence of actions Z_{k+1} or *action plan*. Hence, there should be an action map $a_{X_k Z_k}$ from the set of messages $M(X_k, Z_k)$ to the set of action plans $A(n)$ that applied on Y_k translates the message into an action plan $Z_{k+1} = a_{X_k Z_k}(Y_k)$.

GHN (2006) prove that there exists a set of action plans denoted by $A(n)$ of size[9] $|A(n)| = 2^{n(h-H(q))}$ with $h = 1$ corresponding to an *i.i.d.* $(\frac{1}{2}, \frac{1}{2})$ process, such that for every n-length sequence of nature, there exists an n-length sequence of agent's actions belonging to action plan set that matches nature $\lfloor qn \rfloor$ times. Additionally, the set of messages should be larger than the set of action plans.

Call the pair of strategies (Y_k, Z_k) played by the wiser and the agent at a block $k > 2$ as follows: $Y_k = m_{X_k Z_k}(X_{k+1})$ and $Z_k = a_{X_{k-1} Z_{k-1}}(Y_{k-1})$. The strategies for the two first blocks are explained below:

[9]The existence of $A(n)$ can be proved by probabilistic methods. Actually, GHN (2006) they prove such existence that is independent of X and Y. From (2.5) the information constraint of optimization problem, we can write the conditional entropy as $H(p|q) = h - H(q)$ and the size of the set of messages as $|M(n)| = 2^{n(h-H(q))}$.

Case 1. $k = 1$

The wiser plays the actions of the nature of the second block, while the agent plays any sequence, for example a sequence of 1's: $Y_1 = X_2, Z_1 = (1, \ldots, 1)$.

Case 2. $k = 2$

The agent plays a sequence belonging to the set of action plans, and the wiser tells him what to play during the block 3. The only requirement to the agent's sequence is that it has to match the nature's sequence $\lfloor qn \rfloor$ times: $Y_2 = m_{X_2,Z_2}(X_3), Z_2 = a_{X_1 Z_1}(Y_1)$.

2.5.2 Optimal strategies for finite sequences

In this subsection, we construct optimal strategies block for the wiser and the agent and for any sequence of actions played by the nature when the length n is finite. Furthermore, we characterize the optimal length block to guarantee the highest expected payoff for a length of $n = 55$.

We follow the methodology offered in GHN(2006). As known, the number of different sequences of length n that a binary nature may generate is 2^n. The number of different sequences of length n with q proportional matches is the combinatorial number $C_{n,nq}$. Similarly the number of different sequences of length nq with p proportional matches is the combinatorial number $C_{nq,nqp}$. Furthermore, the wiser will use the remaining locations $n(1-q)$ to play any action whether 0 or 1, getting a number of possibilities equals $C_{n(1-q),n(1-q)\frac{1}{2}}$. Thus, the total number of sequences is given by the following combinatorial number expression:[10]

[10] In general, $\begin{pmatrix} n \\ m \end{pmatrix}$ is defined as $\Gamma(n+1)/(\Gamma(m+1)\Gamma(n-m+1))$. Being $\Gamma(n)$ Euler gamma function that satisfies $\Gamma(n) = \int_0^\infty t^{n-1}e^{-t}dt$.

$$\begin{pmatrix} n \\ nq \end{pmatrix} \begin{pmatrix} nq \\ nqp \end{pmatrix} \begin{pmatrix} n(1-q) \\ n(1-q)\frac{1}{2} \end{pmatrix} \geq 2^n \tag{2.8}$$

The expression (2.8) can be approximated by the entropy function as follows:[11]

$$2^{nH(q)} 2^{nqH(p)} 2^{n(1-q)H(1/2)} \geq 2^n \tag{2.9}$$

Or also as the joint entropy:[12]

$$H(p,q) = H(q) + H(p|q) \geq 1 \tag{2.10}$$

Being $H(p|q) = qH(p) + (1-q)H(1/2)$ the conditional entropy.

The term $H(p|q)$ represents the wiser's quantity of information when he matches the nature knowing that the agent does the same and, therefore, both of them get gains. The partial informed agent has imprecise information on the future state of the nature, the quantity of which is measured by $H(q)$. So his lack of information is given by the difference between the maximum value of entropy for an $i.i.d.(\frac{1}{2}, \frac{1}{2})$ binary source, $(H(1/2) = 1)$, and his own available information. Consequently, the information offered by the fully informed wiser to the agent is $(1 - H(q))$. Therefore, the wiser does not need to transmit all the private information on the future state of the nature in order to improve his total gain. Sharing only a portion of his privileged information is enough for both of them to have incentives to set up an scheme of communication as efficient as possible. This scheme will be designed according to the willing degree of match

[11] For $0 < x < 1$, the combinatorial number $\begin{pmatrix} n \\ nx \end{pmatrix}$ is upper bounded by $2^{nH(x)}$, that offers a good approximation when n is large.

[12] For $0 < x < 1$, by approximating the combinatorial number by the upper bound and then taking algorithms, it results: $\frac{1}{n} \log_2 \begin{pmatrix} n \\ xn \end{pmatrix} \doteq H(x)$.

embedded in the pair (p, q). The coordinated action is possible when the wiser may complete the agent's information, by using the mismatches or errors to transmit coded information about the future state of nature, which improves the gain of the team. In other words, the coded information is embedded into the error digits. In addition, there is a trade-off between gains and errors because the fewer errors, the higher total gain but, in turn, there are less chances to inform on the future state of nature, which reduces both the future gains and the total gain. The total number of errors depends on the pair (p, q) that must satisfy the information constraint (2.9) for communication to be feasible. Since there are a number of these pairs (p, q), the wiser and the agent choose the best possible pair.

Let S be the set of pairs (p, q) verifying the above condition (2.9) written after taking logarithms:

$$S = \{(p, q) : H(q) + qH(p) + (1 - q) \geq 1\} \tag{2.11}$$

Note that if $p = 1$ and $q = 1$, both of them have perfect information and the information constraint is not worth: $H(1) + 1H(1) + (1 - 1) = 0 < 1$. Consequently, we get the following two remarks:

Remark 1. S *is a proper subset of* $[0, 1] \times [0, 1]$.

Remark 2. *The information constraint does not depend on* n.

To set a feasible communication system is needed to consider finite length sequences, so that the number of errors must be properly defined as an integer number. Therefore, additional definitions are also needed into the rational number set. As shown below, the criterion used to define the percentage of matches by the agent as a rational number is conservative since it takes as numerator the less integer number than the real number of matches. An alike criterion is applied to the percentage of matches by the wiser, with the proper change of denominator since his matches are subject to the agent's own matches.

Let (p, q) be elements on S. Define the counterpart rational numbers as $\tilde{q}(n) = \frac{\lfloor qn \rfloor}{n}$, $\tilde{p}(n) = \frac{\lfloor pqn \rfloor}{\lfloor qn \rfloor}$, n is the size of the block. If $q \in [0, 1]$ then $\tilde{q} \in \{0, \frac{1}{n}, \dots, \frac{n-1}{n}, 1\}$. Similarly, If $p \in [0, 1]$ then $\tilde{p} \in \{0, \frac{1}{n\tilde{q}}, \dots, \frac{n\tilde{q}-1}{n\tilde{q}}, 1\}$.

Now, rewrite the expression (2.8) with rational numbers:

$$\binom{n}{n\tilde{q}}\binom{n\tilde{q}}{n\tilde{q}\tilde{p}}\binom{n(1-\tilde{q})}{n(1-\tilde{q})\frac{1}{2}} \geq 2^n \tag{2.12}$$

By using the approximation of the entropy function, the information constraint taking into account rational distribution is expressed as follows:

$$H(\tilde{q}) + \tilde{q}H(\tilde{p}) + (1-\tilde{q}) \geq 1 \tag{2.13}$$

We call this constraint as *rational information constraint.*

Now, call $\tilde{S}_n$ the set of pairs $(\tilde{p}, \tilde{q})$ verifying the information constraint:

$$\begin{aligned} \tilde{S}_n = \{(\tilde{p}, \tilde{q}) \in {}_n \times {}_n : & \\ & \tilde{q}(n) = \tfrac{\lfloor qn \rfloor}{n}, q \in [0,1] \\ & \tilde{p}(n) = \tfrac{\lfloor pqn \rfloor}{\lfloor qn \rfloor}, p \in [0,1] \\ & H(\tilde{q}) + \tilde{q}H(\tilde{p}) + (1-\tilde{q}) \geq 1\} \end{aligned} \tag{2.14}$$

We obtain the following three remarks:

Remark 3. $\tilde{S}_n \subseteq S \subsetneq [0, 1] \times [0, 1]$.

Remark 4. *The rational information constraint does depend on n.*

$$H\left(\frac{\lfloor qn \rfloor}{n}\right) + \frac{\lfloor qn \rfloor}{n} H\left(\frac{\lfloor pqn \rfloor}{\lfloor qn \rfloor}\right) + \left(1 - \frac{\lfloor qn \rfloor}{n}\right) \geq 1 \tag{2.15}$$

Remark 5. *Let $n > 0$*

- *Let $D_n = \{m < n : \tilde{S}_m \neq 0\}$. There exists $m^* \in D_n$ and $(p^*, q^*) \in \tilde{S}_{m^*}$ such that p^*q^* is maximal over $(p, q) \in \tilde{S}_m, \forall m \in D_n$. Consider the family $\left\{\frac{\lfloor qm \rfloor}{m}, \frac{\lfloor pqm \rfloor}{\lfloor qm \rfloor}\right\}_{m \in D_n}, \forall m \in D_n$.*

  Notice that $\tilde{S}_m \subset [0,1] \times [0,1]$ is a compact set. Therefore the product pq reaches its maximal value in this set.

  Solving the payoff optimization problem, we find the optimal pair $(\tilde{p}(m), \tilde{q}(m))$ verifying the information constraint:

$$H\left(\frac{\lfloor qm \rfloor}{m}\right) + \frac{\lfloor qm \rfloor}{m} H\left(\frac{\lfloor pqm \rfloor}{\lfloor qm \rfloor}\right) + \left(1 - \frac{\lfloor qm \rfloor}{m}\right) \geq 1 \tag{2.16}$$

  Let (p^*, q^*) be such pairs that reach the maximal value in $\tilde{S}_m$.

2.5.3 Optimal strategies block for $n = 55$

In this subsection we apply the above lemma to construct both $(\tilde{p}, \tilde{q})$ rational distribution for sequences of length 55.

From the definition of the set of pairs $(\tilde{p}, \tilde{q})$ verifying the information constraint given by (2.14), divide the range of definition of q, $0 \leq q \leq 1$, into m disjoint intervals such that:

$$\tfrac{x}{m} \leq q < \tfrac{x+1}{m}, \quad x = 0, 1, \cdots, m \tag{2.17}$$

and call x the number of times the agent and the nature match. On the one hand, for each one of m intervals the corresponding rational number exists in the set:

$$\tilde{q}(m) = \left\{0, \frac{1}{m}, \frac{2}{m}, \cdots, \frac{m-1}{m}, 1\right\} \tag{2.18}$$

On the another hand, given the rational number $\tilde{p}(m) \in [0,1]$ defined conditional on $\tilde{q}(m)$ as $\tilde{p}(m) = \frac{\lfloor pqm \rfloor}{\lfloor qm \rfloor}$ and $\lfloor qm \rfloor = x$, follows that $0 \leq \lfloor pqm \rfloor \leq x$. And, consequently, for each one of m above intervals on q, a set $\tilde{p}(m)$ exists:

$$\tilde{p}(m) = \frac{x}{m} = \left\{\frac{0}{x}, \frac{1}{x}, \cdots, \frac{x-1}{x}, 1\right\}, x \neq 0 \tag{2.19}$$

The special case $x = 0$ corresponds to the interval on q such that $0 \leq q < \frac{1}{m}$. The expression $\tilde{p}(m)$ is now defined for all $p \in [0,1]$.

For $n = 55$ we study the following cases which cover all matching probability pairs $(\tilde{p}(m), \tilde{q}(m))$ that verify the above information constraint: $m = \{2, \ldots, 27\}$. By programming with Mathematica 7.0, we provide with all strategy sets $\tilde{S}_m$. Here, only five of them are reported:[13]

$\tilde{S}_2 = \{(\frac{1}{2}, 1), (0, \frac{1}{2}), (1, \frac{1}{2})\}$

$\tilde{S}_3 = \{(0, \frac{1}{3}), (1, \frac{1}{3}), (0, \frac{2}{3}), (\frac{1}{2}, \frac{2}{3}), (1, \frac{2}{3})\}$

$\tilde{S}_4 = \{(\frac{1}{2}, 1), (0, \frac{1}{4}), (1, \frac{1}{4}), (0, \frac{1}{2}), (\frac{1}{2}, \frac{1}{2}), (1, \frac{1}{2}), (0, \frac{3}{4}), (\frac{1}{3}, \frac{3}{4}), (\frac{2}{3}, \frac{3}{4}), (1, \frac{3}{4})\}$

$\tilde{S}_5 = \{(0, \frac{1}{5}), (1, \frac{1}{5}), (0, \frac{2}{5}), (\frac{1}{2}, \frac{2}{5}), (1, \frac{2}{5}), (0, \frac{3}{5}), (\frac{1}{3}, \frac{3}{5}), (\frac{2}{3}, \frac{3}{5}), (1, \frac{3}{5})(\frac{1}{4}, \frac{4}{5}), (\frac{1}{2}, \frac{4}{5}), (\frac{3}{4}, \frac{4}{5})\}$

Given such sets, we follow identifying those pairs $(\tilde{p}(m), \tilde{q}(m))$ that maximize gains for each m-length block. The table 2.1 reports the information related to optimal pairs $(\tilde{p}(m), \tilde{q}(m))$ and gains for the sets $\tilde{S}_m$ of length $m = \{2, 3, 4, 5\}$. Notice that the best possible total gain is that produced by the strategy $(1, \frac{3}{4})$, that is, the agent's

[13] In the appendix, table 2.12 shows the set of optimal strategies under the rational information constraint.

percentage of matches is 3 over 4 and the wiser's is 3 over 3. Therefore, in a block of length $m = 4$, there is one common intended error, which is properly used by the wiser to communicate to the agent her/his next action. For a whole sequence of length $n = 55$, this strategy consists of dividing the sequence into $\lfloor \frac{55}{4} \rfloor = 13$ blocks of length 4 and one first block of length 3.

Table 2.1: Optimal strategies for blocks of length $m = \{2, 3, 4, 5\}$ under the rational information constraint.

m	(p^*, q^*)	Gain/Block	p^*q^*	Blocks	Total Gain
2	$(1, \frac{1}{2})$, $(\frac{1}{2}, 1)$	1	$\frac{1}{2}$	27	27
3	$(1, \frac{2}{3})$	2	$\frac{2}{3}$	18	36
4	$(1, \frac{3}{4})$	3	$\frac{3}{4}$	13	39
5	$(1, \frac{3}{5})$,$(\frac{3}{4}, \frac{4}{5})$	3	$\frac{3}{5}$	10	30

The second best strategy corresponds to the pair $(1, \frac{2}{3})$ that yields a total gain equals 36. The interpretation is very similar except in the following: since one error is needed to make coordination possible, there are 18 blocks of length $m = 3$, and one digit is left at the beginning to communicate the first play.

The third best strategy consists of building 27 blocks of length $m = 2$ and making an intended error. Although two strategies fulfil the information constraint, only the first makes more sense. The strategy $(1, \frac{1}{2})$ means the agent's action matches the nature's action the half of times and the wiser's action always matches the agent's action. When the process of nature is *i.i.d.* $(\frac{1}{2}, \frac{1}{2})$, this strategy is equivalent to follow a naive behavior such as: *the wiser always matches the nature and the agent takes the same action over and over.*

Finally, there are also two optimal theoretical strategies for blocks of length $m = 5$, which correspond to the pairs $(1, \frac{3}{5})$ and $(\frac{3}{4}, \frac{4}{5})$. In this case two errors are needed to earn a payoff of 30. The pair $(1, \frac{3}{5})$ represents two errors made by the agent and no additional errors by the wiser. The pair $(\frac{3}{4},\frac{4}{5})$ indicates that both players made one relevant error.

It seems clear that one-error strategies will be easier to implement than two-or-more-error strategies, particularly in the setting of lab with human subjects. To that purpose, it is necessary to establish the precise coordination rule that allows to undoubt identify the signaling stages. Furthermore, only feasible strategies are actually implementable. Next subsection is devoted to characterize the feasible strategies from the optimal theoretical strategy set.

Characterizing implementable strategies: *the majority rule*

A strategy $(\tilde{p}(m), \tilde{q}(m))$ that fulfills the rational information constraint (2.16) will be implementable for large sequences, but not for any length m. That is due to the fact that the rational information constraint provides us with an upper bound of the amount of information shared by the wiser-agent team. It is possible to find a strategy that fulfills the rational information constraint but it is not actually implementable, because of the total number of m-length sequences is less than the one required by the expression (2.12) in the page 56. Consequently, to construct a special strategy it is necessary to verify that the exact number of m-length sequences with a proportional matching of $\tilde{q}(m)$ by the agent and $\tilde{p}(m)$ by the wiser is at least the number of different m-length sequences, 2^m. We defined *the implementable information constraint* as follows:[14]

$$\begin{pmatrix} m \\ m\tilde{q} \end{pmatrix}\begin{pmatrix} m\tilde{q} \\ m\tilde{q}\tilde{p} \end{pmatrix}\begin{pmatrix} m(1-\tilde{q}) \\ m(1-\tilde{q})\frac{1}{2} \end{pmatrix}+\begin{pmatrix} m \\ m \end{pmatrix}\begin{pmatrix} m \\ m(1-\tilde{q}\tilde{p}) \end{pmatrix} \tag{2.20}$$

[14]In general, $\begin{pmatrix} n \\ m \end{pmatrix}$ is defined as $\Gamma(n+1)/(\Gamma(m+1)\Gamma(n-m+1))$. Being $\Gamma(n)$ Euler gamma function that satisfies $\Gamma(n)=\int_0^\infty t^{n-1}e^{-t}dt$. For $n(1-q)=1$, we consider $\begin{pmatrix} n(1-q) \\ n(1-q)\frac{1}{2} \end{pmatrix}=2$. That means that with one digit is possible to build the two basic sequences: 0 and 1.

Notice that the second summand represents the total number of m-length sequences with a number of errors equals $m(1-\tilde{q}\tilde{p})$. It is added in an attempt to fulfill the constraint.

We check for the feasibility of optimal theoretical strategies in $\tilde{S}_m$, for $m = \{2,3,4,5\}$:

- For 2-length blocks, the optimal strategy is $p^* = 1$ and $q^* = 1/2$

$$\binom{2}{1}\binom{1}{1}\binom{1}{1/2}+\binom{2}{2}\binom{2}{1} = 6 \geq 2^2 = 4$$

- For 3-length blocks, the optimal strategy is $p^* = 1$ and $q^* = 2/3$

$$\binom{3}{2}\binom{2}{2}\binom{1}{1/2}+\binom{3}{3}\binom{3}{1} = 9 \geq 2^3 = 8$$

- For 4-length blocks, the optimal strategy is $p^* = 1$ and $q^* = 3/4$

$$\binom{4}{3}\binom{3}{3}\binom{1}{1/2}+\binom{4}{4}\binom{4}{1} = 12 \not\geq 2^4 = 16$$

- For 5-length blocks, the optimal strategy is $p^* = 3/4$ and $q^* = 4/5$

$$\binom{5}{4}\binom{4}{3}\binom{1}{1/2}+\binom{5}{5}\binom{5}{2} = 50 \geq 2^5 = 32$$

These results indicate that it is not possible to build blocks of length $m = 4$ with only one error[15]. Therefore, 2-length blocks and 3-length blocks are feasible strategies that implement one intended error as signaling action.

The 2-length block strategy consists of dividing the n-length sequence in subsequences of length 2. The first stage of a block is the signaling stage, where the wiser plays the nature's second stage action. In this way, the wiser advances information to the agent about the nature's future playing, and both play accordingly to match the nature's action in the second stage of a block. This strategy guarantees a payoff of 1 per block or 1/2 per stage. Let's see the following example for a sequence of length 16, where the guarantee payoff is 8 (1×8 blocks). Figures in bold indicate signaling actions. In the first stage of a block, the agent can play any action, whether 0 or 1, we write $*$ instead. In the second stage of a block, the triple action (nature, wiser, agent) is the nature's action. Already a matching probability exists in the first stage of a block. In fact that matching probability is 1/4, so that it is expected a payoff of 5/4 per block or 5/8 per stage.

Table 2.2: 2-length block strategy

Nature	1	1	0	0	1	0	1	1	1	1	0	1	0	0	0	0
Wiser	**1**	1	**0**	0	**0**	0	**1**	1	**1**	1	**1**	1	**0**	0	**0**	0
Agent	*	1	*	0	*	0	*	1	*	1	*	1	*	0	*	0
Payoff	*	1	*	1	*	1	*	1	*	1	*	1	*	1	*	1

The 3-length blocks[16] strategy is ruled such that in each block after the first stage, the agent's actions match the nature's actions in 2 out of 3 stages, at least.

[15]For 4-length blocks, there exists the feasible pair with two errors $(\frac{2}{3}, \frac{3}{4})$ that produces a lower total gain of 24.

[16]Notice the binary sequences of length 3 are: (0,0,0), (0,0,1), (0,1,0), (1,0,0), (1,1,0), (1,0,1), (0,1,1) and (1,1,1). There exist four sequences with majority rule 0, and four sequences with majority rule 1. The probability of the majority rule 'equals 0' is given by $prob(majority = 0) = prob(000 \cup 001 \cup 010 \cup 100) = 4\frac{1}{8} = \frac{1}{2}$. Similarly, the probability of the majority rule 'equals 1' is equal to $prob(majority = 1) = prob(110 \cup 101 \cup 011 \cup 111) = 4\frac{1}{8} = \frac{1}{2}$. Thus, the probability of two consecutive blocks have the same majority is $\frac{1}{2}$. The probability that an intended mistake (say x) becomes a random match is equal to: $P(x = majority = 0)P(majority = 0)P(majority = 0) + P(x = majority = 1)P(majority = 1)P(majority = 1) = \frac{1}{4}$.

The agent's triple action is either (0,0,0) or (1,1,1) in each block, whereas the wiser's actions in a block signal to the agent the majoritarian action of nature in the next block. This signaling is achieved by playing the nature's majoritarian action of the next block in a singled-out stage of the current block. If the actions of the agent match the actions of nature at all stages of the current block, then the third stage of the blocks is the one singled out to signal the majority rule for the next block. If the actions of the agent match the sequence of states of nature in exactly two out of three stages, the mismatched stage is the one singled out. That strategy guarantees a payoff of 2/3 per stage. Let's continue with the above example by implementing a 3-length strategy. Notice that there is only one intended error (wiser's actions in bold) and the total guarantee payoff is at least 10 (2 $\times$ 5 blocks), and the guarantee average payoff is $\frac{10}{16} = 0.625$ per stage. Furthermore, the signaling action may match the majoritarian action of the current block with a chance of $\frac{1}{4}$. Thus, there is an extra expected payoff equals 1.25 ($\frac{1}{4} \times 5$ blocks). So, the average expected payoff is $\frac{11.25}{16} = 0.70$ per stage.

Table 2.3: Majority rule strategy

Nature	1	1	0	0	1	0	1	1	1	1	0	1	0	0	0	0
Wiser	**0**	**1**	0	0	1	**1**	1	1	1	**0**	0	**0**	0	0	0	0
Agent	*	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
Payoff	*	**0**	1	1	1	**0**	1	1	1	**0**	1	**0**	1	1	1	1

2.6 Experimental design

This section presents the experiment to test the above theory. The experiment consisted of two sessions of 60 subjects each one and was run at LINEEX, the experimental economics lab at the University of Valencia in Spain. Subjects were all third and fourth year students of Economics, International Business and Business Administration at the University of Valencia. In each session, the students were grouped in pairs and randomly assigned a permanent role: Type 1 or Type 2. Type 1 played the role of the wiser, with complete information about the sequence of nature. Type 2 played the role of the agent, with incomplete information.

At the beginning of the session and before grouping, students performed several tests. First, the Cognitive Reflexion Test (CRT), a three questions' intelligence test that lasted three minutes.[17] Second, a Team Work Test (TWT) of twenty five questions. We used subjects' performance in the TWT to rank students from more to less collaborative. Thirty pairs were formed by taking consecutive people two by two. This way, the pair number 1 was composed by the two most collaborative ones, and the pair number 30 was formed by the two less collaborative ones in the sample.

Each pair of subjects played the following matching pennies repeated game: the random nature, called Prize, was defined as *i.i.d* random variable taking values 0 or 1 with the same probability ($\frac{1}{2}$). A 55-length sequence was generated at the beginning of the play phase by a random number generator. At that time, the subject assigned Type 1 was allowed to know the complete sequence of Prize. However, the subject Type 2 had only historical information about played actions. The 55 rounds are sequentially played, without interruption. In each round, the pair earns 1 if and only if both of them match Prize's action. No losses are possible. The subjects played two sequences of 55 rounds each.

A key feature introduced in the experimental design was a pre-play phase consisting of an online chat for a short time (three minutes). Thus, participants could share knowledge, skills, experience, etc. in order to design some mechanism of communication, which allowed them to transmit information during the play phase and, therefore, coordinate their actions to earn as much as possible. Once the chat was finished, Type 1 was informed in private about the sequence of nature and the game started. At the

[17]This test measures how reflective a person is in its decision making.

end of each played sequence, subjects were informed in private about the earnings they obtained.

A pilot session of 8 periods was ran for subjects to have an accurate understanding of the frame of the experiment. Once the pilot finished, the real experiment started.

At the end of the experimental session each participant was paid in cash according to his performance in the experiment. Particularly, as specified in the instructions, the subject's payoff depended on the number of rounds in which the Prize was earned. More specifically, the Prize of a round was 1 ECU (Experimental Currency Unit) and the ECU/Euro exchange rate was 1 ECU $= \frac{1}{4}$ Euro. Average payoffs were approximately 18 Euros.

There are three hypotheses that we want to test with this experiment.

H1: There exist different payoff-enhancing communication levels.

H2: In superior communication levels, the agent's matching probability q is expected to be around the optimal value of $\frac{2}{3}$ for a 55-length sequence.

H3: In superior communication levels, the wiser's matching conditional probabilities p_1 and p_2 are expected to be around the respective optimal values of 1 and $\frac{1}{2}$ for a 55-length sequence.

The theoretical model is based on the random character of the nature. In the experiment, we generate two sequences of length 55 per session, that is four sequences of length 55, $\{s_1, \ldots, s_4\}$. They were generated just before the start of the play phase by using a random number generator. These sequences are considered the realizations of an *i.i.d.* $(\frac{1}{2}, \frac{1}{2})$ variable taking values 0 and 1, and represent the random play of nature.

To know how random the generated sequences are, we use the Wald-Wolfowitz runs test for randomness (WWR) performed under the null hypothesis of the sequence is random. The classical definition of a run, say, of zeros is a sequence of one or more zeros which are followed and preceded either by one or by no symbol at all[18]. The test statistic (U) is defined as the total number of runs of 0s and 1s in the entire sequence.[19]

Table 2.4: Wald-Wolfowitz Runs Test for Randomness (WWR)

Concept	Sequences of Nature			
	s_1	s_2	s_3	s_4
Number of 1s (m)	26	31	34	26
Number of 0s (n)	29	24	21	29
Number of runs of 1s	13	12	11	10
Number of runs of 0s	13	13	10	10
Number of runs (U)	26	25	21	20
z-test	-0.523	-0.707	-1.577	-2.161
p-value	0.602	0.479	0.116	0.029

Two-sided test with H_0: the sequence is random, at 5% of α confidence level.

Table 2.4 reports the values of the z-test and the corresponding p-values for the four sequences of nature played throughout the experiment. The high numbers of p-values allow us to accept the null hypothesis with a negligible mistake, so then the sequences are random. Notice that the fourth sequence exhibits a small p-value of 2.9% scarcely greater than 2.5% enough to fail to reject the null hypothesis in the

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

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

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

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

two-sided test. 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, but communication rules or strategies can do it when there exists an external device of communication such as a chat.

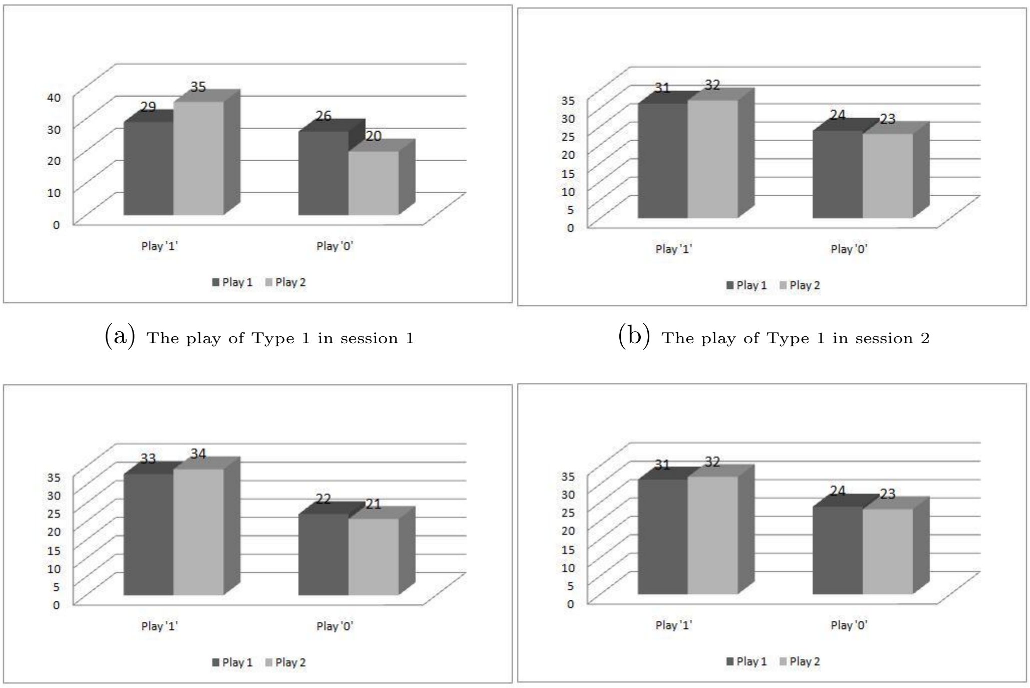
2.7 Main results

In this section, we first conduct a statistical analysis on the matching series from the two experimental sessions. It follows a cluster analysis to identify experimental strategies by payoff levels and finally an econometric version of the theoretical model is estimated.

Our first observation of experimental data reported in figures 2.3(a) to (d), is about the actions actually taken by players in the experiment. We find, on average, that players mostly played the action '1' in all sessions and plays. However, within the Prize's 55-length sequence, the most repeated random number was '0' in play 1 and '1' in play 2 of session 1 -the opposite occurred in session 2. In fact, the number of ones is 26 in sequences 1 and 4, whereas the number of ones in the sequence 2 is 31, and 34 in the sequence[20] 3. Therefore, in order to match the Prize as much as possible in play 1 of session 1 (or in play 2 of session 2), the player Type 1 should have mostly played '0' and informed the player Type 2 about it. So, we may interpret a swing in Type 1's playing as a signal to inform Type 2 about the Prize's next majoritarian action. In conclusion, in the first(second) play of session 1(2), the pair of players could have increased the average number of matchings if the informed player had changed his most played action to '0' and transmitted it to the uninformed player.

Tables 2.5 and 2.6 report descriptive statistics on the number of matchings and coordination levels, respectively. Looking at results of session 1 and play 1, the players

[20] In the long-term, the 3-length block strategy earns $\frac{2}{3}$ on the length of a balance sequence.



(a) The play of Type 1 in session 1

(b) The play of Type 1 in session 2

(c) The play of Type 2 in session 1

(d) The play of Type 2 in session 2

Figure 2.3: The frequency of players' actions and matches with the Prize

matched the Prize 28.97 out of 55 times, on average. In the play 2, after the second chat time, players improved coordination strategies, reaching an average of 35.23. Moreover, the confidence interval for equal means hypothesis at 95% is [3.901, 8.632], since 0 is not included into the interval we may claim that there is a statistically significant difference between means from the play 1 to the play 2, in this first session.

In session 2, there is not a significant increase of the average number of matchings from play 1 to play 2. In fact, the null hypothesis of equal means can not be rejected[21].

As already mentioned, the cheap-talk pre-play phase, by means of a 3-minute online chat, allowed pairs to design coordination strategies. So before playing the coordination game, the pair could define or revise its strategy and improve it.

In order to classify coordination strategies, we executed the K-MEANS clustering

[21] Also, according to the Wilcoxon sum rank test for small samples the null hypothesis of equal medians between play 1 and 2 can be rejected at the level of 1% in session 1, but not in session 2 at all.

Table 2.5: Statistics on the number of matchings/total payoffs.

Descriptive Statistics	Session 1		Session 2	
	Play 1	Play 2	Play 1	Play 2
Max.	37	44	42	41
Min.	18	21	21	18
Average	28.97	35.23	31.20	32.07
CI(mean)	[3.901, 8.632]		[-1.219, 2.953]	
Median	28	37.50	32	32
St.D.	4.83	5.38	8.24	5.69
Rate	0.51	0.68	0.58	0.58
Obs.	30	30	30	30

(∗) Paired-sample confidence interval at 95% for equal means hypothesis. Rate is a matching percentage defined as the quotient between median and the length of sequence.

algorithm (MacQueen, 1967) on the number of matchings, which is implemented in the scientific program Matlab[22]. It allowed us to identify three levels of communication efficiency in our experimental sample, which gives support to our first hypothesis.

In session 1, coordination strategies are grouped into three clusters:

- The first cluster that is denoted as C_1 includes the lowest efficiency strategies. In this cluster, we might find strategies carrying no communication where the wiser plays the nature's action and whether the agent always plays the same action or randomly plays any action. Both of them are naive strategies and are characterized by the pair (p, q) equals $(1, \frac{1}{2})$, a payoff of $\frac{1}{2}$ per stage and a total payoff of $55 \times \frac{1}{2} = 27.5$.

- The second cluster C_2 includes suboptimal communication strategies for the length of 55. Such is the case of the 2-length block strategy, with a guarantee payoff of 1 per stage and an expected payoff of $\frac{5}{8}$ per stage, which means a total payoff laying within the interval $[27.5, 34.37]$.

[22]The distance measure applied is the sum of absolute differences, known as the $L1$ distance. Each centroid is the component-wise median of the points in that cluster: $d(x, c) = \sum_{j=1}^{p} |x_j - c_j|$.

- Into the third cluster C_3, superior communication strategies are grouped. For instance, a 3-length block strategy will produce a total payoff into the interval[23] $[36.66, 41.25]$.

Similarly, in the play 1 of the session 2 three clusters are formed. However in the play 2 of that session the strategies are distributed among two clusters, being the second cluster of play 2 comparable to the third one of the play 1.

Looking at table 2.6 on statistical data by coordination clusters, a few differences in median values between the plays 1 and 2 are found. In session 1, according to the Wilcoxon sum-rank test, there exists a powerful significant difference between the medians of clusters C_3 of each play ($z = -3.241, p - value = 0.0012$). Presumably, players designed more and superior coordination strategies and attained higher payoffs in the second play. In session 2, a significant difference is found when are compared the clusters C_2 ($z = -3.114, p - value = 0.0018$), but not when the cluster C_3 of play 1 is compared to the cluster C_2 of play 2. That might mean that pairs did not make an additional effort of coordination in the second play. At the sight of results, we may conclude that pairs were able to coordinate their actions by information-codifying strategies at different levels of efficiency. This evidence provides us with the first result:

Result 1: In the experimental sample, there exist three coordination clusters corresponding to three different communication efficiency levels. So, our hypothesis 1 is accepted.

[23] A guarantee payoff of $\frac{2}{3}55 = 36.66$, and an expected payoff of $\frac{3}{4}55 = 41.25$. Also worth mentioning that the 3-length block strategy implemented on the sequence 1 yields the joint percentage of 74.54%, on the sequences 2 and 3 the percentage of 69.09%, and on the sequence 4 the 70.90%.

Table 2.6: Statistics on coordination clusters.

Descriptive Statistics	Session 1						Session 2				
	Play 1			Play 2			Play 1			Play 2	
	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2
Max.	28	33	37	29	34	44	29	34	42	31	41
Min.	18	30	34	21	31	36	21	31	36	18	32
Average	25.67	31	36	26.50	32.40	38.74	25.10	32.71	37.83	27.29	36.25
Median	26	30	37	27.50	32	39	26	33	37.50	28	35.50
St.D	2.38	1.41	1.29	2.88	1.52	1.79	3.07	1.20	2.23	3.63	3.36
Rate	0.47	0.54	0.67	0.5	0.58	0.71	0.47	0.6	0.68	0.51	0.64
Obs.	18	5	7	6	5	19	10	14	6	14	16

Rate is a matching percentage defined as the quotient between Median and the length of sequence 55.

2.7.1 Experimental strategies (p, q)

Regarding strategies (p, q) implemented in the experiment, we take a first look at the distribution of pairs according to the proportions of matchings q and p [24]. The 3-dimensional figures 2.4(a) to 2.4(d) show those values by pairs.

Figures 2.4(a) and 2.4(b) correspond to session 1. Both figures depict three clusters, the left-hand cluster corresponds to strategies C_1, and the right-hand one to strategies C_3. Strategies grouped into upper clusters are characterized by higher values q. In other words, superior coordination strategies convey more information that the player Type 2 decodes according to the communication rule to match the nature's action in the percentage q. The wiser decides to make one or more errors to inform to his partner about the nature's future playing. Thus, the wiser matches both the agent and the nature's actions in the percentage p_1 and the nature's actions only in the percentage p_2.

Main statistics on experimental values q and p are reported in table 2.7. In the session 1 and play 1, by implementing naive strategies C_1, the pairs reached a joint percentage of 47.3%, being the agent's matching percentage slightly below 50% and the wiser's just 100%, all in median values. Whereas the highest efficiency strategies form-

[24]We keep the nomenclature from the theoretical model to denote as p and q, the matching percentage of the player Type 1 and the player Type 2, respectively.

ing cluster C_3 obtained results closed to theoretical optimal ones: the wiser matched the agent and the nature's actions just below 100% and the agent matched the nature's actions a little bit over $\frac{2}{3}$, achieving the joint matching of the 65.4%, in median. In play 2, those joint percentages raised up to the 50.9% and the 69.12%, respectively[25]. In overall, similar results were recorded in the session 2. However, in superior clusters there was a negative difference between the plays 1 and 2. In the play 1, strategies in the cluster C_3 reached the median joint matching of 71.74%, then falling slightly below $\frac{2}{3}$ in the cluster C_2 of the second play[26].

The above evidence can be interpreted as that the players of session 1 were able to learn from the play 1 and then defined and implemented superior strategies in the play 2. On the contrary, in the session 2, the median of differences between plays 1 and 2 is zero at conventional levels. Generally speaking, the players of session 2 were unable to substantively improve the result of their first play.

Table 2.7 also reports the Sign test on one population median (η). We first contrast the null hypothesis on q at theoretical values for the three communication efficiency levels of the experiment:

- Low efficiency strategies C_1:

  $H_0 : \eta_1(q) = \frac{1}{2}$

  $H_1 : \eta_1(q) < \frac{1}{2}$

[25]For the agent's playing the null hypothesis of no differences between plays 1 and 2 for clusters C_1 and C_3 can be rejected at the respective significance levels of 5% and 1% by Wilcoxon sum-rank test. For the wiser's playing, there only exist a significant difference between plays in the cluster C_1 $(z = 3.005, p - value = 0.0027)$.

[26]Regarding the wiser's playing, by testing the null hypothesis of no differences between the plays 1 and 2 of the session 2 we do not find significant differences at level of 5% between the clusters C_1 $(z = -1.646, p-value = 0.099)$ nor between the superior clusters C_3 and C_2 $(z = 1.742, p-value = 0.081)$. Neither did the wiser behave differently in the superior clusters $(z = -1.918, p - value = 0.055)$.

- Medium efficiency strategies C_2:

  $H_0 : \eta_2(q) = \frac{5}{8}$

  $H_1 : \eta_2(q) < \frac{5}{8}$

- High efficiency strategies C_3:

  $H_0 : \eta_3(q) = \frac{2}{3}$

  $H_1 : \eta_3(q) > \frac{2}{3}$

Notice that the acceptance of null hypothesis represents strategies on the efficiency frontier, whereas its rejection means strategies inside the corresponding set. Regarding strategies implemented in the session 1, the null hypothesis on the agent's playing (q) is accepted at the level of 5% for high efficiency strategies in the play 1, but not in the play 2 -the opposite happens to other efficiency levels. In the session 2, only it is rejected the null hypothesis corresponding to medium efficiency strategies.. Thus, we can conclude that the agent behaved according to the theoretical prediction at each efficiency level. We are now ready to offer our second result:

Result 2: In the highest efficiency cluster, the agent played to match the nature's actions at least $\frac{2}{3}$ of times. We can conclude that the hypothesis 2 is valid for the data of the experiment.

We continue to contrast the wiser's behavior from the theoretical prediction. The result has two parts:

case a) $p_1 = 1$

When the agent matches the nature's action, the wiser will match both of them the 100% of times.

$H_0 : \eta(p_1) = 1$

$H_1 : \eta(p_1) < 1$

We find that, in the session 1, the null hypothesis can be rejected at the levels of 10% and 1% by the sign test for strategies within the clusters C_3 of both respective plays. Also, in the session 2, it can be rejected at 5% in clusters C_2. This evidence shows two important features: (i) the wiser makes errors in an effort to transmit information to the agent, (ii) but more errors than necessary specially in the highest communication efficiency cluster.

case b) $p_2 = \frac{1}{2}$

When the agent does not match the nature's action, the wiser optimally will match the nature's action the 50% of times.

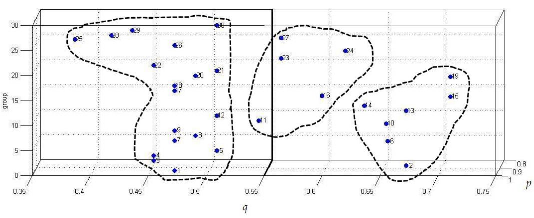
$H_0 : \eta(p_2) = \frac{1}{2}$

$H_1 : \eta(p_2) \neq \frac{1}{2}$

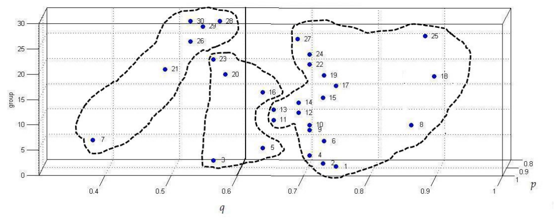
Looking at the results of Sign test that are reported in the table 2.8, it seems that the wiser's behavior fits quite well the theoretical prediction. Second, we also perform the test in the range 0 to 1, by accepting the null hypothesis at level of 10% then we build the candidate value intervals for each communication efficiency cluster. Because the width of some intervals is very large, we suspect that results are not quite conclusive. Nevertheless, in overall, wider intervals with larger superior extremes are placed in the session 2, what might indicate that the wiser matched the nature much more times than the optimal -the opposite happens in the session 1.

The conclusion on the wiser's behavior exhibited in the experiment establishes our third result.

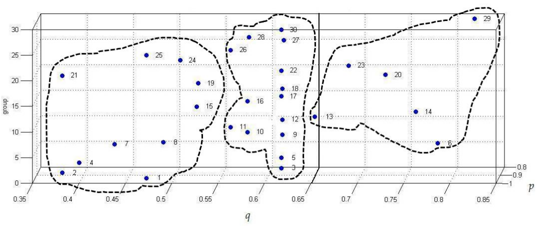
Result 3: There exists the transmission of information based on errors. The wiser's signaling behavior is quite close to the theoretical prediction of $p_1 = 1$, regardless the efficiency of the strategy implemented. However, his behavior might deviate from the theoretical prediction of $p_2 = \frac{1}{2}$. Therefore, the hypothesis 3 is partially verified.



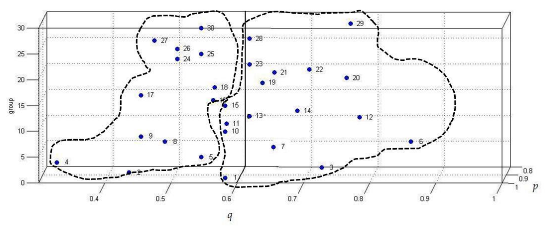
(a) (p_1, q) from session 1, play 1



(b) (p_1, q) from session 1, play 2



(c) (p_1, q) from session 2, play 1



(d) (p_1, q) from session 2, play 2

Figure 2.4: The distribution of pairs according to (p_1, q)

Table 2.7: Statistics on experimental strategies (p_1, q) by coordination clusters.

Statistics and Contrasts	Session 1												Session 2									
	Play 1						Play 2						Play 1						Play 2			
	C_1		C_2		C_3		C_1		C_2		C_3		C_1		C_2		C_3		C_1		C_2	
	q	p_1	q	p_1	q	p_1	q	p_1	q	p_1	q	p_1	q	p_1	q	p_1	q	p_1	q	p_1	q	p_1
Max.	0.509	1	0.618	1	0.709	1	0.564	1	0.636	1	0.891	1	0.527	1	0.618	1	0.818	1	0.582	1	0.855	1
Min.	0.382	0.857	0.545	0.941	0.636	0.944	0.382	0.839	0.564	0.971	0.655	0.833	0.382	0.958	0.564	0.941	0.655	0.800	0.327	0.962	0.582	0.872
Average	0.470	0.992	0.578	0.975	0.673	0.973	0.506	0.956	0.596	0.989	0.734	0.963	0.460	0.992	0.603	0.987	0.739	0.935	0.500	0.993	0.677	0.977
Median	0.473	1	0.564	0.968	0.673	0.972	0.527	0.966	0.582	1	0.709	0.975	0.473	1	0.618	1	0.745	0.963	0.509	1	0.655	1
St.D.	0.034	0.034	0.030	0.025	0.028	0.026	0.065	0.060	0.037	0.016	0.067	0.048	0.057	0.016	0.022	0.019	0.060	0.082	0.068	0.015	0.082	0.042
—Sign test— Null hypothesis at theoretical values	$\frac{1}{2}$	1	$\frac{5}{8}$	1	$\frac{2}{3}$	1	$\frac{1}{2}$	1	$\frac{5}{8}$	1	$\frac{2}{3}$	1	$\frac{1}{2}$	1	$\frac{5}{8}$	1	$\frac{2}{3}$	1	$\frac{1}{2}$	1	$\frac{2}{3}$	1
$p-value$	**0.015**	0.500	**0.031**	0.125	0.500	**0.062**	0.890	**0.062**	0.500	0.250	**0.001**	**0.001**	0.171	0.250	**0.001**	**0.031**	0.109	0.125	0.788	0.125	0.772	**0.015**
Null hypothesis at candidate values*	0.49	1	0.61	1	0.70	0.99	0.56	0.99	0.63	1	0.72	0.99	0.52	1	0.61	0.99	0.81	1	0.54	1	0.72	0.99
$p-value$	0.118	0.5	0.187	0.125	0.226	0.5	0.109	0.343	0.5	0.250	0.5	0.323	0.052	0.250	0.910	0.910	0.109	0.125	0.395	0.125	0.105	0.894
Obs.	18	18	5	5	7	7	6	6	5	5	19	19	10	10	14	14	6	6	14	14	16	16

(*)Candidate value is a value in the range 0 to 1 that satisfies the null hypothesis against the alternative one to be less than.
Figures in bold indicate the rejection of null hypothesis at the significance levels of 1%, 5%, and 10%.

Table 2.8: Statistics on the wiser's matching probability p_2 by coordination clusters.

Descriptive Statistics	Session 1						Session 2				
	Play 1			Play 2			Play 1			Play 2	
	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2
Max.	1	0.458	0.600	1	0.600	0.833	1	1	1	1	1
Min.	0	0	0.105	0	0	0	0	0	0.083	0	0.125
Average	0.358	0.201	0.328	0.493	0.169	0.277	0.526	0.582	0.668	0.568	0.665
Median	0.167	0.190	0.313	0.519	0.043	0.188	0.615	0.821	0.751	0.759	0.642
St.D.	0.416	0.177	0.191	0.431	0.255	0.208	0.504	0.440	0.315	0.466	0.282
—Sign test— Null hypothesis at the value of $\frac{1}{2}$ $p-value$	0.237	**0.062**	0.453	1.000	0.375	**0.001**	1.000	0.790	0.218	0.790	0.454
Candidate value interval*	$[0.01, 0.52]$	$[0.01, 0.46]$	$[0.16, 0.56]$	$[0.01, 0.99]$	$[0.01, 0.6]$	$[0.15, 0.34]$	$[0.01, 1]$	$[0.06, 0.95]$	$[0.08, 0.99]$	$[0.06, 0.99]$	$[0.47, 0.99]$
Obs.	18	5	7	6	5	19	10	14	6	14	16

Figures in bold indicate the rejection of null hypothesis at the significance levels of 1%, 5%, and 10%.
(*) Null hypothesis can not be rejected at conventional levels.

2.7.2 Estimating the model

According to the theoretical model, codification rules implicitly define the agent and the wiser matching probabilities q and p, which, in turn, determine the long term expected payoff $(q \cdot p \cdot n)$. In previous sections, we characterized the optimal pair (p, q) for a finite sequence of nature of lenght 55. Actually, the optimal pair is $(1, \frac{2}{3})$ and the corresponding strategy is the majority rule for 3-length blocks.

Recall that the agent's probability q is defined as the probability of the agent's action $Z(X, Y)$ matches the nature's action X, given the information available. The agent knows the random process of nature, the nature's and the wiser's past actions, and the information conveyed in the wiser's action $Y(X)$ according to the strategy agreed in the pre-game phase: $q = Prob(Z(X, Y) = X)$. The wiser is a fully informed player about the nature's future realizations. Thus, the wiser's conditional probability p_1 that is defined as the probability of the wiser's action $Y(X)$ matches the nature's action X given so does the agent: $p_1 = Prob(Y(X) = X|Z(X, Y) = X)$. Otherwise, the wiser's conditional probability is defined as $p_2 = Prob(Y(X) = X|Z(X, Y) \neq X)$

In this subsection, we estimate the model by a binary logit model. Thus, we define the two following binary logit models corresponding to the agent and the wiser matching probabilities:

1. The agent's matching probability

$$\begin{aligned} q &= Prob(M = 1|Nature, Wiser, C_2, C_3) \\ &= \Lambda(\beta_0 + \beta_1 Nature + \beta_2 Wiser + \beta_3 C_2 + \beta_4 C_3) \end{aligned}$$

Being the binary dependent variable M defined as follows:

$$M = \begin{cases} 1 & if \quad Agent = Nature \\ 0 & otherwise \end{cases}$$

The covariates *Nature*, *Wiser* and *Agent* indicate the respective action sequences. The independent variables C_2 and C_3 are dummy variables defined for coordination levels. The lower coordination level C_1 is taken as the reference level.

2. The wiser's matching probability

case a)

$$\begin{aligned} p_1 &= Prob(M = 1 | Nature, C_2, C_3) \\ &= \Lambda(\beta_0 + \beta_1 Nature + \beta_2 C_2 + \beta_3 C_3) \end{aligned}$$

The binary variable M is defined as:

$$M = \begin{cases} 1 & if \quad Wiser = Nature \quad and \quad Agent = Nature \\ 0 & if \quad Wiser \neq Nature \quad and \quad Agent = Nature \end{cases}$$

case b)

$$\begin{aligned} p_2 &= Prob(M = 1 | Nature, C_2, C_3) \\ &= \Lambda(\beta_0 + \beta_1 Nature + \beta_2 C_2 + \beta_3 C_3) \end{aligned}$$

Now, the binary variable M is defined as:

$$M = \begin{cases} 1 & if \quad Wiser = Nature \quad and \quad Agent \neq Nature \\ 0 & if \quad Wiser \neq Nature \quad and \quad Agent \neq Nature \end{cases}$$

Notice that $\Lambda(z)$ is the logistic distribution function:

$$\Lambda(z) = \frac{1}{1 + e^{-z}}$$

Table 2.9 reports the marginal effects of logit model for the probabilities q of sessions 1 and 2. We first find that the Nature has a positive effect on q, that is when the Nature changes from 0 to 1, the Agent's matching probability increases, and conversely. The sign of marginal effect of action played by the Wiser is negative in the Play 1 of session 1, and Play 2 of session 2. In other words, when this player changes his playing from 1 to 0 in order to inform the Agent that the Nature plays 0, then the matching probability q increases. Regarding the remaining plays, the marginal effect of the Wiser's action is positive, that is when he changes from 0 to 1, the matching probability increases. Summing up, when the three players take mostly the action '1' , the marginal effects of Nature and Wiser are positive. However when Nature plays '0' mostly, the marginal effect of Wiser is negative, meaning that the matching probability increases when the three players play '0'. Finally, the marginal effects of coordination level variables are both positive. We remark this evidence in the following result.

Result 4: The agent's action is significantly explained by the nature's and the wiser's actions. The wiser's action shift conveys the nature's mostly played action. The difference between medium and high communication levels (0.204-0.107) is closed to the theoretical one $(\frac{3}{4} - \frac{5}{8})$.

The estimation of the wiser's probability p_1 is reported in table 2.10. Recall that the estimation of p_1 is made by considering the wiser's actions conditional on the agent's action matches the nature's action $(Y(X)|Z(X,Y) = X)$. If the wiser behaves as theory predicts, the nature's action shift has no effect on the wiser's probability p_1, which will be 1, meaning that three actions match $(Y(X) = Z(X,Y)|Z(X,Y) = X)$. Looking at the marginal effects of the nature on the probability p_1, they are not statistically significant except in the case of the session 2 and play 1. That means that the nature's action shift does not explain the wiser's matching probability, whether because he always matches the nature when the agent does or he makes a balanced matching. So, we interpret the nature's marginal effect as an evidence of a predominant action in the wiser's playing. On the other hand, we find that p_1 depends on the coordination cluster. Being the probability corresponding to cluster C_2 greater than that of cluster C_3. Negative marginal effects might be due to *over-signaling* in the wiser's playing. Because of intended mistakes, it is possible the wiser communicates the nature's future actions to the agent, which will increase the probability of matching q, as shown in table 2.9:

Table 2.9: The marginal effects of logit model for probability q.

	Session 1		Session 2	
	Play 1	Play 2	Play 1	Play 2
Variables				
$Nature$	0.269	0.183	0.137	0.071
	$(10.33)^{***}$	$(6.80)^{***}$	$(4.31)^{***}$	$(2.20)^{**}$
$Wiser$	−0.069	0.067	-0.038	−0.043
	$(-2.46)^{**}$	$(2.46)^{**}$	(-1.17)	(-1.32)
C_2	0.107	0.0719	0.148	0.176
	$(3.17)^{***}$	$(2.13)^{**}$	$(5.36)^{***}$	$(7.33)^{***}$
C_3	0.204	0.235	0.267	
	$(7.11)^{***}$	$(7.79)^{***}$	$(9.59)^{***}$	
N	1650	1650	1650	1650
Predicted q	0.539	0.680	0.587	0.598
Log-likelihood	-1063.480	-975.650	-1072.492	-1084.734
Pseudo-R2	0.066	0.072	0.042	0.026
Goodness of fit	0.654	0.675	0.549	0.610

The measure of goodness is based on the $2x2$ hits and misses table
and the threshold probability is 0.5.
Figures in parenthesis are the *pseudo* t-values of estimators.
$***$ at 1% significance level
$**$ at 5% significance level
$*$ at 10% significance level

the higher coordination level is, the higher the probability q is too. However, the fully informed player could use more mistakes than necessary by implementing suboptimal coordination strategies, which actually happens, and as a result the probability p_1 would be less than 1. For instance, in the Play 2 of session 2, the probability p_1 for strategies C_2 is 0.965, on average. Thus, the excess of mistakes by the wiser might be interpreted as an over-signaling, which allows the agent to match the nature more closely at the expense of the wiser matching.

A similar evidence is found related to the wiser's probability p_2. Table 2.11 shows the corresponding marginal effects of the logit model to estimate $prob(Y(X) = X|Z(Y,X) \neq X)$. On overall, the wiser of the session 2 plays with a higher probability than the wiser of the session 1 does. Furthermore, the highest probability corresponds to the upper cluster of the session 2 -the opposite occurs in the session 1. In the session 1, the predicted probability is around 0.3, whereas in the session 2 it is around 0.6. That reinforces the presence of over-signaling in the first session.

Result 5: There is some kind of mis-signaling in the wiser's action: when the agent's matches the nature's action, the wiser's and the agent's actions match between the 90% and 99.6% of times. Whereas when the agent's action does not match the nature's action, the wiser's action matches the nature's action between the 15% and 53% of times in the session 1, and between the 58% and 81% of times in the session 2.

Table 2.10: The marginal effects of logit model for the probability p_1.

	Session 1		Session 2	
	Play 1	Play 2	Play 1	Play 2
Variables				
$Nature$	0.005	0.0180	0.026	0.004
	(0.74)	(1.50)	(2.51)**	(0.56)
C_2	−0.025	0.030	−0.012	−0.018
	(−1.25)	(2.78)***	(−1.00)	(−2.36)**
C_3	−0.023	0.007	−0.077	
	(−1.64)	(0.54)	(−2.01)**	
N	883	1098	961	981
Predicted p_1	0.987	0.966	0.985	0.983
Log-likelihood	-68.683	-171.490	-99.938	-91.062
Pseudo-R2	0.044	0.020	0.137	0.028
Goodness of fit	0.984	0.962	0.973	0.980

The measure of goodness is based on the $2x2$ hits and misses table and and the threshold probability is 0.5.

Figures in parenthesis are the *pseudo* t-values of estimators.

∗ ∗ ∗ at 1% significance level

∗∗ at 5% significance level

∗ at 10% significance level

Table 2.11: The marginal effects of logit model for the probability p_2.

	Session 1		Session 2	
	Play 1	Play 2	Play 1	Play 2
Variables				
Nature	0.050	−0.122	0.242	0.013
	(1.37)	(−3.12)***	(6.10)***	(0.36)
C_1		0.230		
		(4.84)***		
C_2	−0.172	−0.152	0.143	0.183
	(−4.19)***	(−3.18)***	(3.40)***	(4.96)***
C_3	−0.047		0.232	
	(−1.06)		(4.66)***	
N	767	561	689	669
Predicted p_2	0.33	0.3	0.58	0.61
Log-likelihood	-481.59	-323.72	-446.07	-434.70
Pseudo-R2	0.015	0.076	0.049	0.026
Goodness of fit	0.665	0.711	0.624	0.612

The measure of goodness is based on the 2x2 hits and misses table and the threshold probability is 0.5.

Figures in parenthesis are the *pseudo* t-values of estimators.

∗ ∗ ∗ at 1% significance level

∗∗ at 5% significance level

∗ at 10% significance level

2.8 Conclusions

The main goal of this study is to implement in the setting of a laboratory the GHN's (2006) communication model, which is based on a repeated version of 3-player matching pennies game. As a central point of that model, it considers binary sequences of infinite length. Hence, the first challenge to face is to determine the length of a finite sequence to generate randomly in a lab and characterize those communication strategies to be agreed by participants in the experiment, who are grouped in 2-person teams. In GHN (2006), a communication strategy is said feasible when it transmits an amount of information that fulfills the called information constraint. Such constraint expresses the amount of information available for the team in terms of entropy, which is usually used in the information theory. As shown in the subsection 3.5.6, we provide a rational version of GHN information constraint to consider rational communication strategies only. In other words, we define a new information constraint when the number of bytes for players to transmit information each other is limited. This constraint is a necessary condition for communication to be possible but it is not sufficient. An operational communication device should be actually implementable. To that purpose, an implementable information constraint is defined by taking into account the precise number of finite sequences under the requirements of communication jointly established by the team.

To implement in the lab our version of theoretical model, two communication devices are necessary. One device takes the form of chatting room, where players design their own communication rules or strategies, it is a pre-play phase. The other device is implicit in the actions played during the game. As arranged, the team will play the repeated matching pennies game according to those rules. How much information is transmitted will depend on how rich the strategy of the team is, and it will eventually determine the payoff reached by the team.

Our major concern is to test the robustness of GHN theory. Firstly, we set three main hypotheses relative to the optimal theoretical strategy for a sequence of length 55: the majority rule for 3-length blocks. And secondly, we contrast the GHN model by an econometric version that represents the relations between the three players' play.

As presumed by the first hypothesis, teams were able to design a rich variety of strategies that were clustered by increasing payoffs, arising three levels of communication. The second hypothesis is relative to the agent's behavior, in particular at the superior communication level. It is expected that the agent's behavior at that level does not significantly deviate from the optimal predicted by theory. Result 2 also allows us to accept the second hypothesis. The wiser's behavior is doubly contrasted: *a*) when he plays the same action as the agent and the nature and *b*) when he plays the same action as the nature but not as the agent. The part *a*) of the hypothesis 3 can not be rejected for values really close to the optimal. Therefore, it is concluded that the wiser behaves almost optimally when the agent matches the nature. We contrast the null hypothesis of the part *b*) on a width range of candidate values, revealing that it is hard to accept the wiser's behavior as the optimal predicted. These findings provide our Result 3 to conclude that the third hypothesis is partially verified.

According to above theory, the agent's play depends on the nature's and the wiser's play. In fact, the full informed player (the wiser) communicate with the uninformed player (the agent) via the communication rule or strategy that is designed in a common arrangement during the pre-play phase. While the wiser's play ultimately only depends on the nature's play that is fully known beforehand at the beginning of the game phase. To estimate the matching probabilities we apply binary logit models. Results in subsection 2.7.2 provide the conclusions for the agent and the wiser, respectively. Result 4 supports the theoretical relation between the agent's actions and the nature's and the wiser's actions. The wiser's action shift conveys the nature's mostly played action. Relative to the wiser's matching probabilities, it is shown Result 5 that concludes the existence of some kind of mis-signaling. In particular, when the agent does match the nature, the wiser makes errors in excess deviating from the theoretical prediction between $10\% - 1\%$. And when the agent does not match the nature, the active wiser reaches a 35% of errors in excess in the session 1. While the passive wiser makes less errors than predicted, between $8\% - 31\%$ of matches in excess in the session 2.

As an overall conclusion, it may be claimed that the GHN theory is robust enough to explain the players' behavior in the setting of a lab.

References

Agastya, M., Bag, P. K., and Chakraborty, I. (2014a). Communication and authority with a partially informed expert. *The RAND Journal of Economics*, 45(1):176–197.

Agastya, M., Bag, P. K., and Chakraborty, I. (2014b). Proximate preferences and almost full revelation in the crawford–sobel game. *Economic Theory Bulletin*, pages 1–12.

Allon, G. and Bassamboo, A. (2011). Buying from the babbling retailer? the impact of availability information on customer behavior. *Management Science*, 57(4):713–726.

Allon, G., Bassamboo, A., and Gurvich, I. (2011). "we will be right with you": Managing customer expectations with vague promises and cheap talk. *Operations research*, 59(6):1382–1394.

Ambrus, A., Azevedo, E. M., and Kamada, Y. (2013). Hierarchical cheap talk. *Theoretical Economics*, 8(1):233–261.

Austen-Smith, D. and Banks, J. S. (2000). Cheap talk and burned money. *Journal of Economic Theory*, 91(1):1–16.

Barraclough, D. J., Conroy, M. L., and Lee, D. (2004). Prefrontal cortex and decision making in a mixed-strategy game. *Nature neuroscience*, 7(4):404–410.

Battaglini, M. (2002). Multiple referrals and multidimensional cheap talk. *Econometrica*, pages 1379–1401.

Blume, A. and Ortmann, A. (2007). The effects of costless pre-play communication: Experimental evidence from games with pareto-ranked equilibria. *Journal of Economic theory*, 132(1):274–290.

Camerer, C. F. and Karjalainen, R. (1994). Ambiguity-aversion and non-additive beliefs in non-cooperative games: experimental evidence. In *Models and experiments in risk and rationality*, pages 325–358. Springer.

Charness, G. and Grosskopf, B. (2004). What makes cheap talk effective? experimental evidence. *Economics Letters*, 83(3):383–389.

Chen, Y. (2011). Perturbed communication games with honest senders and naive receivers. *Journal of Economic Theory*, 146(2):401–424.

Chiappori, P.-A., Levitt, S., and Groseclose, T. (2002). Testing mixed-strategy equilibria when players are heterogeneous: The case of penalty kicks in soccer. *American Economic Review*, pages 1138–1151.

Cohen, M. X. and Ranganath, C. (2007). Reinforcement learning signals predict future decisions. *The Journal of neuroscience*, 27(2):371–378.

Cooper, R., DeJong, D. V., Forsythe, R., and Ross, T. W. (1989). Communication in the battle of the sexes game: some experimental results. *The RAND Journal of Economics*, pages 568–587.

Cooper, R., DeJong, D. V., Forsythe, R., and Ross, T. W. (1992). Communication in coordination games. *The Quarterly Journal of Economics*, pages 739–771.

Crawford, V. (1998). A survey of experiments on communication via cheap talk. *Journal of Economic theory*, 78(2):286–298.

Crawford, V. P. and Sobel, J. (1982). Strategic information transmission. *Econometrica: Journal of the Econometric Society*, pages 1431–1451.

Devetag, G. and Ortmann, A. (2007). When and why? a critical survey on coordination failure in the laboratory. *Experimental economics*, 10(3):331–344.

Duffy, S., Hartwig, T., and Smith, J. (2014). Costly and discrete communication: An experimental investigation. *Theory and decision*, 76(3):395–417.

Eliaz, K. and Rubinstein, A. (2011). Edgar allan poe's riddle: Framing effects in repeated matching pennies games. *Games and Economic Behavior*, 71(1):88–99.

Farrell, J. and Rabin, M. (1996). Cheap talk. *The Journal of Economic Perspectives*, pages 103–118.

Fox, C. R. and Tversky, A. (1995). Ambiguity aversion and comparative ignorance. *The quarterly journal of economics*, pages 585–603.

Fox, C. R. and Weber, M. (2002). Ambiguity aversion, comparative ignorance, and decision context. *Organizational Behavior and Human Decision Processes*, 88(1):476–498.

Gilligan, T. W. and Krehbiel, K. (1989). Asymmetric information and legislative rules with a heterogeneous committee. *American Journal of Political Science*, pages 459–490.

Golosov, M., Skreta, V., Tsyvinski, A., and Wilson, A. (2014). Dynamic strategic information transmission. *Journal of Economic Theory*, 151:304–341.

Gossner, O., Hernandez, P., and Neyman, A. (2006). Optimal use of communication resources. *Econometrica*, 74(6):1603–1636.

Green, J. R. and Stokey, N. L. (2007). A two-person game of information transmission. *Journal of Economic Theory*, 135(1):90–104.

Grossman, S. J. (1981). The informational role of warranties and private disclosure about product quality. *Journal of law and economics*, pages 461–483.

Hertel, J. and Smith, J. (2013). Not so cheap talk: Costly and discrete communication. *Theory and decision*, 75(2):267–291.

Ivanov, M. (2010). Communication via a strategic mediator. *Journal of Economic Theory*, 145(2):869–884.

Ivanov, M. (2015). Dynamic information revelation in cheap talk. *The BE Journal of Theoretical Economics*.

Kartik, N. (2005). Information transmission with cheap and almost-cheap talk. Technical report, www. najecon. org.

Kartik, N. (2009). Strategic communication with lying costs. *The Review of Economic Studies*, 76(4):1359–1395.

Krishna, V. and Morgan, J. (2001). Asymmetric information and legislative rules: Some amendments. *The American Political Science Review*, 95(2):435.

Lai, E. K., Lim, W., and Wang, J. T.-Y. (2011). Experimental implementations and robustness of fully revealing equilibria in multidimensional cheap talk. Technical report, Working paper.

McCabe, K. A., Mukherji, A., and Runkle, D. E. (2000). An experimental study of information and mixed-strategy play in the three-person matching-pennies game. *Economic Theory*, 15(2):421–462.

Milgrom, P. R. (1981). Rational expectations, information acquisition, and competitive bidding. *Econometrica: Journal of the Econometric Society*, pages 921–943.

Mookherjee, D. and Sopher, B. (1994). Learning behavior in an experimental matching pennies game. *Games and Economic Behavior*, 7(1):62–91.

Oprea, R., Charness, G., and Friedman, D. (2014). Continuous time and communication in a public-goods experiment. *Journal of Economic Behavior & Organization*, 108:212–223.

Rand, D. G., Fudenberg, D., and Dreber, A. (2015). It's the thought that counts: The role of intentions in noisy repeated games. *Journal of Economic Behavior & Organization*.

Shachat, J. and Swarthout, J. T. (2004). Do we detect and exploit mixed strategy play by opponents? *Mathematical Methods of Operations Research*, 59(3):359–373.

Sobel, J. (2011). Giving and receiving advice.

Sobel, J. (2012). Complexity versus conflict in communication. In *Information Sciences and Systems (CISS), 2012 46th Annual Conference on*, pages 1–6. IEEE.

Vickery, T. J., Chun, M. M., and Lee, D. (2011). Ubiquity and specificity of reinforcement signals throughout the human brain. *Neuron*, 72(1):166–177.

Watson, J. (1996). Information transmission when the informed party is confused. *Games and Economic Behavior*, 12(1):143–161.

2.9 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: 'the wiser' and 'the agent'. 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 'the wiser' or 'the agent' has consequences:

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

Moreover, participant 'the agent' knows that participant 'the wiser' will be aware of the values of Prize for each block just after the chat time. the wiser knows that the agent 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.

2.10 Appendix 2

Table 2.12: Optimal strategies for blocks of length $m = \{2, 3, 4, \ldots, 27\}$ under the rational information constraint.

m	(p^*, q^*)	*Gain/Block*	p^*q^*	Blocks	Total Gain
2	$(1, \frac{1}{2})$, $(\frac{1}{2}, 1)$	1	$\frac{1}{2}$	27	27
3	$(1, \frac{2}{3})$	2	$\frac{2}{3}$	18	36
4	$(1, \frac{3}{4})$	3	$\frac{3}{4}$	13	39
5	$(1, \frac{3}{5})$,$(\frac{3}{4}, \frac{4}{5})$	3	$\frac{3}{5}$	10	30
6	$(1, \frac{4}{6})$,$(\frac{4}{5}, \frac{5}{6})$	4	$\frac{2}{3}$	9	36
7	$(1, \frac{5}{7})$,$(\frac{5}{6}, \frac{6}{7})$	5	$\frac{5}{7}$	7	35
8	$(1, \frac{6}{8})$,$(\frac{6}{7}, \frac{7}{8})$	6	$\frac{3}{4}$	6	36
9	$(\frac{7}{8}, \frac{8}{9})$	7	$\frac{7}{9}$	6	42
10	$(\frac{8}{9}, \frac{9}{10})$	8	$\frac{4}{5}$	5	40
11	$(1, \frac{8}{11})$,$(\frac{8}{9}, \frac{9}{11})$,$(\frac{8}{10}, \frac{10}{11})$	8	$\frac{8}{11}$	4	32
12	$(1, \frac{9}{12})$,$(\frac{9}{10}, \frac{10}{12})$,$(\frac{9}{11}, \frac{11}{12})$	9	$\frac{3}{4}$	4	36
13	$(1, \frac{10}{13})$,$(\frac{10}{11}, \frac{11}{13})$,$(\frac{10}{12}, \frac{12}{13})$	10	$\frac{10}{13}$	4	40
14	$(\frac{11}{12}, \frac{12}{14})$,$(\frac{11}{13}, \frac{13}{14})$	11	$\frac{11}{14}$	3	33
15	$(\frac{12}{13}, \frac{13}{15})$	12	$\frac{4}{5}$	3	36
16	$(1, \frac{12}{16})$,$(\frac{12}{13}, \frac{13}{16})$,$(\frac{12}{14}, \frac{14}{16})$,$(\frac{12}{15}, \frac{15}{16})$	12	$\frac{3}{4}$	3	36
17	$(1, \frac{13}{17})$, $(\frac{13}{14}, \frac{14}{17})$,$(\frac{13}{15}, \frac{15}{17})$, $(\frac{13}{16}, \frac{16}{17})$	13	$\frac{13}{17}$	3	39
18	$(\frac{14}{15}, \frac{15}{18})$, $(\frac{14}{16}, \frac{16}{18})$, $(\frac{14}{17}, \frac{17}{18})$	14	$\frac{7}{9}$	3	42
19	$(\frac{15}{16}, \frac{16}{19})$, $(\frac{15}{17}, \frac{17}{19})$	15	$\frac{15}{19}$	2	30
20	$(\frac{16}{17}, \frac{17}{20})$, $(\frac{16}{18}, \frac{18}{20})$	16	$\frac{4}{5}$	2	32
21	$(1, \frac{16}{21})$, $(\frac{16}{17}, \frac{17}{21})$, $(\frac{16}{18}, \frac{18}{21})$, $(\frac{16}{19}, \frac{19}{21})$, $(\frac{16}{20}, \frac{20}{21})$	16	$\frac{16}{21}$	2	32
22	$(1, \frac{17}{22})$, $(\frac{17}{18}, \frac{18}{22})$, $(\frac{17}{19}, \frac{19}{22})$, $(\frac{17}{20}, \frac{20}{22})$	17	$\frac{17}{22}$	2	34
23	$(\frac{18}{19}, \frac{19}{23})$, $(\frac{18}{20}, \frac{20}{23})$, $(\frac{18}{21}, \frac{21}{23})$	18	$\frac{18}{23}$	2	36
24	$(\frac{19}{20}, \frac{20}{24})$, $(\frac{19}{21}, \frac{21}{24})$, $(\frac{19}{22}, \frac{22}{24})$	19	$\frac{19}{24}$	2	38
25	$(\frac{20}{21}, \frac{21}{25})$, $(\frac{10}{11}, \frac{22}{25})$	20	$\frac{4}{5}$	2	40
26	$(\frac{21}{23}, \frac{23}{26})$	21	$\frac{21}{26}$	2	42
27	$(\frac{21}{22}, \frac{22}{27})$,$(\frac{21}{23}, \frac{23}{27})$,$(\frac{23}{24}, \frac{24}{27})$,$(\frac{21}{25}, \frac{25}{27})$	21	$\frac{7}{9}$	2	42

Table 2.13: Naive Strategies in Session 1.

Play 1																																																							
Nature	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
One-Pure Strategy																																																							
Wiser	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
Agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matching	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
Total matches	26																																																						
Zero-Pure Strategy																																																							
Agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matching	1	0	1	0	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	0	1	0	1	1	1	0	1	1	0	1	0	0	0	0	1	1	0
Total matches	29																																																						
Play 2																																																							
Nature	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
One-Pure Strategy																																																							
Wiser	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
Agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matching	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
Total matches	31																																																						
Zero-Pure Strategy																																																							
Agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matching	1	0	0	1	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	1	1	0	0	0	0	1	1	0	1	0	1	1	1	1	0	1	1
Total matches	24																																																						

Table 2.14: Naive Strategies in Session 2.

Play 1																																																							
Nature	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
One-Pure Strategy																																																							
Wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
Agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matching	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
Total matches	34																																																						
Zero-Pure Strategy																																																							
Agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matching	0	0	1	1	0	0	0	1	1	0	0	1	1	0	0	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	1	1	1	0	0	0	0	1	1	0	0
Total matches	21																																																						
Play 2																																																							
Nature	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
One-Pure Strategy																																																							
Wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
Agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matching	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
Total matches	26																																																						
Zero-Pure Strategy																																																							
Agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matching	1	1	0	1	1	0	0	0	1	1	1	1	1	0	1	1	1	0	0	1	0	0	0	0	1	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	0	1	1	0
Total matches	29																																																						

Table 2.15: 3-length block strategies in Session 1.

Play 1																																																							
Nature	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
Wiser	1	1	1	1	1	1	0	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0
Agent		1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0
Matching		1	0	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	0
Total matches	41																																																						
Play 2																																																							
Nature	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
Wiser	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Agent		1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Matching		1	1	0	1	0	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	0	0	0	1	0	1	1	0	1	1	0	1	1	0	1	0	1	1	1	1	0	1	1
Total matches	38																																																						

Table 2.16: 3-length block Strategies in Session 2

Play 1																																																							
Nature	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
Wiser	0	1	0	0	1	1	0	0	0	0	1	0	0	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1
Agent		0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1
Matching		0	1	1	1	1	0	1	1	0	0	1	1	1	1	0	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1	1	1	0	0	1	1
Total matches	38																																																						
Play 2																																																							
Nature	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
Wiser	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1
Agent		0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
Matching		1	0	1	0	1	1	0	1	1	1	1	1	0	0	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	1	1	0	1	1	0
Total matches	39																																																						

Table 2.17: Experimental strategies in session 1 (a).

$$H(p,q) = H(q) + qH(p_1) + (1-q)H(1/2)$$
$$p(x) = \frac{3x}{1+2x},\ q(x) = \frac{1+2x}{3}$$
$$y = H(x) + (1-x)\log_2 3$$

	Play 1						Play 2					
Pair	Cluster	(p,q)	$H(p,q)$	$x = pq$	$(p(x),q(x))$	y	Cluster	(p,q)	$H(p,q)$	$x = pq$	$(p(x),q(x))$	y
1	C_1	$(1, 0.47)$	1.53	0.47	$(0.73, 0.65)$	1.837	C_3	$(0.95, 0.74)$	1.30	0.70	$(0.88, 0.8)$	1.348
2	C_3	$(1, 0.67)$	1.24	0.67	$(0.86, 0.78)$	1.438	C_3	$(0.97, 0.72)$	1.28	0.70	$(0.87, 0.8)$	1.361
3	C_1	$(1, 0.45)$	1.54	0.45	$(0.71, 0.63)$	1.865	C_2	$(1, 0.56)$	1.43	0.56	$(0.79, 0.71)$	1.687
4	C_1	$(1, 0.45)$	1.54	0.45	$(0.71, 0.63)$	1.865	C_3	$(1, 0.7)$	1.18	0.70	$(0.88, 0.8)$	1.357
5	C_1	$(1, 0.5)$	1.50	0.50	$(0.75, 0.67)$	1.792	C_2	$(0.97, 0.63)$	1.44	0.61	$(0.82, 0.74)$	1.580
6	C_3	$(0.94, 0.65)$	1.50	0.61	$(0.82, 0.74)$	1.581	C_3	$(0.95, 0.72)$	1.34	0.68	$(0.87, 0.79)$	1.401
7	C_1	$(1, 0.47)$	1.53	0.47	$(0.73, 0.65)$	1.837	C_1	$(1, 0.38)$	1.58	0.38	$(0.65, 0.59)$	1.941
8	C_1	$(1, 0.49)$	1.51	0.49	$(0.74, 0.66)$	1.808	C_3	$(0.87, 0.85)$	1.23	0.74	$(0.89, 0.83)$	1.240
9	C_1	$(1, 0.47)$	1.53	0.47	$(0.73, 0.65)$	1.837	C_3	$(1, 0.7)$	1.18	0.70	$(0.88, 0.8)$	1.357
10	C_3	$(0.97, 0.65)$	1.41	0.63	$(0.84, 0.75)$	1.536	C_3	$(1, 0.7)$	1.18	0.70	$(0.88, 0.8)$	1.357
11	C_2	$(1, 0.54)$	1.46	0.54	$(0.78, 0.69)$	1.724	C_3	$(1, 0.65)$	1.28	0.65	$(0.85, 0.77)$	1.489
12	C_1	$(1, 0.5)$	1.50	0.50	$(0.75, 0.67)$	1.792	C_3	$(0.97, 0.69)$	1.34	0.67	$(0.86, 0.78)$	1.440
13	C_3	$(1, 0.67)$	1.24	0.67	$(0.86, 0.78)$	1.438	C_3	$(1, 0.65)$	1.28	0.65	$(0.85, 0.77)$	1.489
14	C_3	$(1, 0.63)$	1.32	0.63	$(0.84, 0.75)$	1.537	C_3	$(0.97, 0.69)$	1.34	0.67	$(0.86, 0.78)$	1.440
15	C_3	$(0.94, 0.7)$	1.41	0.66	$(0.85, 0.77)$	1.469	C_3	$(0.97, 0.72)$	1.28	0.70	$(0.87, 0.8)$	1.361
16	C_2	$(1, 0.6)$	1.37	0.60	$(0.82, 0.73)$	1.605	C_2	$(0.97, 0.63)$	1.44	0.61	$(0.82, 0.74)$	1.580
17	C_1	$(1, 0.47)$	1.53	0.47	$(0.73, 0.65)$	1.837	C_3	$(0.95, 0.74)$	1.30	0.70	$(0.88, 0.8)$	1.348
18	C_1	$(1, 0.47)$	1.53	0.47	$(0.73, 0.65)$	1.837	C_3	$(0.89, 0.89)$	1.05	0.79	$(0.92, 0.86)$	1.067
19	C_3	$(0.94, 0.7)$	1.41	0.66	$(0.85, 0.77)$	1.469	C_3	$(0.95, 0.72)$	1.34	0.68	$(0.87, 0.79)$	1.401
20	C_1	$(1, 0.49)$	1.51	0.49	$(0.74, 0.66)$	1.808	C_2	$(1, 0.58)$	1.40	0.58	$(0.81, 0.72)$	1.647
21	C_1	$(1, 0.5)$	1.50	0.50	$(0.75, 0.67)$	1.792	C_1	$(1, 0.49)$	1.51	0.49	$(0.74, 0.66)$	1.808
22	C_1	$(1, 0.45)$	1.54	0.45	$(0.71, 0.63)$	1.865	C_3	$(1, 0.7)$	1.18	0.70	$(0.88, 0.8)$	1.357
23	C_2	$(0.96, 0.56)$	1.57	0.54	$(0.78, 0.69)$	1.729	C_2	$(1, 0.56)$	1.43	0.56	$(0.79, 0.71)$	1.687
24	C_2	$(0.94, 0.61)$	1.55	0.57	$(0.8, 0.72)$	1.661	C_3	$(1, 0.7)$	1.18	0.70	$(0.88, 0.8)$	1.357
25	C_1	$(0.85, 0.38)$	1.81	0.32	$(0.59, 0.55)$	1.981	C_3	$(0.83, 0.87)$	1.26	0.72	$(0.89, 0.81)$	1.293
26	C_1	$(1, 0.47)$	1.53	0.47	$(0.73, 0.65)$	1.837	C_1	$(0.96, 0.52)$	1.60	0.50	$(0.75, 0.67)$	1.794
27	C_2	$(0.96, 0.56)$	1.57	0.54	$(0.78, 0.69)$	1.729	C_3	$(1, 0.69)$	1.20	0.69	$(0.87, 0.79)$	1.385
28	C_1	$(1, 0.41)$	1.57	0.41	$(0.68, 0.61)$	1.912	C_1	$(0.83, 0.56)$	1.80	0.46	$(0.72, 0.64)$	1.845
29	C_1	$(1, 0.43)$	1.56	0.43	$(0.69, 0.62)$	1.889	C_1	$(0.96, 0.54)$	1.59	0.52	$(0.76, 0.68)$	1.762
30	C_1	$(1, 0.5)$	1.50	0.50	$(0.75, 0.67)$	1.792	C_1	$(0.96, 0.52)$	1.60	0.50	$(0.75, 0.67)$	1.794

Table 2.18: Experimental strategies in session 2 (a).

$$H(p,q) = H(q) + qH(p|q) + (1-q)H(1/2)$$
$$p(x) = \frac{3x}{1+2x},\ q(x) = \frac{1+2x}{3}$$
$$y = H(x) + (1-x)\log_2 3$$

	Play 1						Play 2					
Pair	Cluster	(p,q)	$H(p,q)$	$x=pq$	$(p(x),q(x))$	y	Cluster	(p,q)	$H(p,q)$	$x=pq$	$(p(x),q(x))$	y
1	C_1	$(1, 0.47)$	1.53	0.47	$(0.73, 0.65)$	1.837	C_2	$(1, 0.58)$	1.40	0.58	$(0.81, 0.72)$	1.647
2	C_1	$(1, 0.38)$	1.58	0.38	$(0.65, 0.59)$	1.941	C_1	$(1, 0.44)$	1.55	0.44	$(0.7, 0.63)$	1.877
3	C_2	$(1, 0.62)$	1.34	0.62	$(0.83, 0.75)$	1.560	C_2	$(1, 0.73)$	1.11	0.73	$(0.89, 0.82)$	1.269
4	C_1	$(1, 0.4)$	1.57	0.40	$(0.67, 0.6)$	1.922	C_1	$(1, 0.33)$	1.58	0.33	$(0.6, 0.55)$	1.977
5	C_2	$(1, 0.62)$	1.34	0.62	$(0.83, 0.75)$	1.560	C_1	$(1, 0.55)$	1.44	0.55	$(0.79, 0.7)$	1.706
6	C_3	$(0.88, 0.78)$	1.39	0.69	$(0.87, 0.79)$	1.394	C_2	$(0.87, 0.85)$	1.23	0.74	$(0.89, 0.83)$	1.240
7	C_1	$(0.96, 0.44)$	1.66	0.42	$(0.69, 0.61)$	1.898	C_2	$(1, 0.65)$	1.28	0.65	$(0.85, 0.77)$	1.489
8	C_1	$(1, 0.49)$	1.51	0.49	$(0.74, 0.66)$	1.808	C_1	$(1, 0.49)$	1.51	0.49	$(0.74, 0.66)$	1.808
9	C_2	$(0.97, 0.62)$	1.46	0.60	$(0.82, 0.73)$	1.602	C_1	$(1, 0.45)$	1.54	0.45	$(0.71, 0.63)$	1.865
10	C_2	$(1, 0.58)$	1.40	0.58	$(0.81, 0.72)$	1.647	C_2	$(1, 0.58)$	1.40	0.58	$(0.81, 0.72)$	1.647
11	C_2	$(1, 0.56)$	1.43	0.56	$(0.79, 0.71)$	1.687	C_1	$(0.97, 0.58)$	1.51	0.56	$(0.79, 0.71)$	1.682
12	C_2	$(0.97, 0.62)$	1.46	0.60	$(0.82, 0.73)$	1.602	C_2	$(0.95, 0.78)$	1.20	0.74	$(0.9, 0.83)$	1.236
13	C_3	$(1, 0.65)$	1.28	0.65	$(0.85, 0.77)$	1.489	C_2	$(1, 0.62)$	1.34	0.62	$(0.83, 0.75)$	1.560
14	C_3	$(1, 0.76)$	1.04	0.76	$(0.9, 0.84)$	1.175	C_2	$(1, 0.69)$	1.20	0.69	$(0.87, 0.79)$	1.385
15	C_1	$(1, 0.53)$	1.47	0.53	$(0.77, 0.69)$	1.742	C_2	$(1, 0.58)$	1.40	0.58	$(0.81, 0.72)$	1.647
16	C_2	$(1, 0.58)$	1.40	0.58	$(0.81, 0.72)$	1.647	C_1	$(1, 0.56)$	1.43	0.56	$(0.79, 0.71)$	1.687
17	C_2	$(1, 0.62)$	1.34	0.62	$(0.83, 0.75)$	1.560	C_1	$(1, 0.45)$	1.54	0.45	$(0.71, 0.63)$	1.865
18	C_2	$(0.97, 0.62)$	1.46	0.60	$(0.82, 0.73)$	1.602	C_1	$(0.97, 0.56)$	1.54	0.54	$(0.78, 0.7)$	1.719
19	C_1	$(0.97, 0.53)$	1.57	0.51	$(0.76, 0.68)$	1.770	C_2	$(0.97, 0.64)$	1.43	0.62	$(0.83, 0.75)$	1.558
20	C_3	$(0.93, 0.73)$	1.38	0.68	$(0.86, 0.79)$	1.415	C_2	$(0.98, 0.76)$	1.14	0.74	$(0.9, 0.83)$	1.224
21	C_1	$(1, 0.38)$	1.58	0.38	$(0.65, 0.59)$	1.941	C_2	$(0.97, 0.65)$	1.41	0.63	$(0.84, 0.75)$	1.536
22	C_2	$(1, 0.62)$	1.34	0.62	$(0.83, 0.75)$	1.560	C_2	$(1, 0.71)$	1.16	0.71	$(0.88, 0.81)$	1.328
23	C_3	$(1, 0.69)$	1.20	0.69	$(0.87, 0.79)$	1.385	C_2	$(1, 0.62)$	1.34	0.62	$(0.83, 0.75)$	1.560
24	C_1	$(1, 0.51)$	1.49	0.51	$(0.76, 0.67)$	1.776	C_1	$(1, 0.51)$	1.49	0.51	$(0.76, 0.67)$	1.776
25	C_1	$(1, 0.47)$	1.53	0.47	$(0.73, 0.65)$	1.837	C_1	$(1, 0.55)$	1.44	0.55	$(0.79, 0.7)$	1.706
26	C_2	$(1, 0.56)$	1.43	0.56	$(0.79, 0.71)$	1.687	C_1	$(1, 0.51)$	1.49	0.51	$(0.76, 0.67)$	1.776
27	C_2	$(0.94, 0.62)$	1.54	0.58	$(0.81, 0.72)$	1.641	C_1	$(0.96, 0.47)$	1.64	0.45	$(0.71, 0.63)$	1.863
28	C_2	$(0.97, 0.58)$	1.51	0.56	$(0.79, 0.71)$	1.682	C_2	$(1, 0.62)$	1.34	0.62	$(0.83, 0.75)$	1.560
29	C_3	$(0.8, 0.82)$	1.45	0.66	$(0.85, 0.77)$	1.474	C_2	$(0.88, 0.76)$	1.44	0.67	$(0.86, 0.78)$	1.441
30	C_2	$(1, 0.62)$	1.34	0.62	$(0.83, 0.75)$	1.560	C_1	$(1, 0.55)$	1.44	0.55	$(0.79, 0.7)$	1.706

Table 2.19: Experimental strategies in session 1 (b).

$$H(p,q) = H(q) + qH(p_1) + (1-q)H(p_2)$$
$$p_1(x) = \frac{3x}{1+2x},\ q(x) = \frac{1+2x}{3}$$
$$y = H(x) + (1-x)\log_2 3$$

	Play 1							Play 2						
Pair	Cluster	(p_1, q)	p_2	$H(p,q)$	$x = p_1 q$	$(p_1(x), q(x))$	y	Cluster	(p_1, q)	p_2	$H(p,q)$	$x = p_1 q$	$(p_1(x), q(x))$	y
1	C_1	(1, 0.47)	0	1	0.47	(0.73, 0.65)	1.837	C_3	(0.95, 0.74)	0.07	1.13	0.70	(0.88, 0.8)	1.348
2	C_3	(1, 0.67)	0.33	1.22	0.67	(0.86, 0.78)	1.438	C_3	(0.97, 0.72)	0.13	1.15	0.70	(0.87, 0.8)	1.361
3	C_1	(1, 0.45)	0	1	0.45	(0.71, 0.63)	1.865	C_2	(1, 0.56)	0	1	0.56	(0.79, 0.71)	1.687
4	C_1	(1, 0.45)	0.03	1.10	0.45	(0.71, 0.63)	1.865	C_3	(1, 0.7)	0.18	1.09	0.70	(0.88, 0.8)	1.357
5	C_1	(1, 0.5)	0.29	1.43	0.50	(0.75, 0.67)	1.792	C_2	(0.97, 0.63)	0.20	1.34	0.61	(0.82, 0.74)	1.580
6	C_3	(0.94, 0.65)	0.15	1.36	0.61	(0.82, 0.74)	1.581	C_3	(0.95, 0.72)	0.13	1.22	0.68	(0.87, 0.79)	1.401
7	C_1	(1, 0.47)	1	1	0.47	(0.73, 0.65)	1.837	C_1	(1, 0.38)	1	0.96	0.38	(0.65, 0.59)	1.941
8	C_1	(1, 0.49)	1	1	0.49	(0.74, 0.66)	1.808	C_3	(0.87, 0.85)	0.68	1.22	0.74	(0.89, 0.83)	1.240
9	C_1	(1, 0.47)	0.44	1.52	0.47	(0.73, 0.65)	1.837	C_3	(1, 0.7)	0.18	1.09	0.70	(0.88, 0.8)	1.357
10	C_3	(0.97, 0.65)	0.10	1.22	0.63	(0.84, 0.75)	1.536	C_3	(1, 0.7)	0.36	1.16	0.70	(0.88, 0.8)	1.357
11	C_2	(1, 0.54)	0	1	0.54	(0.78, 0.69)	1.724	C_3	(1, 0.65)	0.11	1.11	0.65	(0.85, 0.77)	1.489
12	C_1	(1, 0.5)	0.03	1.10	0.50	(0.75, 0.67)	1.792	C_3	(0.97, 0.69)	0.42	1.33	0.67	(0.86, 0.78)	1.440
13	C_3	(1, 0.67)	0.22	1.17	0.67	(0.86, 0.78)	1.438	C_3	(1, 0.65)	0.35	1.26	0.65	(0.85, 0.77)	1.489
14	C_3	(1, 0.63)	0.60	1.31	0.63	(0.84, 0.75)	1.537	C_3	(0.97, 0.69)	0.35	1.32	0.67	(0.86, 0.78)	1.440
15	C_3	(0.94, 0.7)	0.31	1.38	0.66	(0.85, 0.77)	1.469	C_3	(0.97, 0.72)	0.20	1.20	0.70	(0.87, 0.8)	1.361
16	C_2	(1, 0.6)	0.27	1.31	0.60	(0.82, 0.73)	1.605	C_2	(0.97, 0.63)	0.60	1.43	0.61	(0.82, 0.74)	1.580
17	C_1	(1, 0.47)	1	1	0.47	(0.73, 0.65)	1.837	C_3	(0.95, 0.74)	0.14	1.19	0.70	(0.88, 0.8)	1.348
18	C_1	(1, 0.47)	0	1	0.47	(0.73, 0.65)	1.837	C_3	(0.89, 0.89)	0.83	1.02	0.79	(0.92, 0.86)	1.067
19	C_3	(0.94, 0.7)	0.56	1.41	0.66	(0.85, 0.77)	1.469	C_3	(0.95, 0.72)	0.40	1.33	0.68	(0.87, 0.79)	1.401
20	C_1	(1, 0.49)	0	1	0.49	(0.74, 0.66)	1.808	C_2	(1, 0.58)	0.04	1.08	0.58	(0.81, 0.72)	1.647
21	C_1	(1, 0.5)	0	1	0.50	(0.75, 0.67)	1.792	C_1	(1, 0.49)	0	1	0.49	(0.74, 0.66)	1.808
22	C_1	(1, 0.45)	0.33	1.50	0.45	(0.71, 0.63)	1.865	C_3	(1, 0.7)	0.18	1.09	0.70	(0.88, 0.8)	1.357
23	C_2	(0.96, 0.56)	0.08	1.30	0.54	(0.78, 0.69)	1.729	C_2	(1, 0.56)	0	0.99	0.56	(0.79, 0.71)	1.687
24	C_2	(0.94, 0.61)	0.19	1.44	0.57	(0.8, 0.72)	1.661	C_3	(1, 0.7)	0.18	1.09	0.70	(0.88, 0.8)	1.357
25	C_1	(0.85, 0.38)	0.79	1.65	0.32	(0.59, 0.55)	1.981	C_3	(0.83, 0.87)	0	1.13	0.72	(0.89, 0.81)	1.293
26	C_1	(1, 0.47)	0	1	0.47	(0.73, 0.65)	1.837	C_1	(0.96, 0.52)	0.53	1.60	0.50	(0.75, 0.67)	1.794
27	C_2	(0.96, 0.56)	0.45	1.56	0.54	(0.78, 0.69)	1.729	C_3	(1, 0.69)	0.29	1.16	0.69	(0.87, 0.79)	1.385
28	C_1	(1, 0.41)	0.53	1.56	0.41	(0.68, 0.61)	1.912	C_1	(0.83, 0.56)	0.50	1.80	0.46	(0.72, 0.64)	1.845
29	C_1	(1, 0.43)	0.96	1.12	0.43	(0.69, 0.62)	1.889	C_1	(0.96, 0.54)	0.92	1.31	0.52	(0.76, 0.68)	1.762
30	C_1	(1, 0.5)	0	1	0.50	(0.75, 0.67)	1.792	C_1	(0.96, 0.52)	0	1.12	0.50	(0.75, 0.67)	1.794

Table 2.20: Experimental strategies in session 2 (b).

$$H(p,q) = H(q) + qH(p_1) + (1-q)H(p_2)$$
$$p_1(x) = \frac{3x}{1+2x},\ q(x) = \frac{1+2x}{3}$$
$$y = H(x) + (1-x)\log_2 3$$

Pair	Play 1							Play 2						
	Cluster	(p_1,q)	p_2	$H(p,q)$	$x=p_1q$	$(p_1(x),q(x))$	y	Cluster	(p_1,q)	p_2	$H(p,q)$	$x=p_1q$	$(p_1(x),q(x))$	y
1	C_1	$(1,0.47)$	1	1	0.47	$(0.73,0.65)$	1.837	C_2	$(1,0.58)$	1	0.98	0.58	$(0.81,0.72)$	1.647
2	C_1	$(1,0.38)$	0	0.96	0.38	$(0.65,0.59)$	1.941	C_1	$(1,0.44)$	0.03	1.10	0.44	$(0.7,0.63)$	1.877
3	C_2	$(1,0.62)$	0	0.96	0.62	$(0.83,0.75)$	1.560	C_2	$(1,0.73)$	0.47	1.11	0.73	$(0.89,0.82)$	1.269
4	C_1	$(1,0.4)$	0.03	1.09	0.40	$(0.67,0.6)$	1.922	C_1	$(1,0.33)$	0.05	1.11	0.33	$(0.6,0.55)$	1.977
5	C_2	$(1,0.62)$	1	0.96	0.62	$(0.83,0.75)$	1.560	C_1	$(1,0.55)$	1	0.99	0.55	$(0.79,0.7)$	1.706
6	C_3	$(0.88,0.78)$	0.08	1.26	0.69	$(0.87,0.79)$	1.394	C_2	$(0.87,0.85)$	0.13	1.17	0.74	$(0.89,0.83)$	1.240
7	C_1	$(0.96,0.44)$	1	1.10	0.42	$(0.69,0.61)$	1.898	C_2	$(1,0.65)$	1	0.93	0.65	$(0.85,0.77)$	1.489
8	C_1	$(1,0.49)$	0	1	0.49	$(0.74,0.66)$	1.808	C_1	$(1,0.49)$	0	1	0.49	$(0.74,0.66)$	1.808
9	C_2	$(0.97,0.62)$	0.05	1.19	0.60	$(0.82,0.73)$	1.602	C_1	$(1,0.45)$	0.13	1.30	0.45	$(0.71,0.63)$	1.865
10	C_2	$(1,0.58)$	1	0.98	0.58	$(0.81,0.72)$	1.647	C_2	$(1,0.58)$	1	0.98	0.58	$(0.81,0.72)$	1.647
11	C_2	$(1,0.56)$	0.83	1.28	0.56	$(0.79,0.71)$	1.687	C_1	$(0.97,0.58)$	1	1.09	0.56	$(0.79,0.71)$	1.682
12	C_2	$(0.97,0.62)$	0.81	1.35	0.60	$(0.82,0.73)$	1.602	C_2	$(0.95,0.78)$	0.58	1.20	0.74	$(0.9,0.83)$	1.236
13	C_3	$(1,0.65)$	1	0.93	0.65	$(0.85,0.77)$	1.489	C_2	$(1,0.62)$	1	0.96	0.62	$(0.83,0.75)$	1.560
14	C_3	$(1,0.76)$	0.77	0.98	0.76	$(0.9,0.84)$	1.175	C_2	$(1,0.69)$	0.71	1.16	0.69	$(0.87,0.79)$	1.385
15	C_1	$(1,0.53)$	1	1	0.53	$(0.77,0.69)$	1.742	C_2	$(1,0.58)$	1	0.98	0.58	$(0.81,0.72)$	1.647
16	C_2	$(1,0.58)$	0.96	1.08	0.58	$(0.81,0.72)$	1.647	C_1	$(1,0.56)$	1	0.99	0.56	$(0.79,0.71)$	1.687
17	C_2	$(1,0.62)$	0.95	1.07	0.62	$(0.83,0.75)$	1.560	C_1	$(1,0.45)$	1	0.99	0.45	$(0.71,0.63)$	1.865
18	C_2	$(0.97,0.62)$	0	1.08	0.60	$(0.82,0.73)$	1.602	C_1	$(0.97,0.56)$	0.21	1.42	0.54	$(0.78,0.7)$	1.719
19	C_1	$(0.97,0.53)$	0.23	1.47	0.51	$(0.76,0.68)$	1.770	C_2	$(0.97,0.64)$	0.60	1.42	0.62	$(0.83,0.75)$	1.558
20	C_3	$(0.93,0.73)$	0.73	1.34	0.68	$(0.86,0.79)$	1.415	C_2	$(0.98,0.76)$	0.46	1.14	0.74	$(0.9,0.83)$	1.224
21	C_1	$(1,0.38)$	1	0.96	0.38	$(0.65,0.59)$	1.941	C_2	$(0.97,0.65)$	0.68	1.38	0.63	$(0.84,0.75)$	1.536
22	C_2	$(1,0.62)$	0	0.96	0.62	$(0.83,0.75)$	1.560	C_2	$(1,0.71)$	0.31	1.13	0.71	$(0.88,0.81)$	1.328
23	C_3	$(1,0.69)$	0.82	1.10	0.69	$(0.87,0.79)$	1.385	C_2	$(1,0.62)$	0.81	1.22	0.62	$(0.83,0.75)$	1.560
24	C_1	$(1,0.51)$	0	1	0.51	$(0.76,0.67)$	1.776	C_1	$(1,0.51)$	0	1	0.51	$(0.76,0.67)$	1.776
25	C_1	$(1,0.47)$	1	1	0.47	$(0.73,0.65)$	1.837	C_1	$(1,0.55)$	1	0.99	0.55	$(0.79,0.7)$	1.706
26	C_2	$(1,0.56)$	1	0.99	0.56	$(0.79,0.71)$	1.687	C_1	$(1,0.51)$	1	1	0.51	$(0.76,0.67)$	1.776
27	C_2	$(0.94,0.62)$	0.29	1.49	0.58	$(0.81,0.72)$	1.641	C_1	$(0.96,0.47)$	0.52	1.64	0.45	$(0.71,0.63)$	1.863
28	C_2	$(0.97,0.58)$	0.30	1.46	0.56	$(0.79,0.71)$	1.682	C_2	$(1,0.62)$	0.43	1.33	0.62	$(0.83,0.75)$	1.560
29	C_3	$(0.8,0.82)$	0.60	1.45	0.66	$(0.85,0.77)$	1.474	C_2	$(0.88,0.76)$	0.46	1.44	0.67	$(0.86,0.78)$	1.441
30	C_2	$(1,0.62)$	0.95	1.07	0.62	$(0.83,0.75)$	1.560	C_1	$(1,0.55)$	1	0.99	0.55	$(0.79,0.7)$	1.706

Chapter 3

Words and actions as communication devices

Communication is to a relationship what breathing is to maintaining life.

-Virginia Satir

3.1 Introduction

COMMUNICATION is intrinsic to human being, but also is one of the most complex and strategic activities. It is the activity of transmitting information by exchanging words, signals, messages, thoughts, and behavior among other forms of interaction. Obstacles to effectiveness of communication are the lack of congruence between the sender and the receiver and the private cost of formulating and absorbing the content of a communication, thus moral hazard may occur even when forming a team sharing perfectly aligned preferences; Dewatripont and Tirole (2005).

Given the device of information transmission, communication can be classified as explicit or tacit. Explicit communication entails the existence of an external device to support such activities, for instance, sending e-mails, chatting, WhatsApp, etc. Nevertheless, there exists another kind of communication that is not usually recognized as that. As Schelling (1960) pointed out, this is the tacit communication that may occur when a natural understanding emerges between individuals, for instances by their agent's action, common beliefs etc. Indeed, the most basic type of communication is implicit communication through actions rather than words. It is the combination of words and actions that makes up the complete communication toolbox. In particular, communication between agents may be explicitly conveyed through explicit messages or, communication may be tacitly transmitted through actual action in the course of business. In this sense, this chapter deals with explicit as well as tacit transmission of information among players that play a pure coordination game. Our main goal is to evaluate the two sort of communication and to distinguish the possible effect of the explicit on the tacit communication. For this purpose, we design an experiment which permits the natural arising of the two types, tacit and explicit communication under a coordination set-up allowing us to calibrate the possible effects.

Based on Gossner et al. (2006) (GHN, henceforth), we implement a 2-player pure coordination finitely repeated game with a pre-play phase. During the game, the coordination activity that players have to implement is not only between them but also with the nature's action. During the pre-play phase, players chat by sending messages back and forth. This exchange of information is not binding and the two players may exchange messages to later improve their actions against future nature's realization. Before the play starts, the sequence of actions played by nature is revealed to only one player called the wiser player. The non-informed player is called the agent player. After the chat stage, players play the finitely repeated game. At each stage both players learn the three action profile played by the nature and the two players. This structure of information is common knowledge for both players as the asymmetric information between the two players.

In this game explicit communication may take place only before the game is played in the chat phase, and tacit signals can be implemented just during the game, through the actions played. In this chapter, taking into account the above feature, we design an experiment to measure the two communications taken in the lab. Two treatments are implemented, one without chat (NC) and one with chat (C) in which players may first send messages and then play the game.

Our first result is related to the existence of *tacit* communication. In the treatment without chat, several wiser players make an intentional mistake to induce a change in the other agent's actions. Several agent players, by being aware of the wiser's actions, make some kind of guess about the future actions of nature. As a result, there are subject-pairs that make an attempt to coordinate their actions, thus improving their average payoff. However, on average, we do not find evidence of tacit communication through actions in NC. In other words, most of the subject-pairs do not develop tacit communication. Hence, this result implies that the existence of common aligned preferences is not enough to achieve salient level of communication.

A second result states that *explicit* communication between players improves average payoffs. When the chat is performed, players establish a way of understanding messages that are actually used in their actions when playing the game. Generally speaking, the efficient use of the chat implies explicit communication leading to better average payoffs by designing sophisticated communication strategies. Notice that the existence of explicit communication through explicit messages involving coordination rules may make better the tacit communication through embodied codes in the actions played during the coordination 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 by improving the tacit mechanism in the course of the game. Moreover, the strategies performed by the subjects 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 implementable strategies in the theoretical paper of GHN.

Finally, our third result states that 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 tacit communication, while the chat effect is the consequence of explicit communication getting both sources of communication.

The rest of the chapter is structured as follows. Section 3.2 make a review of the literature on communication. Section 3.3 describes the game on which the experiment is based. We dedicate Section 3.4 to the experimental design. In Section 3.5 we detail the data analysis and highlight the main results. Section 3.6 concludes. An appendix at the end includes the instructions given to experimental subjects as well as some tables showing examples of the dialogs that subjects wrote in the sessions with chat.

3.2 Related literature

Although ours is the first experimental work that explicitly deals with the measurement of efficiency in 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.

Related to theory on communication, our work contributes to understand the strategies that agents perform in two scenarios, either before agents play as a cheap-talk stage or playing a repeated game. Some of these results in this brand of literature stem on the construction of sophisticated-structured strategies (see Aumann and Hart (2003), Forges and Koessler (2005), Ben-Porath (2003), Heller et al. (2012), among others). Attending the literature of repeated game, the block-strategies structure has been widely used as in Renault and Tomala (2004), Fudenberg and Levine (2009), among other. For both strand of literature, this work contributes to accept some of those constructions as behavioural strategies.

The theory of communication by Dewatripont and Tirole (2005) is built on the literature on psychology rather than on economics. This theory is based on costly communication in which the mode of communication and the transfer of knowledge are endogenously determined by the sender's and receiver's motivations and abilities. Clearly, the effectiveness of communication increases with the sender's communication effort and with the receiver's attention effort, as well as with exogenous factors such as background, language, or references in common. One of results is that a decrease in the ease of communication leads to a decrease in total communication effort. Thus, it would be expected a little amount of information to be transmitted within unfamiliar or unfriendly communication environments for the parties. The present study's first experimental result meets that theoretical result: it is found that tacit communication is really difficult to emerge without conventions or previous agreements between the sender and the receiver.

Related to explicit communication through a pre-play cheap talk phase, Ellingsen and Östling (2010) study the case of inexperienced players who communicate their intentions each other. By using the level-k model of strategic thinking to describe players' beliefs, the authors characterize the effects of pre-play communication in symmetric 2x2 games. In particular, they find that communication facilitates coordination in common interest games with positive spillovers and strategic complementarities, however there are also games in which any type of communication hampers coordination. In our experiment, we find that the cheap talk phase was helpful to arrange payoff-enhancing coordination strategies and when repeated it also allowed players to learn and design more efficient coordination strategies.

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 and Strassmair (2009), and Camera et al. (2011) 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. (2010) 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. (2006) 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, tacit as well as explicit communication are a possibility for subjects who play a coordination game with aligned interests. In such a context, we measure the interrelation between the two types of communication as well as to which extent the communication process is efficient, in the sense of achieving higher payoffs.

3.3 Theoretical framework

In this section we describe the game played by subjects in the experiment: A 2-player pure coordination game with asymmetric information about 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 the players. Each player's set of actions is $\{0, 1\}$. The wiser is a fully informed player, in the sense that he knows in advance the sequence played by nature. The agent is a less informed player, since he does not know the sequence played by nature. Players get 1 when their actions match nature's actions, and 0 otherwise. No losses are possible. Formally, we denote *nature* as player i, the *wiser* as player j and, the *agent* as player k. The stage-game payoff is as follows:

$$g(i, j, k) = \begin{cases} 1 & if \quad i = j = k \\ 0 & otherwise \end{cases} \tag{3.1}$$

It can also be represented in matrix way:

	$k = 0$	$k = 1$
$j = 0$	1	0
$j = 1$	0	0

$i = 0$

	$k = 0$	$k = 1$
$j = 0$	0	0
$j = 1$	0	1

$i = 1$

where the wiser chooses the row, the agent chooses the column, and the nature chooses the matrix.

Let us consider the n-repetition version of our game with a cheap-talk first stage and the following timing of the game: 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 fully informed about the sequence of nature's actions which is the realization of n $i.i.d$ random variables with law $(\frac{1}{2}, \frac{1}{2})$; 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. Coordination may be achieved either intentionally or by chance. The first coordination requires an effort by agents: at least one agent takes into account the other's behavior and attempts to predict it to coordinate both actions. The second coordination occurs without the need for agents to guess the other's behavior. 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 the more information they contain, therefore imply more communication between players and higher payoffs. The following examples illustrate both the random coordination case and the intentional coordination case, respectively.

Strategy profile 1: random coordination The wiser plays nature's action and the agent randomly plays $\{0, 1\}$ with equal probability. Therefore, the probability of coordination that is the probability of the two events $(1, 1, 1)$ and $(0, 0, 0)$) equals $\frac{1}{2}$. Then, the stage-game expected payoff is $\frac{1}{2}$ [1]. Another random coordination strategy earning the expected common payoff of $\frac{1}{2}$ per round consists of the wiser plays nature's actions in every round and the agent plays either '0' or '1' in all rounds. If the agent decides to play '1' in all rounds, he respectively gives $prob(k = 0) = 0$ and $prob(k = 1) = 1$. The corresponding expected common payoff is $1 \cdot prob(1, 1, 1) = 1 \cdot prob(k =$

[1]The joint probability $prob(i, j, k)$ can be expressed in terms of conditional probability as the product $prob(k|i, j) \cdot prob(j|i) \cdot prob(i)$. Since the wiser always matches the nature, the conditional probability $prob(j|i)$ is equal to 1. On the other hand, the play of the agent does depend on neither the nature's nor the wiser's actions. As a result, the joint probability is $prob(i, j, k) = prob(k) \cdot prob(i) = \frac{1}{4}$, and the expected common payoff is $1 \cdot prob(1, 1, 1) + 1 \cdot prob(0, 0, 0) = 1 \cdot \frac{1}{4} + 1 \cdot \frac{1}{4} = \frac{1}{2}$ per round.

$1) \cdot prob(i = 1) = \frac{1}{2}$ per round. Similarly, when the agent plays '0' in all rounds, the event $(1, 1, 1)$ is not possible and takes null probability. Clearly, the expected common payoff is also $\frac{1}{2}$ per round.

Strategy profile 2**.** In the repeated version of the game, one would expect that players thought of emitting tacit communication to coordinate each other so much as possible. A naive tacit communication strategy consists of a signal sent by the wiser to announce the following action of nature. Roughly speaking, the implicit message in the wiser's signaling action would be something like: *Today, I tell you the action for tomorrow, and the day after tomorrow we will talk again.* This signal is emitted in the way of a mistake at the current stage, when the wiser does not match the nature, and the agent decodes the message involved in the intentional mistake as the action to be played at the next stage. The corresponding sequences of actions are the followings:

$$\begin{aligned} nature &= (i_1, i_2, i_3, i_4, \cdots, i_n) \\ wiser &= (i_2, i_2, i_4, i_4, \cdots, i_n) \\ agent &= (k_1, i_2, k_3, i_4, \cdots, i_n) \end{aligned}$$

Notice that the expected payoff is guarantee and equals 1 at even stages, since the probability of matching is 1, whereas that probability is $\frac{1}{4}$ at the odd stages. Therefore, the average expected payoff is $\frac{5}{8}$ per round of the game. As a consequence, there is an improvement of the coordination level because of tacit communication.

Strategy profile 3**: A 3-length block strategy.** This strategy consists of dividing the nature's sequence in 3-length blocks. In each block, the wiser intentionally makes a mistake to signal nature's majority action for the next block. According to the coding rule previously set (eg. in an online chat), the agent decodes the signal and plays that action in each stage of the next block. By following this strategy, players match nature's action at least twice per block[2] Let us consider the following 25-rounds of a sequence, divided in blocks of three. We include also the actions of the wiser and the agent as well as each player's payoff for each round:

Table 3.1: Strategy profile 3

Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Nature	0	1	0	1	0	1	1	1	0	0	1	1	0	0	0	0	0	0	1	1	0	1	0	1	0
Wiser	**1**	1	**1**	1	**0**	1	1	**1**	0	0	1	1	**0**	0	0	<u>0</u>	0	0	**1**	1	**0**	1	0	**1**	0
Agent	*	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0
Payoff	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	0	1

In the table above, notice that figures in bold highlight the signaling round within each block, the wiser signals by a mistake the action that the agent should play in the three rounds of the next block. In absence of mistakes, the signaling round is established by the players. In the case of this example, the wiser uses the last stage of a block to signal the majority action of the next block: underlined, in round 16 (last round of the 5th block), the wiser marks that the majority action that nature plays next block is a '0', and this means that the agent should play '0' for the three rounds of that block in order to match the nature 2 times over 3. Thus, the average expected common payoff is $\frac{2}{3}$ per round, and the total expected payoff is $\frac{2}{3} \cdot (25-1) = 16$.

In order to test whether players are able to commit on strategies that contain communication, we design an experiment. Next section is dedicated to explain the details of our design, and we also offer the main hypotheses that we want to test.

[2]In general, the 3-length possible sequences are: 000, 001, 010, 100, 110, 101, 011, and 111. The probability of the majority rule 'equals 0' is given by $prob(majority = 0) = prob(000 \cup 001 \cup 010 \cup 100) = 4\frac{1}{8} = \frac{1}{2}$. Similarly, the probability of the majority rule 'equals 1' is equal to $prob(majority = 1) = prob(110 \cup 101 \cup 011 \cup 111) = 4\frac{1}{8} = \frac{1}{2}$. Thus, the probability of two consecutive blocks have the same majority is $\frac{1}{2}$. The probability that an intended mistake (say x) becomes a random match is equal to: $P(x = majority = 0)P(majority = 0)P(majority = 0) + P(x = majority = 1)P(majority = 1)P(majority = 1) = \frac{1}{4}$.

3.4 Experimental design

In our experiment, a wiser with perfect information about the nature's sequence and an agent with imperfect information, play simultaneously a pure coordination game with aligned payoffs during a finite number of periods. Two treatments and three sessions are run: one session (Session 0) of a baseline without chat (NC) and two sessions (sessions 1 and 2) of a treatment with chat (C) . There are two types of subjects: player 1 and player 2. Player 1 plays the role of the *wiser* and player 2 plays the role of the *agent*.[3] Common to both treatments, in an experimental session, players play twice the coordination game.

Specifically, a session is divided in two parts: In the first part, named Play 1, subjects play the coordination game during 55 rounds.[4] Immediately after, the second part, named Play 2, is played. Play 2 is exactly the same as Play 1 but nature plays a different sequence. Both parts in a session have the same structure: each subject-pair plays the simultaneous coordination game in which, first, the 55 sequence of nature's actions is generated and privately transmitted to the wiser, and then wiser and agent play 55 rounds of the game. At the end of each round, subjects are privately informed about actions played in the past by nature, wiser and agent, as well as about own earnings in that specific round. Therefore, both parts in a session differ just in the fact that, when Play 2 starts, subjects have already played the 55 rounds of Play 1.

Only in treatment C, each part of the session has a pre-play chat stage of 3 minutes before the coordination game is played. During the time of the chat, subjects are allowed to send messages to each other in order to share information and experience. The chat time starts simultaneously for all pairs in the session, and even though sub-

[3]Although *player 1* and *player 2* is the notation used in the experiment for the type of subject, throughout the chapter we use the general notation of *wiser* and *agent*.

[4]This length allows for a complexity level of the sequence such that subjects are not able to learn it by heart.

jects may close it before the end of the third minute, all pairs start the game at the same time.

The experiment was conducted at LINEEX, the experimental economics lab of the University of Valencia in Spain. A total of 180 subjects participated in the experiment, distributed over the three independent sessions of 60 participants each. Subjects were students/volunteers recruited from the third and fourth years in Economics, International Business, and Business Administration at the University of Valencia. The experiment was programmed using z-Tree (Fischbacher, 2007). Each session lasted about 45 minutes.

At the beginning of a session, subjects are randomly assigned to a seat in the lab, and given the written general instructions of the experiment. Before the actual experiment starts, subjects perform several tests.[5] Additionally, subjects answer an *ad hoc* test of several questions about the game in order to test whether they understand how the incentives work in the coordination game. In order to have subjects with a solid understanding of the experiment, a pilot session of 8 periods is run before the real experiment starts[6]. When the subjects are all grouped into pairs, each participant is randomly given her permanent role in the pair: player 1 (the wiser) or player 2 (the agent). Once the role is assigned, the pair of subjects remains fixed along the session.

The sequences[7] played by nature were randomly generated at the beginning of each part of the session through a random number generator simulating a '0' and '1' binary variable, each outcome with a constant probability of 1/2. Subjects were informed about the computerized random process as being like tossing a coin (see the instructions in appendix 1).

Three are the hypotheses that we want to test with this experiment. The first

[5] In particular, they performed the Cognitive Reflexion Test (CRT) by Frederick (2005), and the Team Work Test (TWT) with twenty-five selected questions.

[6] The data obtained in the pilot are not part of the present analysis.

[7] A total of six, two per session.

one relates the baseline, the treatment without chat (NC):

H1: In treatment NC, players will hardly signal strategies that allow them to communicate.

The second and third hypothesis relate the treatment C, aiming at testing the chat effect:

H2: In comparison with treatment NC, higher payoffs are expected in treatment C.

H3: In treatment C, players are able to design behavioral rules based on mistakes to communicate through actions.

3.5 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.

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.[8]

3.5.1 Treatment NC - Session 0

In this subsection we study the decision making of at Session 0 where players are not allowed to chat. It is only possible *tacit* communication. In case that tacit communication emerges then there should exist some kind of natural language that should emerge between the fully informed player and the imperfectly informed player, such that the latter, being aware of his informational disadvantage, does closely follow

[8]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.

the former's playing to discover the message encoded in the wiser's actions. Thus, tacit communication, on the one hand, involves the transmission of information through the wiser's actions to the agent and, on the other hand, the translation of that information or message in actions played later by the agent.

We find two types of strategies implemented by the *agents*:

- First, and mostly used, *a Random strategy*, that is to say, the player chooses her action emulating the nature's known $(1/2, 1/2)$ random process. As a result, each possible action, 0 or 1, is played within $40\% - 60\%$ times. Specifically, 21 out of 30 subjects implemented this kind of strategy it in Play 1 as well as in Play 2. At the appendix, table 3.22 reports some experimental examples of wiser-agent team's strategies when the agent plays randomly and, therefore, without taking into account the wiser's playing. This kind of agent player does not make any effort to understand the message codified in the wiser's actions, which makes impossible any communication. Presumably, that agent would expect that the wiser match nature all times and, thus, obtain an expected total payoff of $\frac{1}{2} \cdot 55 = 27.5$.

- Second, *a Pure strategy* in the sense that an action, whatever 1 or 0, is played at least 75% times. Only 8 out of 30 agent players used this strategy. Similarly to the earlier strategy, the agent player would expect to gain a payoff of $\frac{1}{2}$ per round or period[9].

Whenever the agent performs strategies different from the random and the pure strategies, we use the label *'Other'*. In this group of strategies we find just two observations that correspond to the same wiser-agent pair. The strategy followed by the agent consists of playing the wiser's last action. It happens that, in the play 1, the agent plays randomly in the first 8 periods, but then he follows, although with some mistakes, the wiser's last action in 40 out of 47 remaining periods. Looking at the

[9] See tables 3.23 and 3.24 for an example of pure strategies.

panel A of Table 3.2, it seems clear that the wiser and agent almost perfectly coordinate their actions from the period 21. Notice that the wiser plays with anticipation of the nature's majoritarian action into next periods (eg. 000 or 111). Similarly, in the play 2, the agent begins following the wiser's action from the second period, in fact, he does it 46 out of 54 times. In conclusion, the wiser and the agent are able to coordinate each other to match the nature, by defining in the very course of the game an implicit communication rule based on the wiser's intended mistakes [10]. Therefore, as a result, the wiser is able to transmit information (*a message*) and the agent is able to understand the signal from the wiser's mistake and translate it into an action to play in the next periods (*action plan*).

Regarding the strategies followed by the *wisers*, we observe that, in general, the wiser replicates exactly the sequence played by the nature. Since the wiser has perfect information on the nature's future realizations, she can follow this naive strategy, that we call *Nature*. We consider that a wiser has played *Nature* whenever her actions match nature at least 75% of the times.[11]

When the wiser plays otherwise, it is said that the wiser plays a *No-nature* strategy to indicate that the wiser's playing conveys some information about future. Specially, when the wiser does not match nature, he intentionally makes a mistake that works as a signal to the agent on the nature's next actions. Furthermore when the wiser's *No-nature* strategy is combined with the agent's *'Other'* strategy, then the team establishes a *tacit* communication channel, and the information send by the wiser through his actions is successfully received and interpreted by the agent. In this way, the agent reduces his level of uncertainty on the nature's next future and plays accordingly. As already mentioned, only 1 out of 30 wiser-agent pairs combines these two strategies, shown in table below, which indicates how difficult communication is

[10] Intended mistakes are highlighted in bold in table 3.25

[11] As shown in onward pages, when there is communication, the optimal strategy matches nature 2/3 times sequence's length ($2/3 \cdot 55 = 37$).

in the setup of this treatment without any kind of pre-arrangement. Nevertheless we would expect to find a stronger evidence of communication with a larger number of sessions, which would allow the players to learn, being learning clearly harder for agent players than for wiser players.

Table 3.2: Tacit communication in Treatment NC

Pair	Round	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Panel A: Session 0, Play 1																																																								
	Nature	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
4	Wiser	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0
4	Agent	1	1	1	0	0	0	0	0	1	0	0	1	0	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0
Panel B: Session 0, Play 2																																																								
	Nature	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
4	Wiser	1	1	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0
4	Agent	0	1	1	0	1	1	1	1	0	0	1	0	0	0	0	1	0	0	1	0	1	1	0	1	0	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Looking at the histogram of wiser reported in figure 3.1, we can see the distribution of wisers' matching with the nature: 17 out of 30 wisers do all times (100%) in both plays. In Play 1, 4 wiser players attempt to inform their partner by doing among 12 and 6 intended mistakes, what represents a percentage of matching among 78% and 89%. In Play 2, 7 out of 30 wiser players make signaling by mistakes, and they match the nature between 76% and 87% of times. In other cases, mistakes do not have any informative value since they are random, as verified.

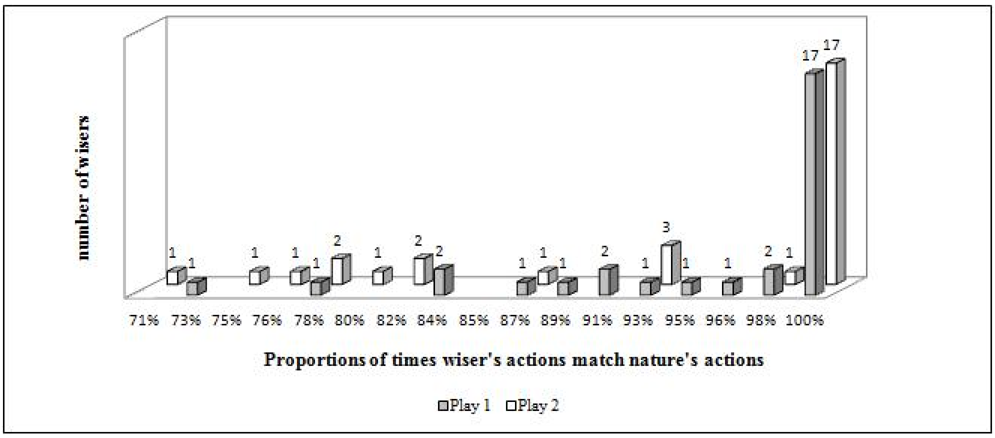


Figure 3.1: Histograms of the wiser's matchings with the nature

Table 3.3 shows the number of times each type of strategy was used by each type of player.

Table 3.3: Number of players performing the different types of strategies in NC

Strategy		wiser			
		Play 1		Play 2	
		Nature	No-nature	Nature	No-nature
agent	Random	20	1	16	5
	Pure	6	2	7	1
	Other	-	1	-	1

In this session, 26 out of 30 wisers played *Nature* in Play 1, and 23 did it in Play 2.[12] Moreover, the average number of matchings along the session were 27.83 in Play 1 and 24.57 in Play 2. Contrary to what was expected, the experience acquired in Play 1 did not result in an improvement in the coordination level for Play 2. Overall, this may evidence that players, specially agents, did not make an effort to reach a higher number of matchings with respect to Play 1. Therefore, we can conclude that, on average, *tacit* communication is not found in the setting of the game played, and this will be our reference point of no-communication.

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. On average, tacit communication is not found in treatment NC. So, hypothesis 1 is accepted.

Our data allow us to confirm the first hypothesis. This means that the existence of common aligned interests is not a sufficient condition for reaching a salient level of

[12]More specifically, in Play 1, 24 wisers matched the nature more than 90% of the times, 28 players more than 80% of the times, and 29 players more than 75% times. In Play 2, the respective numbers are 21, 24, and 28 players.

communication so that higher payoffs can be achieved. Subjects may need a pre-play mechanism so that communication takes place.

3.5.2 Treatment C - Sessions 1 and 2

With treatment C, we are testing for the existence of explicit communication via an online chat and its influence on coordination. Our guess is that subject-pairs will use the chat stage in order to define profitable coordination strategies that will be performed afterwards during the game. Interestingly, our data confirm not only the existence of explicit communication through explicit messages involving coordination rules, but also a clear evidence of tacit communication through embodied codes in the actions played during the coordination 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. On average, subjects get significantly higher payoffs in treatment C than in treatment NC.

Table 3.4 reports the descriptive statistics of the number of matchings by session, as well as the results of Kurskall-Wallis test for testing the hypothesis of equality of populations and Two-sample Wilcoxon rank-sum (Mann-Whitney) test for equality of medians. Additional test for normality, independence and etcetera are also performed[13].

Observe in the table above that Kruskal-Wallis test reveals that there is a sig-

[13]We performs Skewness-Kurtosis test for normality. The null hypothesis of normality can be rejected (at 1% level) on data from sessions 0 and 1, but not on data from Session 2. The independence of populations is confirmed by Kendall's test for independence. To test the hypothesis of equal variances between sessions, it is applied Levene's test. It shows that Session 0's variance is significantly different from the Session 1's and Session 2's variance ($W = 19.9$, $p < 0.01$ and $W = 4.30$, $p < 0.01$, respectively). However, it is accepted at 5% that sessions 1 and 2 have the same variance ($W = 3.238$, $p = 0.074$). Finally, according to Kolgomorov-Smirnov test for equality of distribution functions, the null hypothesis cannot be rejected in the case of sessions 1 and 2 ($D = 0.1667$, $p = 0.304$).

Table 3.4: Statistics on the number of matchings, by session

Descriptive S./Contrast Test	Session 0	Session 1	Session 2
Treatment	NC	C	C
Min.	12	18	18
Max.	33	44	42
Average	26.20	32.10	31.63
Median	26.50	32.00	32.00
Coefficient of Variation	15.31%	18.61%	17.21%
Kruskal-Wallis equality-of-populations rank test			
Session 1	26.484 *		
Session 2	31.129 *	0.179	
Sessions 0-1-2		38.471*	
Wilcoxon rank-sum test for equal medians			
Session 1	-5.157*		
Session 2	-5.591*	0.423	
Obs.	60	60	60

* 1% significance level , ** 5% significance level , *** 10% significance level

nificant difference between the populations of the three sessions ($\chi^2 = 38.47$, p-value < 0.01). When compared sessions with explicit communication (sessions 1 and 2), we cannot reject the null hypothesis of equality of populations ($\chi^2 = 0.179$, $p-value = 0.67$). However, there is a significant difference at 1% level between the session with tacit communication (NC) only and each session with explicit communication (C). As a result, explicit communication makes an important effect on coordination. In fact, the average number of matching is higher in sessions with treatment C (32.10 and 31.63) than in the session with treatment NC (26.20). Similarly it happens to median values, according to Wilcoxon rank-sum test there is a difference of medians that is significant at 1% level between the sessions 0 and 1 ($z = -5.157$, $p-value < 0.01$), and sessions 0 and 2 as well ($z = -5.591$, $p-value < 0.01$). Furthermore, the coefficient of variation (CV) in treatment NC (15.31%) is significantly lower than the ones observed in treatment C (18.61% and 17.21%), which means that subjects in Session 0 displayed more similar strategies than those of sessions 1 and 2. However, by comparing sessions 1 and 2 no significant differences in average and median values are found.

In conclusion, a general observation here is that it seems that subjects made a profitable use of the chat and establish payoff-enhancing strategies. Furthermore, the fact of reaching higher average payoffs when the chat is a possibility, may, at the same time, evidence that subjects maybe implemented some communication strategies in their decision making.

In the next subsections we will analyze the existence of communication in the treatment with chat. Notice that since the payoff of both players coincide, it is the strategy profile that matters and not the individual actions. We will distinguish between two levels of communication:

- *no-communication*, denoted by L_0, and
- *a positive level of communication*, denoted by L_1.

Three criteria will be used in order to analyze the existence of communication in this treatment: the 'Chat-strategy' (C), the 'Actions' (A), and the 'Theory' (T) criteria:

- The first criterium follows on from 'the strategies declared in the chat': the discrimination among strategies will be through the chat conversations during the experimental sessions. The feasible payoff intervals are constructed using the minimum and maximum payoffs obtained by the experimental subjects.
- The second criterium is based on 'the actions' actually followed by wiser and agent during the game. The feasible payoff intervals depend on the minimum and maximum payoffs obtained by the experimental subjects.
- The third criterium follows on from 'the theory': the payoff discrimination predicted by GHN. We discriminate among strategies with no communication generating a feasible payoff interval. By using the optimal strategies, we can characterize the upper bound that corresponds to strategies involving communication.

For the three criteria, the notation will be, respectively: L_0^C, L_0^A, L_0^T for the strategies that do not involve communication whatsoever, and L_1^C, L_1^A, L_1^T for the strategies that involve communication.

In order to confirm that the salient higher payoffs in the session C come for communication resources we provide robust test to declare not only the nature of the communication but also the kind of communication strategies implemented in the play phase. We close the circle by contrasting with the theoretical result that GHN provide, in particular, the important feature that the construction of equilibrium strategies suggested by the authors, it is actually by using mistakes as the codification-communication device as the mechanism to accomplish tacit communication. The following subsections state the results following the three criteria and finally it is checked that all of them offer the same discrimination.

3.5.3 The 'chat strategy' (C) criterium

Our first criterium follows on from the chat: the discrimination among strategies will be through the chat conversations during the experimental sessions. Under this criterium, the feasible payoff intervals will now depend on the minimum and maximum payoffs obtained by the experimental subjects.

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. Table 3.14 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 3.15, subjects in pair 1 agree on an L_1 strategy by stating '*Let's start with 1 and when I (the agent) see that you (the wiser) 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 (the wiser) make a mistake, I mean that my last action indicates the following numbers coming*'. Therefore, we consider that there exists an attempt to communicate information in the chat 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[14].

Table 3.5: Descriptive statistics of the communication levels under the 'chat strategy' criterium

Number of matches	Session 1				Session 2			
	Play 1		Play 2		Play 1		Play 2	
	L_0^C	L_1^C	L_0^C	L_1^C	L_0^C	L_1^C	L_0^C	L_1^C
Max.	34	37	39	44	36	42	36	41
Min.	18	28	21	28	21	33	18	30
Average	27.09	35.14	30	37.14	29.67	37.33	28.71	36.46
Median	26	37	29.50	38.50	31	37.50	30	37
St.D.	3.46	3.29	5.76	3.83	4.53	2.94	4.40	3.95
Obs.	23	7	8	22	24	6	17	13
%Obs.	77%	23%	27%	73%	80%	20%	57%	43%

As expected, in the first chat most agreed strategies are non-communication strategies. In fact, the 77% of strategies in Session 1 and the 80% of strategies in Session 2 are strategies at L_0 level. A more important fact is that pairs redefine those strategies to transmit information by communication strategies at L_1 level in the second chat. Furthermore, subjects in Session 1 make a greater effort than subjects in Session 2, increasing their percentage of communication strategies up to the 73% versus the 43% achieved by their counterparts in Session 2. As a result, the online chat actually helps communication occurs, but it eventually depends on how active subjects are on thinking of codified communication rules to be applied in the repeated game.

[14]In the appendix, tables from 3.18 to 3.21 tells us the pairs that follow the strategies declared in the chats.

3.5.4 The 'actions' (A) criterium

This criterium follows the strategies declared by the wiser and actually followed by the agent[15]. At the appendix, Tables 3.33 to 3.36 report the real actions played by the wiser and the agent of each pair. Thus, it is possible identify the wiser's signaling actions and the agent's following actions. For example, in the Table 3.33, the pair 1 implemented a L_0 strategy consisting of playing the action 1 all time. This pair improved its strategy in the second play, where it played a majority rule for unequal length block strategy. As shown in Table 3.34, the wiser made a signal at the stages 1, 26, 35, and 44 in order to transmit the agent's next action, who played that action up to a new signal.

Again the payoff intervals are constructed using, respectively, the minimum and maximum payoffs obtained by the experimental subjects in each specific Play.

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. Nevertheless, what makes the difference is the quality of the rule in the sense of how much information is transmitted through a specific rule. As already agreed at the chat stage, the wiser may, on purpose, make a mistake, this mistake will act as an informative signal for the agent. Therefore, a code is established between players, which constitutes explicit 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 your action'. Define L_1^A as the interval for communication: *the pair changes its joint action by a previous signal from the wiser player.* It is important to stress that the inter-

[15] A full description of implemented strategy can be found in tables 3.18 to 3.21.

val 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.

The findings in Session 1 of treatment C show some discrepancies[16]between the strategies agreed on during the chat and the ones actually played. As far as Session 2 of treatment C is concerned, almost 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 and we define the experimental communication intervals from the actually played strategies.

Differences between Session 1 and 2 are reported in Table 3.6. In Session 1, Play 1, 19 out of 30 pairs behaved very poorly, no information was transmitted between players in a team, therefore L_0^A strategies were implemented. The worst team of these reached a result of 18 matches, whereas the best one did 30 matches. The remaining teams were able to design a higher profitable strategies involving some transmission of information, they obtained within 37 and 28 matches[17]. Notice that in Play 2 of the this same session, 20 out of 30 subject-pairs played L_1^A strategies getting an average number of matches of 38.25. In addition, two teams played highly profitable strategies reaching a maximum of 44. Regarding 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^A increases from 7 in Play 1 to 12 in Play 2. This increase of 5 new pairs implementing communication strategies is a positive fact, and it can be interpreted as

[16]Although most pairs implemented the strategy agreed on in the chat, several subject-pairs were able to redefine it while playing the game in order to transmit information and to reach higher profits, as a result. In Play 1, four out of 30 teams played a more sophisticated strategy than the one agreed on during the chat: in particular, they agreed to an L_0^A strategy but played an L_1^A one, which involves signaling. Likewise, in Play 2, three subject-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, so that, they played a L_0 strategy. In Appendix 3, tables 3.18 to 3.21 give summaries of the strategies played in treatment C.

[17]Some teams implemented poor communication strategies and obtained a lower number of matches than that of teams played non-communication strategies. This is the case of team 12 that implemented a majority rule for 55-length block strategy. This strategy consisted of a unique signaling stage at the very beginning of Play, where the wiser played the nature's majority action over 55 stages. Team did 28 matches.

a positive consequence of chat device. Nevertheless, and surprisingly, we also realize that, in this session, pairs may have been victims of what we could call the *wealth effect*. That is, subjects got high enough payoffs in the Play 1 so that, presumably, they did not make an additional effort to improve communication strategies in the second part of the session.

Table 3.6: Descriptive statistics of the communication levels under the 'actions' criterium

Number of matches	Session 1				Session 2			
	Play 1		Play 2		Play 1		Play 2	
	L_0^A	L_1^A	L_0^A	L_1^A	L_0^A	L_1^A	L_0^A	L_1^A
Min.	18	28	21	34	21	33	18	30
Max.	30	37	39	44	36	42	36	41
Average	26	34.09	29.20	38.25	29.52	36.71	28.78	37
Median	26	35	28.50	39	31	37	30	37.50
St.D.	2.65	3.08	4.66	2.27	4.57	3.15	4.28	3.59
Obs.	19	11	10	20	23	7	18	12
%Obs.	63%	37%	33%	67%	77%	23%	60%	40%

3.5.5 The 'theory' (T) criterium

In this subsection we characterize theoretically the intervals of communication L_0^T and L_1^T in the treatment with chat (C). We use the GHN characterization to compute such intervals. Specifically, GHN's work provides a theoretical approach which allows us to define optimal coordination *block* strategies requiring explicit communication[18].

[18]Formally, the strategies are defined over n-length blocks in such a way that for any sequence of nature, the proportion of stages for which the agent's action matches the nature's action is denoted by $q = prob(k = i) \in [0, 1]$, and, conditional on this constraint, the proportion of stages for which the wiser's action matches the nature's is $p = prob(j = i|k = i) \in [0, 1]$. Then, the proportion of stages

Roughly speaking, the fact that a coordination strategy is associated to an amount of information, in turn, implies that the payoff associated to that strategy involves that same amount of information. Thus, the payoff that players are able to reach with a coordination strategy depends on the amount of information transmitted by the wiser and received by the agent. This amount of information is bounded by the called *information constraint*: the information used by the agent does not exceed the information transmitted by the wiser. This constraint is necessary but not enough for the optimality of strategies. Next subsection presents the strategies associated to an amount of shared information.

Optimal communication strategies

In GHN it is shown that the wiser may efficiently transmit online information to the agent about the play of nature. In particular, the authors obtain the optimal strategies which maximize the long-run average expected payoff. In that paper, it is studied the joint dynamic on the action triple (i, j, k) corresponding to the state of the nature, and the specification of players' strategies. The authors characterize that dynamic by a set of joint probability distributions Q, which are implementable by any pair strategy (j, k) whenever the information used by the agent does not exceed the information transmitted by the wiser. This condition leads to an information-theoretic inequality that authors call *information constraint* and it is expressed using the Shannon entropy function $H(x)$ [19] . Hence, it is provided a methodology to design communication strategies verifying the information constraint. From fulfilling the information constraint, it could be computed the maximum payoff that is implemented by the above strategies á la GHN.

for which the three players' actions match is close to $prob(i = j = k) = prob(j = i|k = i) \cdot prob(k = i) = p \cdot q$, which, in turn, is equal to the average long-run payoff.

[19] $H(x) = -xlog_2 x - (1-x)log_2(1-x)$ for $0 \leq x \leq 1$. Notice that $H(0) = H(1) = 0$, and $H(\frac{1}{2}) = 1$.

GHN's main result is twofold: on the one hand, for any strategy of the players given a fixed length n, the average distribution during the n stages fulfills the information constraint; on the other hand, for any joint distribution Q satisfying the information constraint, there exists a pair of strategies for both players such that the long-run average distribution of actions is Q.

Formally, the strategies á la GHN are defined over n-length blocks in such a way that for any sequence of nature, the proportion of stages for which the agent's action matches the nature's action is denoted by $q = prob(k = i) \in [0, 1]$, and, conditional on this constraint, the proportion of stages for which the wiser's action matches the nature's is $p = prob(j = i|k = i) \in [0, 1]$. Then, the proportion of stages for which the three players' actions match is close to $prob(i = j = k) = prob(j = i|k = i) \cdot prob(k = i) = p \cdot q$, which, in turn, is equal to the long-run average payoff. Thus, the pair (p, q) is determined by the communication strategy designed by players to fulfil the information constraint, which can be expressed as $H(p|q) \geq 1 - H(q)$, being $H(p|q)$ the amount of information that the wiser can send to the agent, and $1 - H(q)$ the maximum amount of information used by the agent[20].

Now, let us review strategy profiles 1 and 2 from the section 2. Recall the first strategy does not convey communication at all, the wiser plays nature and the agent plays $\{0, 1\}$ like flipping a coin. If the nature plays $\{0, 1\}$ in a balanced sequence $(\frac{1}{2}, \frac{1}{2})$, then the agent will match it the half of times ($q = \frac{1}{2}$), the wiser will always match the agent ($p = 1$) and the average expected payoff will be $pq = \frac{1}{2}$. This random coordination strategy verifies the information constraint: $H(1) \geq 1 - H(\frac{1}{2})$. Regarding the second strategy, tacit communication is emitted by the wiser's action played at odd stages, which allows players to match at even stages. Again, the agent and the nature will match the half of times ($q = \frac{1}{2}$) and the wiser will match the agent's action all the times ($p = 1$), being the guarantee average payoff $\frac{1}{2}$. Because there already exists the

[20]See the appendix 1 for a complete presentation of the characterization of the theoretical solution.

probability of matching $\frac{1}{4}$ at odd stages, the average expected payoff is $\frac{5}{8}$.

In conclusion, both strategies are feasible and fulfil the information constraint, but the second one is more efficient than the first one. Furthermore, the theoretical strategy that achieves an average guarantee payoff of $\frac{5}{8}$ consists of playing 8-length blocks with 3 mistakes, which implies a pair $(\frac{5}{6}, \frac{6}{8})$, it means that the wiser makes 3 mistakes for signaling the play in the next block. Nevertheless, an even more efficient strategy exists: the optimal strategy for 8-length blocks, which involves less mistakes and yields a higher payoff. It is defined by the pair $(\frac{6}{7}, \frac{7}{8})$, and it needs 2 mistakes to guarantee an average payoff of $\frac{6}{8}$.

Strategies with more than one intended mistake are very complicated to emerge in an experimental lab. Being optimist, in the treatment with chat, we would expect that players to set strategies with one mistake for the blocks of length 2 and 3, somewhat like strategy profiles 2 and 3. The strategy profile 3 is eventually well defined by the pair $(1, \frac{2}{3})$, with a guarantee average payoff of $\frac{2}{3}$. Also, it is the optimal strategy for the whole sequence implemented in our experiment[21].

In the next subsubsection, we discriminate between the targeted payoff associated to some communication level and other payoffs with no-communication.

The intervals of communication from the theoretical criterium

Let us denote L_0^T those strategies with no communication, that is to say players do not take each other into account. For this kind of strategies, we are able to identify two extreme strategies. The worst strategy consists of both wiser and agent play balanced sequences at random[22]. In such a case, the average number of nature-wiser-agent matches is $\frac{1}{4}$ times the length of the sequence, and the expected payoff is $\frac{1}{4}n$=13.75, since $n = 55$. The best of those strategies is the following: the wiser matches nature

[21]A demonstration for the finite sequence of length 55 can be found in García-Gallego et al.(2015).
[22]That is, with the same number of '0' and '1'.

and the agent plays the same action at all stages[23], either '0' or '1'. We define the interval L_0^T as $(\frac{1}{4}n, \max\{\sum_{i=1}^{55} x_i, 55 - \sum_{i=1}^{55} x_i\})$ for a specific realization of the nature $(x_1, \ldots, x_{55})$. Table 3.7 reports non-communication intervals for each experimental session and play. Notice that the lower bound of interval L_0^T is fixed at 13, but the upper bound depends on nature sequences, any coincidence is merely by chance.

Regarding communication interval L_1^T, it conveys strategic behavior, that is, players implement strategies by using some kind of signaling and attain payoffs exceeding the upper bound of the interval L_0^T. Furthermore, 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 a 3-length block strategy or majority rule strategy[24], which guarantees an average payoff of $\frac{2}{3}$ per round.

Therefore, a guarantee payoff of $\frac{2}{3}54 = 36$ can be achieved with the majority rule[25]. Moreover, nature, wiser and agent may match by chance in the signaling stages. Such situation happens when the majority action of one block coincides with the one of the next block. Thus, an upper bound exists that is computed as $\frac{2}{3}54 + \frac{1}{3}\frac{1}{4}54 = 40.5$. In conclusion, the 3-length block strategy implemented in the case of 55-length sequence involves payoffs within the optimal interval $[36, 40.5]$.[26]

According to the nature sequences played in the Treatment C - Sessions 1 and 2, the theoretical intervals of communication resulting are in the table below.

Notice that the lower bound in L_1^T is computed by adding one unit to the upper bound in L_0^T, so that it is less than the optimal theoretical value, earlier said 36. In

[23]There are many other strategies with no transmission of information such as, for instance, the one in which the wiser plays *nature* and the agent plays 111000, 110011, 101010, and so on and so forth.

[24]See page 110 for 3-length block strategy mechanism.

[25]Notice that we write $n-1 = 54$ instead of $n = 55$. It is due to the first signaling stage is considered lost.

[26]Notice that this way of codification is the key for implementing optimal strategies à la GHN. In their construction, wiser and agent create a code such that the mistakes are used as signals for future nature actions. In our analysis we compare those payoffs that are associated to a chat strategy using the Chat criterium with those of an implemented strategy by using mistakes following on the Actions criterium.

Table 3.7: Intervals of communication in ‘theory’

	Session 1				Session 2			
	L_0^T	L_1^T	L_0^T	L_1^T	L_0^T	L_1^T	L_0^T	L_1^T
Lower	13	30	13	32	13	35	13	30
Upper	29	40.5	31	40.5	34	40.5	29	40.5

L_0^T: interval with no communication.
L_1^T: interval with communication.

doing so, the theoretical interval encloses all communication strategies implemented by subjects in the experiment, whether optimal or not.

3.5.6 The ‘theory’ (T) criterium: evidence

In this subsection, experimental results are shown according to the theoretical criterium. Taking into account the relationship between payoffs and strategies provided from theory, we count the number of pairs that achieved a payoff belonging to the different theoretical intervals and construct Table 3.8. In other words, in other to classify the communication strategies implemented by pairs we only consider information on final payoffs. In fact, if the theory is robust enough, that is the only necessary information. Thus, we would expect no significant discrepancies between classifications by the ‘theory’ criterium and the ‘actions’ criterium. Next section offers a comparison of the three classification criteria.

3.5.7 Comparison of the three criteria

We have used three criteria and analyzed the communication levels for the different sessions. For the robustness of the results, we claim that there should not be significant differences among a certain level of communication and Play of different sessions under the three criteria. Thus, we look for significant differences between the ‘chat strategies’ and the ‘actions’ criteria. In fact, only few pairs are differently classified by the ‘chat

Table 3.8: Communication levels under the 'theory' criterium

Number of matches	Session 1				Session 2			
	Play 1		Play 2		Play 1		Play 2	
	L_0^T	L_1^T	L_0^T	L_1^T	L_0^T	L_1^T	L_0^T	L_1^T
Min.	18	30	21	32	21	36	18	30
Max.	28	37	31	44	34	42	28	41
Average	25.67	33.92	27.63	38	29.54	37.83	25	34.64
Median	26	34.50	28	39	31	37.50	25	34
St.D.	2.38	2.87	3.20	2.54	4.53	2.23	3.21	3.92
Obs.	18	12	8	22	24	6	8	22
%Obs.	60%	40%	27%	73%	80%	20%	27%	73%

strategy' and the 'actions' criteria. In Session 1, 4 out of 30 pairs played a different strategy to the agreed one (see tables 3.18 and 3.19). In Session 2, almost all pairs followed the agreed strategy in the chat, just 1 pairs deviated (see tables 3.20 and 3.21).

To conduct the statistical comparison between criteria, we use the two-sample Wilcoxon rank-sum test. Results reported in Tables 3.9 and 3.12 indicate that, in general, the medians are not statistically different at any conventional level. Although the 'theory' criterium mostly produces the same discrimination as the two other criteria, in Session 2 and Play 2, significant differences at 5% level are found between L_0^T and L_0^C strategies ($z = 2.119$, $p - value = 0.0341$), and between L_0^T and L_0^A strategies ($z = 2.244$, $p - value = 0.024$). The global robustness of 'theory' criterium can be measured as the percentage of coincidences with the two other criteria, that is $14/16 = 87.5\%$. According to the strategy level, the robustness in discriminating strategies at L_0 level is $7/8 = 87.5\%$, and at L_1 level is $8/8 = 100\%$.

From the above analysis we obtain the following messages. First, the Chat communication is not innocuous since the payoff discrimination taking into account the Chat fits the payoff discrimination of the theory. Second, Chat and Actions are closed related. The payoff comparison between both discrimination gets the same result.

Finally, the theory discrimination that says when a payoff is related to some communication activity is related to the use of strategies that signals by using mistakes. Notice that this way of codification is the key for implementing optimal strategies à la GHN. In their construction, wiser and agent create a code such that the mistakes are used as signals for future nature actions. 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.

Table 3.9: Comparing the three criteria in Session 1 (Wilcoxon (Mann-Whitney) rank-sum test)

Criterium	theory vs chat strategy				theory vs actions				chat strategy vs actions			
W-test	Play 1		Play 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	L_0	L_1	L_0	L_1
Z	-0.187	1.326	0.794	-0.460	0.342	0.474	0.720	0.183	0.950	0.954	0.224	-0.597
$Prob > \|z\|$	0.852	0.185	0.427	0.642	0.732	0.636	0.471	0.855	0.342	0.340	0.823	0.550

Table 3.10: Comparing the three criteria in Session 2 (Wilcoxon (Mann-Whitney) rank-sum test)

Criterium	theory vs chat strategy				theory vs actions				chat strategy vs actions			
W-test	Play 1		Play 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	L_0	L_1	L_0	L_1
Z	0.135	-0.165	2.119	1.275	0.021	-0.585	2.244	1.673	0.107	0.366	-0.017	-0.304
$Prob > \|z\|$	0.893	0.869	0.034	0.202	0.982	0.558	0.024	0.094	0.915	0.714	0.986	0.761

We can summarize the above discussion in our second result as follows:

Result 2. In treatment C, it is detected both an exchange of information during the chat and an exchange of information through the course of the game by using mistakes to signal future events. Subjects design sophisticated strategies which produce higher average payoffs in the play phase.

3.5.8 Other factors

Remember that subject-pairs in both treatments play the game twice. Furthermore, subjects played against a random nature sequence generated just before each Play. Table 3.11 shows main descriptive statistics and contrast test on the number of matches by play within each session. First, according to Kruskall-Wallis test of equality of populations it is found a highly significant difference between the 6 plays. In fact, testing for equality of medians between plays within a session by Wilcoxon signed-rank test, different medians are found within Session 0 and Session 1 , which means subject-pairs played statistically differently in each play of these sessions. Second, differences in variances between plays are not found within any session[27]. And third, testing for normality on data, it is rejected at conventional levels in Session 0, but it cannot be rejected at 5% level in sessions 1 and 2.

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, by Wilcoxon signed-rank test, there is a significant difference in medians between Plays 1 (28) and 2 (24) in treatment NC[28]in Session 0.

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), as well as in median values (28 versus 37.50), being this last difference highly significant at 1% level. Behind that improvement is the effect of the explicit communication via chat. Therefore, we may conclude that a chat effect exists in Session 1. Similarly, in Session 2 there exists an improvement in average values (31.20-32.07) and median values (32-

[27] It is also tested the hypothesis of equal variances between plays of sessions 1 and 2, concluding by Leneve's test that the null hypothesis cannot be rejected at conventional levels. According to Kolgomorov-Smirnov test for equality of distribution functions, the null hypothesis can be accepted in the case Session 2 ($D = 0.1333$, $p-value = 0.952$). Finally, the independence of populations is confirmed by Kendall's test within sessions 0 and 1, but not within Session 2 whose p-value is 0.0255, which adjusted by Bonferroni rises up to 0.3819.

[28]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 by Levene's test ($W = 0.424$, $p-value = 0.51$).

Table 3.11: 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
Min.	16	12	18	21	21	18
Max.	33	31	37	44	42	41
Average	27.83	24.57	28.97	35.23	31.20	32.07
Median	28.00	24.00	28.00	37.50	32.00	32.00
St.D.	3.39	3.96	4.83	5.38	8.24	5.69
Variation C.	12.20%	16.13%	16.68%	15.27%	16.80%	17.75%
Kruskal-Wallis equality-of-populations rank test	61.176*					
Median test	49.7643*					
Wilcoxon signed-rank test for equal medians	3.631*		−4.304*		-0.609	
Levene test for equal variances	0.4241		0.4364		0.1879	
Skewness-Kurtosis test for normality	11.99*	6.25**	0.47	4.70***	0.88	0.40
Obs.	30	30	30	30	30	30

* at 1% significance level , ** at 5% significance level , *** at 10% significance level

Table 3.12: Within and between effects on communication (a proxy)

	Session 1			Session 2		
Criterium	Chat	Actions	Theory	Chat	Actions	Theory
L_1 rate	23%	37%	40%	20%	23%	20%
Growth rate	214%	82%	83%	117%	71%	267%

32) between plays regarding Session 0's values. No significant differences are found in Session 2, which means that subjects similarly behave in Plays 1 and 2, on average.

The explanation for the 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. Nevertheless, the second chat of a session is used differently. Whereas 15 pairs of Session 1 spend the second chat time designing a more profitable strategy, only 7 pairs of Session 2 did it. According to the 'actions' criterium, 9 pairs of Session 1 and 5 pairs of Session 2 implemented an upper strategy in Play 2. In other words, in comparison with Session 1, subjects in Play 2 of Session 2 wasted their chat time, by failing to develop new significantly profitable strategies. Given the above data, it is necessary to further study in more detail the impact of chats on the behavior of individuals.

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, Table 3.12 reports the percentage of communication strategies L_1 in the Play 1 of Sessions 1 and 2 and its growth rate from Play 1 to Play 2. We interpret the first data as a proxy of between-subject effect and the second one as a proxy of within-subject or chat effect. As already mentioned, in Play 1 most pairs develop non-communication strategies, thus the rate of strategies L_1 is quite less than 50%. Conversely, after the second chat the number of strategies L_1 increases importantly. For instance, according to the 'action' criteria the growth rates are $\frac{9}{11} = 82\%$ and $\frac{5}{7} = 71\%$ in Sessions 1 and 2, respectively.

To catch the aforementioned between and within effects, we apply a one-factor repeated measures ANOVA to each session with explicit communication of our experiment.

On the one hand, we denote as *Chat* the repeated within-subject effect for Sessions 1 and 2. If significant, the within-subject effect 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.

On the other hand, the between-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.

Table 3.13 reports the F-test values and the corresponding p-values for the

ANOVA analysis. First, we find that the Chat effect in Session 1 is significant at 1% level, but the Pair effect is not significant, at all. Consequently, on average, subject-pairs in Session 1 follow similar strategies, but 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% level, is observed. Thus, on average, subject-pairs in sessions 1 and 2 develop different strategies. Notice that the Pair effect may be understood as a source of tacit communication. Furthermore, the Chat effect is interpreted as an evidence of explicit communication.

Table 3.13: One-Way Repeated Measure Analysis of Variance, by session

Model	Session 1		Session 2	
	F	$Pr > F$	F	$Pr > F$
Chat	29.36	0.0001	0.72	0.4025
Pair	1.61	0.1041	2.84	0.0032
Total Effect	2.53	0.0072	2.77	0.0037

From this analysis our third result is: **Result 3.** In treatment C it is detected a Pair or between-subject effect, as well as a Chat or within-subject effect. Therefore, these two effects imply tacit and explicit communication.

3.6 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 tacit as well as explicit communication in the lab. Tacit communication is inherent to human behavior. It is the implicit message in the wiser's actions, that the agent gives meaning depending on her own subjective understanding, or experiences in similar circumstances. Explicit 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 wiser and agent.

From the premise that communication always exists in some form, the main purpose of the chapter 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 tacit and explicit communication, our experimental design includes two treatments: a baseline in which only tacit 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 tacit communication. In the baseline, there are several subject-pairs who try to coordinate their actions. The wiser player with full information signals to her partner through her actions when she makes a mistake. The agent 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 explicit 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 tacit and explicit communication have an influence on obtaining higher payoffs. We detect a team or between-subject effect, as well as a chat or within-subject effect by using one-way analysis of variance. We associate these two effects to tacit and explicit 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.

References

Aumann, R. J. and Hart, S. (2003). Long cheap talk. *Econometrica*, pages 1619–1660.

Ben-Porath, E. (2003). Cheap talk in games with incomplete information. *Journal of Economic Theory*, 108(1):45–71.

Blume, A. and Ortmann, A. (2007). The effects of costless pre-play communication: Experimental evidence from games with pareto-ranked equilibria. *Journal of Economic theory*, 132(1):274–290.

Burton, A. and Sefton, M. (2004). Risk, pre-play communication and equilibrium. *Games and Economic Behavior*, 46(1):23–40.

Camera, G., Casari, M., and Bigoni, M. (2011). Communication, commitment, and deception in social dilemmas: experimental evidence.

Chaudhuri, A., Graziano, S., and Maitra, P. (2006). Social learning and norms in a public goods experiment with inter-generational advice. *The Review of Economic Studies*, 73(2):357–380.

Corgnet, B., Kujal, P., and Porter, D. (2010). The effect of reliability, content and timing of public announcements on asset trading behavior. *Journal of Economic Behavior & Organization*, 76(2):254–266.

Dewatripont, M. and Tirole, J. (2005). Modes of communication. *Journal of Political Economy*, 113(6):1217–1238.

Ellingsen, T. and Östling, R. (2010). When does communication improve coordination? *The American Economic Review*, 100(4):1695–1724.

Forges, F. and Koessler, F. (2005). Communication equilibria with partially verifiable types. *Journal of Mathematical Economics*, 41(7):793–811.

Fudenberg, D. and Levine, D. K. (2009). Repeated games with frequent signals-super. *The Quarterly Journal of Economics*, 124(1):233–265.

Gneezy, U. (2005). Deception: The role of consequences. *American Economic Review*, pages 384–394.

Gossner, O., Hernandez, P., and Neyman, A. (2006). Optimal use of communication resources. *Econometrica*, 74(6):1603–1636.

Heller, Y., Solan, E., and Tomala, T. (2012). Communication, correlation and cheap-talk in games with public information. *Games and Economic Behavior*, 74(1):222–234.

Renault, J. and Tomala, T. (2004). Communication equilibrium payoffs in repeated games with imperfect monitoring. *Games and Economic Behavior*, 49(2):313–344.

Schelling, T. C. (1960). The strategy of conflict. *Cambridge, Mass.*

Sutter, M. and Strassmair, C. (2009). Communication, cooperation and collusion in team tournaments—an experimental study. *Games and Economic Behavior*, 66(1):506–525.

Van Huyck, J. B., Battalio, R. C., and Beil, R. O. (1993). Asset markets as an equilibrium selection mechanism: Coordination failure, game form auctions, and tacit communication. *Games and Economic Behavior*, 5(3):485–504.

3.7 Appendix 2: 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: 'the wiser' and 'the agent'. 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.

No Chat treatment.

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.

Chat treatment. Text included in the chat treatment.
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.

To be ‘the wiser’ or ‘the agent’ has consequences:

- If you are ‘the wiser’, at the beginning of each block of 55 rounds, **and after using the chat to communicate with your partner** (only included in chat treatment), you will be aware of the sequence of values of the Prize that corresponds to that block.

- If you are ‘the agent’, you will be aware of the value of the Prize at the end of each round.

Moreover, participant ‘the agent’ knows that participant ‘the wiser’ will be aware of the values of Prize for each block just after the chat time. the wiser knows that the agent 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.

3.8 Appendix 3: Treatment C: Chat dialogs

Table 3.14: Example of L_0 (Session 1, chat 1, pair 1)

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

Table 3.15: Example of L_1 (Session 1, chat 2, pair 1)

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

Table 3.16: Session 0 - Play 1: Real actions.

Pair	Description of real actions	Matching
1	The wiser plays Nature. The agent plays Random.	27
2	The wiser plays Nature. The agent plays the wiser's last action.	29
3	The wiser plays Nature. The agent plays Random.	27
4	The wiser plays No-nature. The agent plays the wiser's signal.	31
5	The wiser plays No-nature. The agent plays a Pure strategy to 0s.	31
6	The wiser plays Nature. The agent plays Random.	28
7	The wiser plays Nature. The agent plays Random.	25
8	The wiser plays No-nature. The agent plays Random.	26
9	The wiser plays Nature. The agent plays Random.	29
10	The wiser plays Nature. The agent plays Random.	25
11	The wiser plays No-nature. The agent plays a Pure strategy to 0s.	24
12	The wiser plays Nature. The agent plays a Pure strategy to 0s.	33
13	The wiser plays Nature. The agent plays Random.	27
14	The wiser plays Nature. The agent plays a Pure strategy to 0s.	31
15	The wiser plays Nature. The agent plays Random.	28
16	The wiser plays Nature. The agent plays a Pure strategy to 0s.	30
17	The wiser plays Nature. The agent plays Random.	26
18	The wiser plays Nature. The agent plays Random.	27
19	The wiser plays Nature. The agent plays a Pure strategy to 0s.	25
20	The wiser plays Nature. The agent plays Random.	26
21	The wiser plays Nature. The agent plays Random.	31
22	The wiser plays Nature. The agent plays a Pure strategy to 0s.	32
23	The wiser plays Nature. The agent plays Random.	29
24	The wiser plays Nature. The agent plays Random.	29
25	The wiser plays Nature. The agent plays Random.	24
26	The wiser plays Nature. The agent plays Random.	26
27	The wiser plays Nature. The agent plays Random.	31
28	The wiser plays Nature. The agent plays Random.	16
29	The wiser plays Nature. The agent plays Random.	31
30	The wiser plays Nature. The agent plays a Pure strategy to 0s.	31

Table 3.17: Session 0 - Play 2: Real actions.

Pair	Description of real actions	Matching
1	The wiser plays Nature. The agent plays Random.	23
2	The wiser plays Nature. The agent plays Random.	25
3	The wiser plays Nature. The agent plays Random.	24
4	The wiser plays No-nature. The agent plays the wiser's signal.	31
5	The wiser plays No-nature. The agent plays Random.	23
6	The wiser plays Nature. The agent plays Random.	30
7	The wiser plays Nature. The agent plays Random.	23
8	The wiser plays No-nature. The agent plays Random.	24
9	The wiser plays Nature. The agent plays Random.	24
10	The wiser plays Nature. The agent plays Random.	22
11	The wiser plays No-nature. The agent plays a Pure strategy to 0s.	20
12	The wiser plays Nature. The agent plays a Pure strategy to 0s and 1s.	20
13	The wiser plays Nature. The agent plays Random.	24
14	The wiser plays Nature. The agent plays a Pure strategy to 0s.	23
15	The wiser plays No-nature. The agent plays Random.	25
16	The wiser plays Nature. The agent plays a Pure strategy to 0s.	30
17	The wiser plays Nature. The agent plays Random.	22
18	The wiser plays No-nature. The agent plays Random.	27
19	The wiser plays Nature. The agent plays a Pure strategy to 0s.	28
20	The wiser plays Nature. The agent plays Random.	27
21	The wiser plays No-nature. The agent plays Random.	22
22*	The wiser plays Nature. The agent plays a Pure strategy to 1s.	30
23	The wiser plays Nature. The agent plays Random.	25
24	The wiser plays Nature. The agent plays Random.	30
25	The wiser plays Nature. The agent plays a Pure strategy to 1s.	27
26	The wiser plays Nature. The agent plays a Pure strategy to 1s.	30
27	The wiser plays Nature. The agent plays the wiser's last action.	19
28	The wiser plays Nature. The agent plays Random.	12
29	The wiser plays Nature. The agent plays Random.	22
30	The wiser plays Nature. The agent plays Random.	22

(*) The wiser plays a Pure strategy to 1s.

Table 3.18: Session 1 - Play 1: Agreed strategies and real actions.

Pair	Chat	Commun. Level	Description of real actions
1	L_0	L_0	Pure strategy to 1s.
2	L_1	L_1	Majority rule for unequal length blocks.
3	L_0	L_0	Pure strategy: 25 to 0s and 30 to 1s.
4	L_0	L_0	Pure strategy to 1s.
5	L_0	L_0	Pure strategy to 1s.
6	L_0	L_1	Majority rule for unequal length blocks.
7	L_0	L_0	The wiser match nature, the agent plays randomly.
8	L_0	L_0	The wiser match nature, the agent plays randomly.
9	L_0	L_0	Pure strategy to 1s.
10	L_1	L_1	Majority rule for unequal length blocks.
11	L_0	L_0	First 25 are 1s, next 30 are 0s.
12	L_1	L_1	Majority of 55-length blocks.
13	L_1	L_1	Majority rule for unequal length blocks.
14	L_1	L_1	0 by default, majority rule 1 for 4-length blocks.
15	L_1	L_1	Majority rule for unequal length blocks.
16	L_0	L_1	Majority rule for unequal length blocks.
17	L_0	L_0	The wiser match nature, the agent plays randomly.
18	L_0	L_0	A pure strategy of 1s.
19	L_1	L_1	2-length blocks.
20	L_0	L_0	A pure strategy: 10 . . . 10.
21	L_0	L_0	A pure strategy: 0000011111 . . . 0000011111.
22	L_0	L_0	A pure strategy of 1s.
23	L_0	L_0	A pure strategy: 1100 . . . 0011.
24	L_0	L_1	Majority rule for unequal length blocks.
25	L_0	L_0	At random.
26	L_0	L_0	A pure strategy of 1s.
27	L_0	L_1	Majority rule for unequal length blocks.
28	L_0	L_0	A pure strategy: 000111 . . . 000111.
29	L_0	L_0	The wiser match nature, the agent plays 1s.
30	L_0	L_0	A pure strategy: 1111100000 . . . 1111100000.

Table 3.19: Session 1 - Play 2: Agreed strategies and real actions.

Pair	Chat	Commun. Level	Description of real actions
1	L_1	L_1	Majority rule for unequal length blocks.
2	L_1	L_1	Majority rule for unequal length blocks.
3	L_0	L_0	A pure strategy: 000111...000111
4	L_1	L_1	Majority rule for unequal length blocks.
5	L_1	L_1	Majority rule for unequal length blocks.
6	L_1	L_1	Majority rule for unequal length blocks.
7	L_0	L_0	The wiser always matches nature, the agent plays randomly.
8	L_1	L_1	Majority rule for unequal length blocks.
9	L_0	L_0	A pure strategy to 1s.
10	L_1	L_1	Majority rule for unequal length blocks.
11	L_0	L_1	Majority rule for unequal length blocks.
12	L_1	L_1	Majority rule for unequal length blocks.
13	L_1	L_1	Majority rule for unequal length blocks.
14	L_1	L_1	Majority rule for unequal length blocks.
15	L_1	L_1	Majority rule for unequal length blocks.
16	L_1	L_1	Majority rule for unequal length blocks.
17	L_1	L_1	Majority rule for unequal length blocks.
18	L_1	L_1	Majority rule for unequal length blocks.
19	L_1	L_1	Majority rule for unequal length blocks.
20	L_0	L_0	A pure strategy: 1100...1100.
21	L_0	L_0	A pure strategy: 1111100000...1111100000.
22	L_1	L_1	Majority rule for unequal length blocks.
23	L_1	L_0	A pure strategy to 1s.
24	L_1	L_1	Majority rule for unequal length blocks.
25	L_1	L_1	Majority rule for unequal length blocks.
26	L_1	L_0	They do not coordinate well.
27	L_1	L_1	Majority rule for unequal length blocks.
28	L_0	L_0	A pure strategy: 000111...000111.
29	L_1	L_0	The wiser matches nature, the agent always plays 1.
30	L_0	L_0	A pure strategy: 1111100000...1111100000.

Table 3.20: Session 2 - Play 1: Agreed strategies and real actions coincide.

Pair	Commun. Level	Description of real actions
1	L_0	The wiser matches nature, the agent plays randomly.
2	L_0	A pure strategy of 0s.
3	L_0	A pure strategy to 1s.
4	L_0	A pure strategy: 0000011111. . . 0000011111.
5	L_0	The wiser matches nature, the agent plays randomly.
6	L_1	Majority rule for unequal length blocks.
7	L_0	The wiser matches nature, the agent plays randomly.
8	L_0	A pure strategy: 1010. . . 1010.
9	L_0	A pure strategy of 1s.
10	L_0	The wiser matches nature, the agent plays randomly.
11	L_0	The wiser matches nature, the agent plays randomly.
12	L_1	2-length block strategy.
13	L_0	The wiser matches nature, the agent plays randomly.
14	L_1	1 by default, majority rule 0 for 2-length blocks.
15	L_0	The wiser matches nature, the agent plays randomly.
16	L_0	The wiser matches nature, the agent plays randomly.
17	L_0	The wiser matches nature, the agent makes a pure 1100. . . 1100.
18	L_1^*	Majority rule strategy for unequal length blocks.
19	L_0	A pure strategy: 0011. . . 0011.
20	L_1	0 by default, majority rule 1 for 3-length blocks.
21	L_0	The wiser matches nature, the agent plays 0.
22	L_0	A pure strategy of 1s.
23	L_1	2-length block strategy.
24	L_0	A pure strategy: 1010. . . 1010.
25	L_0	The wiser matches nature, the agent plays randomly.
26	L_0	The wiser matches nature, the agent plays a fixed number.
27	L_0	A pure strategy of 1s.
28	L_0	A pure strategy of 1s.
29	L_1	2-length blocks strategy.
30	L_0	the wiser matches nature, the agent plays 1.

(*) The strategy defined in the chat was level 0.

Table 3.21: Session 2 - Play 2: Agreed strategies and real actions coincide.

Pair	Commun. level	Description of real actions
1	L_0	The wiser matches nature, the agent plays randomly.
2	L_0	A pure strategy: 0000011111. . . 0000011111.
3	L_1	Majority rule for unequal length blocks.
4	L_0	A pure strategy: 1111100000. . . 1111100000.
5	L_0	The wiser matches nature, the agent plays randomly.
6	L_1	Majority rule for unequal length blocks.
7	L_0	The wiser matches nature, the agent plays randomly.
8	L_0	A pure strategy: 1010. . . 1010.
9	L_0	A pure strategy of 1s.
10	L_0	The wiser matches nature, the agent plays randomly.
11	L_0	The wiser matches nature, the agent plays randomly.
12	L_1	Majority rule for unequal length blocks.
13	L_0	The wiser matches nature, the agent plays randomly.
14	L_1	1 by default, majority rule 0 for 2-length blocks.
15	L_0	The wiser matches nature, the agent plays randomly.
16	L_0	The wiser matches nature, the agent plays randomly.
17	L_0	The wiser matches nature, the agent makes 11. . . 11.
18	L_1	Majority for unequal length block.
19	L_1	0011 by default, the wiser makes a mistake in the sequence 0011 to indicate next majority action.
20	L_1	0 by default, majority rule 1 for 3-length blocks.
21	L_1	Majority rule for unequal length blocks.
22	L_1	Majority rule for unequal length blocks.
23	L_1	Majority rule for unequal length blocks.
24	L_0	A pure strategy: 01. . . 01.
25	L_0	The wiser matches nature, the agent plays randomly.
26	L_0	The wiser matches nature, the agent plays 0.
27	L_0	A pure strategy of 1s.
28	L_1	Majority rule for unequal length blocks.
29	L_1	2-length blocks, one mistake to signal.
30	L_0	The wiser matches nature, the agent plays 1.

Table 3.22: Example of random and no-nature strategies in treatment NC, play 2

Nature	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
wiser	1	1	**1**	1	**1**	1	1	1	0	**0**	0	**0**	0	0	0	**0**	0	0	0	0	**0**	0	**0**	0	**0**	0	0	1	1	1	1	1	**1**	1	1	1	1	1	1	1	**1**	1	**1**	1	1	1	1	**1**	1	0	1	1	0	0	0
agent	0	0	1	0	1	1	0	0	0	1	1	1	1	1	0	0	1	1	0	0	0	1	0	0	1	0	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0	0	1	1	1	1	0
Matching	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	1	0	0	0	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	1	1	0	0	1	1	1	0	0	1
Total matches	23																																																						
Nature	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
wiser	1	1	**1**	1	**1**	1	1	1	0	**0**	0	**0**	0	0	0	**0**	0	0	0	0	**0**	0	**0**	0	**0**	0	0	1	1	1	1	1	**1**	1	1	1	1	1	1	1	**1**	1	**1**	1	1	1	1	0	1	0	1	1	0	0	0
agent	1	0	1	0	1	1	0	0	1	0	1	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	1	0	1	0	0	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	0	1	1	1	1	0
Matching	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	1	1	0	1	0	1	0	1	0	1	0	0	1	0	01	0	0	1	1	1	1	1	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	1	
Total matches	24																																																						
Nature	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
wiser	1	1	**1**	1	**1**	1	1	1	0	1	0	1	0	0	0	**0**	0	0	0	0	1	0	1	0	**0**	0	0	1	1	1	1	1	**1**	1	1	1	1	1	1	1	**1**	1	**1**	1	1	1	1	0	**0**	0	**0**	0	0	0	0
agent	1	1	1	0	1	0	1	1	0	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	0
Matching	1	1	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	0	0	1	0	1	0	1	0	1	0	1	1	0	0	0	0	0	1	1	1	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1
Total matches	25																																																						
Nature	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
wiser	1	1	0	1	**1**	1	1	1	0	**0**	0	1	0	0	0	**0**	0	0	0	0	1	0	1	0	1	0	**1**	1	1	1	1	1	**1**	1	1	1	1	1	1	1	**1**	1	**1**	1	1	1	1	0	**0**	0	**0**	**0**	0	0	0
agent	0	1	1	0	1	1	1	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	1	1	1	0	0	1	1	1	0	1	1	1	1	0	1	1	0	1	0	1	1	1	1	0	0	0	0	0	0
Matching	0	1	0	0	0	1	1	0	0	0	1	0	1	0	1	0	1	0	1	1	0	1	0	0	1	1	0	1	1	0	0	1	0	1	0	1	1	1	1	0	0	1	0	1	0	1	1	0	0	1	0	0	1	1	1
Total matches	28																																																						
Nature	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
wiser	1	1	**1**	1	**1**	1	1	1	**1**	1	**1**	1	0	0	0	**0**	0	0	0	0	**0**	0	**0**	0	**0**	0	0	1	1	1	1	1	**1**	1	1	1	1	1	1	1	**1**	1	**1**	1	1	1	1	**1**	1	**1**	1	1	0	0	0
agent	0	0	1	0	1	0	0	1	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	0	0	1	0	1	1	1	1	1	1	0	1	1	0	1	1	0
Matching	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	1	0	1	0	1	0	1	1	0	0	1	1	0	0	0	1	1	1	1	0	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	1
Total matches	22																																																						

Table 3.23: Example of pure and nature strategies in treatment NC, play 1

Nature	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
agent	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matching	0	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	1	1	0	0	1	1	0	1	1	1	1	0	1	1	0	0	0	1	1	0	1	0	1	1	1	0	1	1	1	0	0	0	1	1	0	0	0	1
Total matches	31																																																						

Table 3.24: Example of pure and no-nature strategies in treatment NC, play 2

Nature	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
wiser	1	1	**1**	1	**1**	1	1	1	0	**0**	0	**0**	0	0	0	**0**	0	0	0	0	**0**	0	**0**	0	**0**	0	0	1	1	1	1	1	**1**	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	**0**	0	**0**	0	0	0	0
agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matching	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	1	1	1	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0	1	1	1
Total matches	20																																																						

Table 3.25: Example of other and no-nature strategies in treatment NC

Play 1																																																						
Nature	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
wiser	0	0	0	0	0	0	1	1	**0**	0	1	1	**1**	1	1	0	0	0	0	1	**0**	0	0	**0**	0	0	0	0	**0**	0	0	1	1	**0**	0	0	**0**	0	**0**	0	0	0	**0**	0	0	0	1	1	1	0	0	1	1	1	0
agent	1	1	1	0	0	0	0	0	1	0	0	1	0	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0
Matching	0	0	0	1	1	1	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0	1	1	0	1	1	1	1	0	1	1	0	0	0	1	1	0	1	0	1	1	1	0	1	1	1	0	1	1	0	1	0	1	0	1
Total matches	31																																																						
Play 2																																																							
Nature	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
wiser	1	1	0	1	**1**	1	1	1	0	1	0	**0**	0	0	0	**0**	0	0	0	0	1	0	1	0	1	0	**1**	1	1	1	1	1	**1**	1	1	1	1	1	1	1	**1**	1	**1**	1	1	1	1	0	1	0	1	1	0	0	0
agent	0	1	1	0	1	1	1	1	0	0	1	0	0	0	0	1	0	0	1	0	1	1	0	1	0	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matching	0	1	0	0	0	1	1	1	1	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	0	1	1	1	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
Total matches	31																																																						

Table 3.26: Naive Strategies in Session 1

Play 1																																																						
Nature	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
One-Pure Strategy																																																						
wiser	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matching	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
Total matches	26																																																						
Zero-Pure Strategy																																																							
agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matching	1	0	1	0	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	0	1	0	1	1	1	0	1	1	0	1	0	0	0	0	1	1	0
Total matches	29																																																						
Play 2																																																							
Nature	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
One-Pure Strategy																																																							
wiser	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Matching	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
Total matches	31																																																						
Zero-Pure Strategy																																																							
agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matching	1	0	0	1	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	1	1	0	0	0	0	1	1	0	1	0	1	1	1	1	0	1	1
Total matches	24																																																						

Table 3.27: 3-length block strategies in Session 1

Play 1																																																							
Nature	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
wiser	1	1	1	1	1	1	0	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0
agent		1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0
Matching		1	0	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	0
Total matches	41																																																						
Play 2																																																							
Nature	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
wiser	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
agent		1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Matching		1	1	0	1	0	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	0	0	0	1	0	1	1	0	1	1	0	1	1	0	1	0	1	1	1	1	0	1	1
Total matches	38																																																						

Table 3.28: 3-length block Strategies in Session 2

Play 1																																																							
Nature	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
wiser	0	1	0	0	1	1	0	0	0	0	1	0	0	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1
agent		0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1
Matching		0	1	1	1	1	0	1	1	0	0	1	1	1	1	0	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1	1	1	0	0	1	1
Total matches	38																																																						
Play 2																																																							
Nature	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
wiser	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1
agent		0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
Matching		1	0	1	0	1	1	0	1	1	1	1	1	0	0	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	1	1	0	1	1	0
Total matches	39																																																						

Table 3.29: Map of wisers' mistakes in Session 0, play 1

Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	mistakes
1																																																								0
2																																																								0
3																																																								0
4									X				X								X			X					X					X			X		X				X													9
5										X			X							X	X			X					X								X		X				X													9
6																																																								0
7																																																								0
8										X			X											X													X		X				X													6
9																																																								0
10																																																								0
11															X						X			X					X		X			X			X		X				X			X				X	X					12
12																																	X																							1
13																																																								0
14																																																								0
15										X														X													X		X				X													5
16																																																								0
17																																																								0
18													X																										X				X													3
19		X				X	X	X	X																																															5
20																																																								0
21																								X					X										X				X													4
22												X												X					X																			X	X			X	X			7
23	X				X																																																			2
24																																																								0
25																																																								0
26																																																								0
27																																																								0
28		X	X	X	X			X			X						X	X				X				X												X		X					X						X		X			15
29											X																																													1
30																																																								0
mistakes	1	2	1	1	2	1	1	2	2	3	2	1	4	0	1	0	1	1	0	1	3	1	0	7	0	1	0	0	5	0	1	0	1	2	0	0	5	1	7	1	0	0	7	0	1	1	0	1	1	1	2	1	2	0	0	

Table 3.30: Map of wisers' mistakes in Session 0, play 2

Pair	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	mistakes
1																																																								0
2																																																								0
3																																																								0
4					X							X				X											X						X								X		X													7
5			X		X					X		X				X					X		X		X								X								X		X					X								12
6																																																								0
7																																																								0
8			X		X					X		X				X					X		X		X								X								X		X													11
9									X							X											X																X													4
10																																																								0
11			X		X					X		X				X					X		X		X								X																X		X	X				12
12																																																								0
13																																																								0
14																																								X																1
15			X		X											X									X								X								X		X						X		X	X				10
16																																																								0
17																																																								0
18					X					X						X											X						X								X		X						X		X	X				10
19												X				X							X		X																															4
20																																																								0
21			X		X				X		X					X					X		X		X								X								X		X					X		X						13
22										X							X	X	X	X		X		X		X	X						X								X		X					X		X						14
23																																																								0
24																																																								0
25																																																								0
26																																																								0
27																									X																X		X					X								4
28					X									X					X		X			X		X		X		X						X		X			X	X			X	X	X						X			16
29																																																								0
30																																																								0
mistakes	0	0	5	0	8	0	0	0	2	5	1	5	0	1	0	9	1	1	2	1	5	1	5	2	7	2	4	1	0	1	0	0	8	0	0	1	0	1	0	1	9	1	9	0	1	1	1	4	3	2	3	3	1	0	0	

Table 3.31: Real actions played in Session 0, play 1

Pair	Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
	nature	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
1	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
1	agent	1	0	1	0	0	0	0	0	1	1	0	0	1	1	0	1	1	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	1	0
2	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
2	agent	1	0	0	1	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1
3	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
3	agent	1	1	1	0	1	1	0	0	1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	0	0	0	0	1	0	1	0	0	1	1	0	0	1	0	1	0	0	1	0	1	0	1	1	1	1	0	1	1	1	1	1
4	wiser	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0
4	agent	1	1	1	0	0	0	0	0	1	0	0	1	0	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0
5	wiser	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0
5	agent	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
6	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
6	agent	1	1	1	1	0	0	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	0	0	1	1	0	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0
7	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
7	agent	1	1	1	1	1	0	0	1	1	1	0	1	1	0	1	0	1	1	0	0	1	0	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1	1	0	1	0	0	1	1	1	1	1	1	0	0	1	0	1	1	0
8	wiser	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0
8	agent	1	0	1	0	0	0	0	1	1	1	0	1	1	0	1	0	1	1	0	0	1	1	0	1	1	1	1	0	1	1	0	0	0	1	1	0	0	0	0	1	1	0	1	0	0	0	1	0	1	1	0	0	1	0	1
9	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
9	agent	0	0	1	1	1	0	0	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	1	1	0	1	0	1	0	0	1	0	1	1	0	1	0	0	0	0	0	1	0	1	0	0
10	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
10	agent	0	0	1	1	1	1	0	1	1	1	0	0	0	0	1	1	0	1	1	1	1	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0
11	agent	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
12	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	0	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
12	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
13	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
13	agent	1	0	0	0	0	0	0	1	1	1	0	0	1	0	1	1	1	1	0	0	1	1	0	0	1	0	1	0	0	1	0	0	1	1	1	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0
14	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
14	agent	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	wiser	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0
15	agent	0	0	0	0	1	0	0	0	1	1	0	1	1	1	0	0	1	1	1	1	1	1	0	1	1	0	0	0	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
16	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
16	agent	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
17	agent	1	1	0	0	0	1	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0
18	wiser	0	0	0	0	0	0	1	1	1	0	1	1	1	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0
18	agent	0	0	1	0	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	1	0	0	1	1	1	1	1	0	1	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0
19	wiser	0	1	0	0	0	1	0	0	0	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
19	agent	0	0	0	1	1	1	0	0	1	1	0	0	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
20	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
20	agent	0	0	1	1	0	0	0	1	1	1	0	1	0	1	1	0	1	0	0	0	1	1	1	1	1	1	1	1	0	1	0	0	1	0	1	1	0	1	0	1	1	0	0	1	0	0	1	0	1	0	0	0	1	0	0
21	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0
21	agent	0	1	0	1	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1
22	wiser	0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0
22	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	wiser	1	0	0	0	1	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
23	agent	0	1	1	1	0	0	0	1	1	0	1	0	0	1	0	1	0	0	0	0	1	1	1	0	0	1	1	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	1	0
24	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
24	agent	1	0	1	1	0	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1
25	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
25	agent	1	0	1	0	0	0	0	1	1	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
26	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
26	agent	1	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1
27	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
27	agent	1	1	0	0	0	1	1	1	0	0	1	0	1	0	1	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	0	0	1	1	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1
28	wiser	0	1	1	1	1	0	1	0	1	0	0	1	0	1	1	0	1	1	0	1	1	1	0	1	0	1	0	0	1	0	0	1	1	1	0	0	1	1	1	1	0	0	1	0	1	0	1	1	1	0	1	1	0	1	0
28	agent	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	1	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0
29	wiser	0	0	0	0	0	0	1	1	1	0	0	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
29	agent	1	0	1	1	0	0	0	1	1	1	0	0	0	0	1	1	0	1	0	1	1	1	0	1	1	0	1	0	1	1	0	1	1	1	1	0	1	1	0	1	0	1	0	1	1	0	1	1	1	1	0	1	1	1	1
30	wiser	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0
30	agent	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0

Table 3.32: Real actions played in Session 0, play 2

Pair	Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
	nature	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
1	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
1	agent	0	1	1	0	0	0	1	0	0	1	1	0	0	1	0	1	1	0	1	0	0	1	0	0	0	0	1	0	0	1	0	1	1	0	1	1	0	1	1	0	1	0	1	1	0	0	1	1	0	1	1	0	0	1	0
2	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
2	agent	1	1	1	0	1	0	1	1	1	0	1	1	1	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	1	1	1	1	0	0	1	0	1	0	0	1	1	1	0	1	1	1	1	1	0
3	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
3	agent	0	1	1	1	1	0	1	0	1	0	1	0	0	1	0	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1	0	0	0	1	1	0	0	1	0	1	1	1	0	1	0	0	1	1	0	0
4	wiser	1	1	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0
4	agent	0	1	1	0	1	1	1	1	0	0	1	0	0	0	0	1	0	0	1	0	1	1	0	1	0	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	wiser	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0
5	agent	0	0	1	0	1	1	0	0	0	1	1	1	1	1	0	0	1	1	0	0	0	1	0	0	1	0	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0	0	1	1	1	1	0
6	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
6	agent	1	1	1	0	0	0	1	1	0	0	1	1	0	0	1	1	1	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	1	0	0	0	0	1	1	0
7	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
7	agent	0	1	1	0	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	0	1	0	1	1	1	1	1	1	0	1	0	0	0	0	0	1	0	1	0	0	0	1	1	0	1	1	1	1	1	1
8	wiser	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	0	0
8	agent	1	0	1	0	1	1	0	0	1	0	1	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	1	0	1	0	0	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	0	1	1	1	1	0
9	wiser	1	1	0	1	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	0	1	1	0	0	0
9	agent	1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	1	0	1	1	0
10	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
10	agent	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	0	1	1	0	0	1	1	1	0	0	1	0	1	1	1	1	1	1
11	wiser	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0
11	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
12	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
13	agent	0	1	1	0	1	0	1	0	0	0	0	0	1	1	0	0	1	0	0	0	1	1	1	1	0	1	1	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	0
14	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
14	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	wiser	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
15	agent	1	1	1	0	1	0	1	1	0	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	0
16	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
16	agent	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
17	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
17	agent	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	1	0	1	1	1	1	0	0	0	1	0	1	0	0	1	1	0	1	0	0	0	1	0	1	1	1	0	0	0	1	1	0	1	0	0	1	1
18	wiser	1	1	0	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
18	agent	0	1	1	0	1	1	1	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	1	1	1	0	0	1	1	1	0	1	1	1	1	0	1	1	0	1	0	1	1	1	1	0	0	0	0	0	0
19	wiser	1	1	0	1	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
19	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
20	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
20	agent	1	1	1	0	1	0	0	0	0	0	0	1	1	0	0	1	0	1	0	1	1	1	1	0	1	0	1	1	1	0	0	0	1	0	0	0	1	1	0	0	1	0	1	1	1	1	0	0	1	1	1	1	1	1	0
21	wiser	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
21	agent	0	0	1	0	1	0	0	1	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	0	0	1	0	1	1	1	1	1	1	0	1	1	0	1	1	0
22	wiser	1	1	0	1	0	1	1	1	0	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
22	agent	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
23	agent	0	1	1	0	0	0	0	0	1	1	1	0	1	0	0	1	0	1	1	0	0	1	1	1	1	0	1	1	0	0	0	1	0	0	0	1	1	1	1	0	0	0	1	0	0	1	1	1	0	1	1	1	1	0	0
24	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
24	agent	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
25	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
25	agent	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
26	agent	1	1	1	0	1	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1
27	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0
27	agent	1	1	1	0	1	0	1	1	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	0	1	1	0	0
28	wiser	1	1	0	1	1	1	1	1	0	1	0	1	0	1	0	1	0	0	1	0	0	0	1	1	1	1	0	0	1	0	1	1	0	1	1	0	1	0	1	1	1	0	0	1	0	0	0	0	1	0	1	1	1	0	0
28	agent	0	1	0	0	0	0	1	1	0	0	0	0	1	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1	1	1	1	1	1	0	1
29	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
29	agent	1	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	1	1	1	0	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
30	wiser	1	1	0	1	0	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1	0	0	0
30	agent	0	0	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	1	0	1	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	1	1	0	0	0	1	1	0

Table 3.33: Real actions played in Session 1, play 1

Pair	Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
	nature	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
1	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	wiser	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
2	agent	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1
3	wiser	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
6	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1
7	wiser	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
7	agent	1	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0	1	1	1	1	0	1	1	1	0	0	0	1	0	0	0	1	1	0	0	0	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0
8	wiser	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
8	agent	0	0	0	1	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	0	0	1	1	0	0	0	0	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	0	0	1
9	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
9	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
10	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
11	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	wiser	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	agent	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	wiser	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
13	agent	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
14	wiser	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0
14	agent	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0
15	wiser	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
15	agent	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
16	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
16	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1
17	wiser	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
17	agent	0	1	1	1	0	1	0	0	0	1	1	0	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	0	0	1	0	1	0	1	0	1	0	0	0	0	1	0	1	1	1	1	0	1	0	1	1	0	1
18	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	wiser	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1
19	agent	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
20	wiser	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
20	agent	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
21	wiser	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
21	agent	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
22	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	wiser	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1
23	agent	0	0	0	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1
24	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
24	agent	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
25	wiser	1	1	0	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	1
25	agent	1	1	1	1	1	0	0	1	1	1	1	0	1	1	1	0	1	0	0	0	1	1	1	0	1	1	1	0	0	0	0	0	1	1	1	0	0	1	1	0	1	1	1	0	1	0	0	1	1	1	1	0	1	1	0
26	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1
27	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
28	wiser	0	0	0	1	1	1	0	0	0	0	1	1	0	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
28	agent	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0
29	wiser	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	1
29	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	wiser	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
30	agent	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0

Table 3.34: Real actions played in Session 1, play 2

Pair	Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
	nature	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
1	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
2	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
3	wiser	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0
3	agent	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0
4	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
4	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
5	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
5	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
6	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
6	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
7	wiser	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
7	agent	0	0	0	1	0	1	1	1	1	1	1	0	0	1	0	1	1	0	1	0	0	1	1	1	1	0	1	1	1	0	1	0	0	1	1	0	0	0	1	0	0	1	1	1	0	0	1	1	0	1	1	1	0	1	0
8	wiser	0	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0
8	agent	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	0	0	1	1	0	0	1	1	1	1	1	0	0	0	1	0	0	0	1	0	1	1	1	1	0	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
9	wiser	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
9	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	0	1	0	0	0	1	1	0	1
10	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
10	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
11	wiser	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
11	agent	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
12	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
12	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
13	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
13	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
14	wiser	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
14	agent	1	1	1	1	0	0	0	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
15	wiser	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
15	agent	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
16	wiser	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	0	0	0
16	agent	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1	1
17	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
17	agent	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
18	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	0	0
18	agent	0	1	1	0	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	1	1	1	1	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0
19	wiser	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
19	agent	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
20	wiser	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	0	1	1	0
20	agent	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
21	wiser	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
21	agent	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
22	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
22	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
23	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
24	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
25	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
25	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	0
26	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0
26	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1
27	wiser	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
27	agent	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
28	wiser	0	0	0	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1	0	0	0	1	1	1	1	0	0	0	0	1	0	1	1	1	0	1	1	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	0
28	agent	0	0	0	0	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	1	1	0	0	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1	1	1
29	wiser	0	1	1	0	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	0	0	1	1	1	0
29	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1
30	wiser	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1
30	agent	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1

Table 3.35: Real actions played in Session 2, play 1

Pair	Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
	nature	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
1	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
1	agent	0	0	0	1	1	0	1	0	0	0	0	1	0	1	1	1	0	0	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	1	0	1	0	0	1	1	0	0	0	0	1
2	wiser	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	wiser	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0
4	agent	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
5	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
5	agent	0	0	0	1	1	1	0	0	0	1	0	0	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	0	1	1	1	1	1	0	0	1	1	1	0	0	0	1	1
6	wiser	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1
6	agent	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1
7	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	0	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
7	agent	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	0	1	1	1	0	1	0	1	1	0	0	0	0	1
8	wiser	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
8	agent	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
9	wiser	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
10	agent	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	0	0	1	0	0	1	1	0	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1
11	wiser	0	1	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
11	agent	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	1	1	1	1	1	1	1	0	0	1	0	1	0	1	1	1	0	1	1	1	1	1	1	0	0	1
12	wiser	1	1	0	0	1	1	0	0	0	1	1	0	0	1	1	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1	0	0	1	1
12	agent	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	1
13	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
13	agent	0	1	0	1	1	1	0	0	0	0	1	0	0	1	1	0	0	1	1	0	1	1	0	0	0	1	1	0	0	1	0	1	1	1	1	1	1	0	0	0	1	0	1	1	0	1	0	1	1	1	0	1	0	0	1
14	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	0	0	1	1	1	1	1	0	0	1	1
14	agent	1	1	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1
15	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
15	agent	1	1	0	1	1	0	0	0	0	1	0	0	1	1	1	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	1	1	0	0	0	1	1	1	0	0	1	0	1	1
16	wiser	1	1	0	0	1	1	0	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
16	agent	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	0	0	1	1	0	0	0	1	0	0	0	0	1	1	1	1	1	0	1	1	1	0	1	0	1	1	0	0	1	1	1	0	1	0	0	1
17	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
17	agent	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
18	wiser	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	wiser	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
19	agent	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	1	1	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
20	wiser	1	1	0	0	1	1	1	0	1	1	1	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1
20	agent	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	1	1	0	1	1	0	0	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	1
21	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
21	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	wiser	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	0	0	1	1	1	1	1	0	0	1	1
23	agent	1	1	1	0	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1	0	1	1	0	1	0	1	0	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1
24	wiser	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
24	agent	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
25	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
25	agent	0	0	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	1	1	0	0	0	1	1	1	1	1	1	0	0	1	0	1	0	0	0	1	1	0	1	1	1	0	1	0	0	0
26	wiser	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
26	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	wiser	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1
27	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	wiser	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1
28	agent	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1
29	wiser	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1
29	agent	1	1	0	0	0	1	0	0	0	1	1	0	0	1	1	0	0	1	1	0	1	1	0	0	0	1	1	1	0	1	0	1	1	1	1	0	0	1	0	0	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1
30	wiser	1	1	1	0	1	1	1	0	0	1	1	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1
30	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3.36: Real actions played in Session 2, play 2

Pair	Player	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
	nature	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	
1	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
1	agent	1	0	1	1	1	0	1	1	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	0	1	1	1	0	1	0	0	1	1	1	1	0
2	wiser	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	1
2	agent	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
3	wiser	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
3	agent	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
4	wiser	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	1
4	agent	1	1	1	1	0	0	0	0	1	1	1	1	0	0	1	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0
5	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
5	agent	1	1	1	1	0	1	1	1	0	0	1	1	1	0	1	0	0	1	1	0	0	1	1	0	0	0	1	1	0	0	0	1	1	0	1	0	0	1	1	0	0	1	0	1	1	1	0	0	0	1	1	0	1	0	0
6	wiser	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1
6	agent	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1
7	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
7	agent	0	0	0	1	0	0	1	1	0	0	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0
8	wiser	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
8	agent	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
9	wiser	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	agent	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
10	agent	0	1	0	1	0	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	0	1	1	1	0	0	0	0	0	1	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	1	0	0	1	1	1	0	0
11	wiser	1	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
11	agent	0	0	0	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0
12	wiser	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1
12	agent	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
13	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
13	agent	0	0	0	1	0	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1	0	0	1	1	1	0	0	0	1	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1	1	0	1
14	wiser	0	0	1	0	0	1	1	1	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0	1
14	agent	1	0	1	1	0	1	1	1	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1
15	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
15	agent	0	0	1	1	1	1	1	0	1	0	1	1	0	1	1	1	0	1	1	0	0	1	1	1	0	0	1	1	0	1	1	1	1	0	0	0	1	1	0	0	1	0	0	1	0	0	1	0	1	1	0	1	1	1	1
16	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
16	agent	1	0	0	1	0	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	1	0	0
17	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
17	agent	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
18	wiser	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0
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19	wiser	0	0	1	1	0	0	1	1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1
19	agent	0	0	1	1	0	0	1	1	0	0	1	0	0	0	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0	0	1	1	0	1	1	1	1	0	1	1	1	1	0	1	0	0	0	1	1	1
20	wiser	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
20	agent	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
21	wiser	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	0	1	1	0	0	0	0	0	1	0	0	1
21	agent	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0
22	wiser	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
22	agent	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
23	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1
23	agent	1	0	0	1	0	0	1	1	1	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0
24	wiser	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
24	agent	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
25	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
25	agent	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1	1	1	1	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1	1
26	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
26	agent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	wiser	1	1	1	1	1	1	1	1	1	0	1	1	0	1 0	0	1	1	1	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	
27	agent	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	wiser	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1
28	agent	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	1	1	0	0	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0
29	wiser	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1
29	agent	1	0	1	1	0	1	1	0	0	0	0	1	0	0	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	1	1	0	1	0	0	0	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	0	1	1
30	wiser	0	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	1
30	agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0

Conclusions

Chapter 1: New evidence on efficency in Spanish stock futures market

The study conducted in chapter 1 has three parts. The first one answers the question related to the existence of autocorrelation patterns in the returns series of stock futures contracts traded in the Spanish Stock Futures Market. Negative first-order autocorrelations are mostly found in the weekday returns series for the two index portfolios. The variance ratios of the equal-weighted index portfolios allow us to reject the random walk hypothesis on all returns series except for Monday's. When the volume-weighted index portfolio is used, the rejection of the null hypothesis at 5% level is acceptable for all weekday returns. Therefore, it might be concluded that there exists negative first-order autocorrelation in the Spanish Derivative Market over the sample period.

The second part analyses the Conrad and Kaul (1998) strategy in order to contrast the existence of profitable arbitrage portfolios. Overall, in the Spanish Stock Futures Market it is not possible to get any return by constructing zero-cost portfolios on a weekly basis, which supports the weak efficiency hypothesis.

Although these arbitrage portfolios are zero-cost portfolios, they are risky. Therefore, some reward-to-risk measures are needed to evaluate their performance. The third part ends this study ranking the trading portfolios and index portfolios according to the Sharpe ratio and other tailor-made performance ratios. As a general result, the arbitrage portfolios behave worse than the index portfolios.

Chapter 2: An experimental online matching pennies game

The main goal of the chapter 2 is to implement in the setting of a laboratory the GHN's (2006) communication model, which is based on a repeated version of 3-player matching pennies game. As a central point of that model, it considers binary sequences of infinite length. Hence, the first challenge to face is to determine the length of a finite sequence to generate randomly in a lab and characterize those communication strategies to be agreed by participants in the experiment, who are grouped in 2-person teams. In GHN (2006), a communication strategy is said feasible when it transmits an amount of information that fulfills the called information constraint. Such constraint expresses the amount of information available for the team in terms of entropy, which is usually used in the information theory. We also provide a rational version of GHN information constraint to consider rational communication strategies only. In other words, we define a new information constraint when the number of bytes for players to transmit information each other is limited. This constraint is a necessary condition for communication to be possible but it is not sufficient. An operational communication device should be actually implementable. To that purpose, an implementable information constraint is defined by taking into account the precise number of finite sequences under the requirements of communication jointly established by the team. To implement in the lab our version of theoretical model, two communication devices are necessary. One device takes the form of chatting room, where players design their own communication rules or strategies, it is a pre-play phase. The other device is implicit in the actions played during the game. As arranged, the team will play the repeated matching pennies game according to those rules. How much information is transmitted will depend on how rich the strategy of the team is, and it will eventually determine the payoff reached by the team.

Our major concern is to test the robustness of GHN theory. Firstly, we set three main hypotheses relative to the optimal theoretical strategy for a sequence of length 55: the majority rule for 3-length blocks. And secondly, we contrast the GHN model by an econometric version that represents the relations between the three players' play.

As presumed by the first hypothesis, teams were able to design a rich variety of strategies that were clustered by increasing payoffs, arising three levels of communication. The second hypothesis is relative to the agent's behavior, in particular at the superior communication level. It is expected that the agent's behavior at that level does not significantly deviate from the optimal predicted by theory. Result 2 also allows us to accept the second hypothesis. The wiser's behavior is doubly contrasted: *a*) when he plays the same action as the agent and the nature and *b*) when he plays the same action as the nature but not as the agent. The part *a*) of the hypothesis 3 can not be rejected for values really close to the optimal. Therefore, it is concluded that the wiser behaves almost optimally when the agent matches the nature. We contrast the null hypothesis of the part *b*) on a width range of candidate values, revealing that it is hard to accept the wiser's behavior as the optimal predicted. These findings provide our Result 3 to conclude that the third hypothesis is partially verified.

According to above theory, the agent's play depends on the nature's and the wiser's play. In fact, the full informed player (the wiser) communicate with the uninformed player (the agent) via the communication rule or strategy that is designed in a common arrangement during the pre-play phase. While the wiser's play ultimately only depends on the nature's play that is fully known beforehand at the beginning of the game phase. To estimate the matching probabilities we apply binary logit models. Results provide the conclusions for the agent and the wiser, respectively. Result 4 supports the theoretical relation between the agent's actions and the nature's and the wiser's actions. The wiser's action shift conveys the nature's mostly played action. Relative to the wiser's matching probabilities, it is shown Result 5 that concludes the existence of some kind of mis-signaling. In particular, when the agent does match the nature, the wiser makes errors in excess deviating from the theoretical prediction between $10\% - 1\%$. And when the agent does not match the nature, the active wiser reaches a 35% of errors in excess in the session 1. While the passive wiser makes less errors than predicted, between $8\% - 31\%$ of matches in excess in the session 2.

As an overall conclusion, it may be claimed that the GHN theory is robust enough to explain the players' behavior in the setting of a lab.

Chapter 3: Words and actions as communication devices

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 study presented in the chapter 3 is the first work on communication applied to economics that studies tacit as well as explicit communication in the lab. Tacit communication is inherent to human behavior. It is the implicit message in the wiser's actions, that the agent gives meaning depending on her own subjective understanding, or experiences in similar circumstances. Explicit communication involves both external devices or channels to transmit information, and above all a code of communication, which ensures that the meaning of the message is understood by both wiser and agent.

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 tacit and explicit communication, our experimental design includes two treatments: a baseline in which only tacit 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 tacit communication. In the baseline, there are several subject-pairs who try to coordinate their actions. The wiser player with full information signals to her partner through her actions when she makes a mistake. The agent 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 explicit 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 tacit and explicit communication have an influence on obtaining higher payoffs. We detect a team or between-subject effect, as well as a chat or within-subject effect by using one-way analysis of variance. We associate these two effects to tacit and explicit 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.