Strategic Environment Effect and Communication*

Ali OZKES† Nobuyuki HANAKI‡

June 23, 2020

Abstract

We study the interaction of the effects of the strategic environment and communication on the observed levels of cooperation in two-person finitely repeated games with a Pareto-inefficient Nash equilibrium. We replicate previous findings that point to higher levels of tacit cooperation under strategic complementarity compared to strategic substitution. We find that this is not due to differences in levels of reciprocity as previously suggested. Instead, we find that slow learning coupled with noisy choices might drive this effect. When subjects are allowed to communicate in free-form online chat before making choices, cooperation levels increase significantly to the extent that the difference between strategic complements and substitutes disappears. A machine-assisted natural language processing approach shows how the content of communication is dependent on the strategic environment and cooperative behavior. In particular, we find that subjects in complementarity games reach full cooperation by agreeing on gradual moves towards it.

Keywords: Communication, Cooperation, Reinforcement learning, Strategic environment, Structural topic modeling
JEL Codes: C7 · C8 · C9 · D83 · L13

Part of this work is carried out when Ozkes was affiliated with Aix-Marseille School of Economics, and Hanaki was affiliated with Université Côte d'Azur, CNRS, GREDEG. We thank these institutions for their supportive environments. This work was supported by ANR grant Investissements d'Avenir under PSL MIFID (IDEX ANR-10-IDEX-0001-02) and UCA^{JEDI} (ANR-15-IDEX-01), an ORA-Plus project "BEAM" (ANR-15-ORAR-0004), and financial aid from Aix-Marseille School of Economics.

†Wirtschaftsuniversität Wien, Institute for Markets and Strategy, Vienna, Austria. E-mail: ali.ozkes@wu.ac.at

‡Institute of Social and Economic Research, Osaka University, Osaka, Japan. E-mail: nobuyuki.hanaki@iser.osaka-u.ac.jp

1 Introduction

In many economic decisions, there is a tension between what is individually rational and what is collectively optimal. As shown in the extant experimental literature, whether or not this dilemma can be resolved in favor of cooperation on the collectively optimal outcomes may depend on a multitude of aspects in the specific context. This paper sheds light on the functioning of two well-known determinants of cooperative behavior in games with Pareto-inefficient Nash equilibrium. Particularly, we study the effect of communication in interaction with the strategic environment, *i.e.,* whether strategic interactions exhibit complementarity or substitution.

Theoretically, as long as interactions are to be repeated certain commonly known times, cooperation unravels in equilibrium due to backward induction.[1] However, ample experimental evidence demonstrates that participants reach and sustain cooperation to a significant extent.[2] In market games, for instance, this extent might depend on the type of the goods, as in Holt (1993), who notes that sellers of substitute goods might find it easier to collude tacitly than sellers of complement goods do.[3] Similar findings in the contexts of price and quantity competition underpinned the argument that this is due to reaction functions being upward sloping in Bertrand games, while they are downward sloping in Cournot games.[4] The former is a case of strategic complementarity and the latter is a case of strategic substitution, hence represent different strategic environments. This paper contributes to the literature in two ways: we build on previous findings first by exploring the behavioral underpinnings of the effect of strategic environment on tacit cooperation and second, by studying if and how communication interacts with this effect.

In our benchmark setting without communication, we follow Potters and Suetens (2009) (PS), who focus on the effect of the strategic environment by controlling for a set of previously discovered potential confounds. Our findings regarding this benchmark confirm previous results that suggest a higher tendency towards cooperation under strategic complementarity as opposed to substitution. We find that under complementarity, choices are higher than equilibrium levels, *i.e.,* more cooperative, which are, in turn, higher than choices under substitution. On the other hand, we find that reciprocity, as suggested by PS, does not explain this effect: changes in partner's choices are followed to the same extent under both strategic environments. We show, however, through maximum likelihood estimations and simulations based on a simple reinforcement learning model that this can be driven by slow learning coupled with noisy choices.

We implemented an extension to the baseline setup, by allowing subjects to chat before making decisions in each period, to determine whether the difference in the degrees of cooperation continues to hold under communication and also to better understand how the strategic environment affects

[1] Our focus is on finitely repeated games. See Mermer et al. (2016) for an analysis on indefinitely repeated games. Furthermore, we want to note that the strategic environment definitions are based on the stage games and as demonstrated by Echenique (2004), Sabarwal and VuXuan (2018), and Vives (2009), these definitions may not extend to repeated interactions.

[2] See, *inter alia*, Embrey et al. (2017) and Mengel (2017) for meta-studies on how cooperation is reached and sustained in repeated social dilemma games. Crawford (2019) provides a recent review on determinants of cooperation, including the role of communication.

[3] The intuition is that in case of substitutes the Bertrand price competition model generates upward sloping reaction functions in prices and hence theory predicts that if one seller moves away from Nash equilibrium toward the collusive outcome, the other seller has a unilateral incentive to respond by raising price toward the collusive outcome.

[4] See Suetens and Potters (2007) for a discussion and review of results on this issue and Potters and Suetens (2013) for a survey on oligopoly experiments.

subjects' reasoning about the game. Although communication is generally found to enhance cooperation in previous literature, its effect on the levels of cooperation is not definite and known to depend on the type, duration, or contents of communication, as well as the specifics of the game.[5] In our experiments, subjects were given the opportunity to communicate in free form before making decisions without any cost or binding agreement.

Fonseca and Normann (2014) investigate the impact of communication in Bertrand markets with different sizes, and find that, free-from communication helps to obtain higher profits and firms continue collusion successfully after communication is disabled. They note, however, referring to Farrell and Rabin (1996) and Whinston (2008), that the effect of communication on dilemma games is subject to debate. Waichman et al. (2014) note that there is only very little attention devoted to the study of the impact of communication on Cournot markets and find that free-form communication boosts collusion levels (measured by both aggregate output and collusion counts), while standardized communication does not have a significant effect.[6]

We find that when subjects can communicate, average choices and payoffs shift substantially and about 75 percent of pairs reach and sustain efficient cooperation in both strategic environments. Thus, communication has an "ironing effect": the impact of the strategic environment on aggregate cooperation disappears. Considering the hardship of eliminating communication in order to avoid collusion in oligopolies, for instance, our finding points to that the strategic environment may not be of major significance as previously thought. Nonetheless, there are some differences to note. Firstly, communication is more effective in helping participants to cooperate, even if not at the efficient level, in substitution than in complementarity. Secondly, under complementarity, the efficient cooperation is more likely to be reached by gradual moves.

We then aim at understanding more about how communication works towards cooperation and if strategic environment is relevant in that regard. To that end, we employ a set of text analysis methods, including the analyses of number of messages sent, the frequencies of most used words, and finally, a machine-assisted natural language processing (NLP) approach. Machine learning methods for text analysis are increasingly employed in economic research (see Gentzkow et al., 2019).[7] However, these methods were not considered in analyses of communication records in experimental games until very recently.[8]

We refer to an unsupervised learning method, for the first time in the literature, for content

[5] Andersson and Wengström (2012) find, for instance, that the possibility of repeated communication does not necessarily lead to more cooperation in two-stage games.

[6] Gomez-Martinez et al. (2016) study the effect of the revelation of firm-specific data in a Cournot game with multiple firms, and find that communication helps to reach collusive agreements in both individual and aggregate information treatments. Awaya and Krishna (2016) investigate, in their theoretical study that is built on a model of repeated oligopoly with secret price cuts, how unverifiable communication about past sales can facilitate collusion. Bigoni et al. (2018) run a series of experiments with an indefinitely repeated noisy Cournot game to investigate the effect of flexibility (ability to respond quickly) on cooperation, and observe rapid convergence to very low levels of cooperation, independent of flexibility.

[7] Recent works include, among others, Hansen and McMahon (2016), who assess the impact of content in central bank communication on real economic variables, Gentzkow and Shapiro (2010), who investigate the demand for like-minded news as a reason behind bias in newspapers, Mueller and Rauh (2018), who suggest implementing topic models in the analysis of newspaper articles to predict timing of political violence, and Grajzl and Murrell (2019), who employ a structural topic model to study features of Francis Bacon's writings in relation to their importance regarding the history of economic thought.

[8] See Brandts et al. (2019) for a survey. Penczynski (2018) and Georgalos and Hey (2019) are the only published works we are aware of that propose a machine learning approach. More on this in Section 4.

analysis of the chat records. In particular, we estimate a *structural topic model* (Roberts et al., 2016) that presumes that subjects' chats are formed as a weighted mixture of topics that are in turn distributions over words. We find that the topical content of subjects' chat records depend on the strategic environment and whether or not they achieve efficient cooperation in the game. For instance, we observe in the choice data that it is equally likely for subjects to realize and swiftly move to efficient cooperation in the two strategic environments. However, we find evidence in chat content that, subjects in complementarity reach efficient cooperation by agreeing on gradual moves towards it, in case they do not start cooperating from the very beginning. In substitution treatment, on the other hand, subjects either do not reach efficient cooperation or they may jump to it later on.

The remainder of the paper is organized as follows. Section 2 is devoted to the experimental design and procedure. Section 3 delivers our major findings on the strategic environment effect and its interaction with the effect of communication. Section 4 contains chat analysis, while Section 5 concludes.

2 The Experiment

Our central experimental questions are the following. First, we ask if tacit cooperation levels are higher under strategic complementarity compared to substitution and what the behavioral underpinnings are. Second, we investigate if there is a difference between strategic environments in terms of the degree of cooperation when subjects can communicate via a free form online chat. Finally, we explore on how the chat content relates to the strategic environment. Our experimental design that we describe in the following section is built on these questions.

2.1 Design

We designed treatments with strategies as substitutes and complements, both with and without communication, based on PS. Thus, we had a 2×2 between-subjects design, in which subjects played the stage game repeatedly for 30 times in fixed pairs (partner matching). The dominance-solvable stage game has a unique (symmetric) Nash equilibrium that is Pareto dominated. Also there is a unique (symmetric) socially efficient outcome, that is called the joint profit maximization (JPM) outcome. In both strategic environments, there is positive externality, *i.e.*, one's own payoff is increasing in partner's actions.[9]

Let $x_1, x_2 \geq 0$ denote the actions for players 1 and 2 in a pair, respectively. We write the quadratic payoff functions for each treatment as

$$\pi_i^{Comp}(x_i, x_j) = c_1 + c_2 x_i + c_3 x_j - c_4 x_i^2 + c_5 x_j^2 + c_6 x_i x_j,$$
$$\pi_i^{Subs}(x_i, x_j) = c_1' + c_2' x_i + c_3' x_j - c_4' x_i^2 + c_5' x_j^2 - c_6' x_i x_j,$$

for $i, j \in \{1, 2\}$ and $i \neq j$. The coefficients satisfy (i) $c_1' = c_1$, (ii) $c_2' = \frac{c_2(2c_4 - c_6)}{2c_4 + c_6}$, (iii) $c_3' = c_3 + \frac{2c_2 c_6}{2c_4 + c_6}$, (iv) $c_4' = \frac{c_4(2c_4 - c_6)^2}{(2c_4 + c_6)^2}$, (v) $c_5' = c_5 + \frac{2c_6^3}{(2c_4 + c_6)^2}$, and (vi) $c_6' = \frac{c_6(2c_4 - c_6)^2}{(2c_4 + c_6)^2}$. These six conditions guarantee that the NE choices and payoffs, the JPM choices and payoffs, the optimal defection

[9] PS find that the sign of externality does not play a significant role on the degree of cooperation.

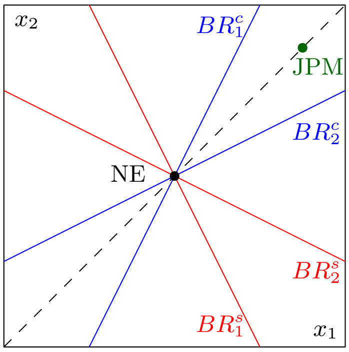


Figure 1. Best response functions and NE and JPM choices.

	Without Communication	*With Communication*
Complementarity	56 (4)	100 (8)
Substitution	64 (6)	74 (5)

Table 1. Number of participants (sessions) in four treatments.

payoff, and the absolute value of the slope of the reaction curve are the same across strategic environments. The latter makes the best-reply dynamics generate the same speed of convergence. Figure 1 summarizes the similarities and the differences between strategic environments.

We follow PS and set $c_1 = -28, c_2 = 5.474, c_3 = 0.01, c_4 = 0.278, c_5 = 0.0055$, $c_6 = 0.165$, and $x \in [0, 28]$, thus our treatments without communication are exact replicates of positive externality treatments in PS. Given these values, we have $x_{NE} = 14$, $x_{JPM} = 25.5$, $\pi_{NE} = 27.71$, $\pi_{JPM} = 41.94$, and the optimal defection payoff $\pi_{\text{defect}} = 60.14$. The slope of the reaction curve under complementarity is 0.3, while it is -0.3 under substitution.

2.2 Procedure

All our computerized sessions were conducted at the Laboratory of Experimental Economics of Nice.[10] In total, 308 student subjects participated in the experiment. Numbers of subjects (sessions) per treatment are provided in Table 1.[11]

Instructions with screenshots were distributed and read aloud at the beginning of each session (see Appendix A). The instructions were exactly the same for complementarity and substitution and subjects were told that their earnings were going to be based on their own decisions and the decision of another participant, with whom they were matched for the session. No reference to any market or economic term was made; the experiment was introduced as a neutral decision-making problem with two persons involved. Each participant received a payoff table showing own payoff corresponding to choices in even numbers between 0 and 28 (see Appendix B). In addition to the payoff table, subjects were provided on their screen a payoff calculator for hypothetical

[10] We used the experimental software toolkit *z-Tree* (Fischbacher, 2007) to program the experiment. Subjects were recruited using ORSEE (Greiner, 2015).

[11] The number of participants and sessions varied across treatments due to variation in show-up rate across our pre-schedules sessions that took place in different periods of the school semester. We base our analysis on 294 subjects excluding 7 pairs, in which at least one subject make choices less than or equal to 2 (which leads to very low payoffs) for half of the experiment or longer.

numbers that they could type in. The number of decimal points for both the calculator and decisions was restricted to be one. In sessions with communication, subjects could communicate voluntarily through a chat box during one minute before moving to the decision stage. Offensive language and identifying messages were banned but there was no further restriction on the content of communication. Subjects' communication language occurred to be exclusively French, although it was not restricted.

The stage game was repeated for 30 periods, starting after a trial period with forced decisions.[12] History of past decisions and payoffs was provided at each period. Payoffs were denoted in points and exchanged for cash at a rate of 100 points = 1 Euro. The final earnings paid at the end of the experiment consisted of a participation fee of 5 Euros and total payoffs throughout the session. Subjects earned on average 15.5 Euros in treatments with communication and 11.3 Euros in treatments without communication, including 5 Euros show-up fee. The average duration of a session without communication was 90 minutes, whereas it was 105 minutes for sessions with communication.

3 Experimental Results

3.1 Aggregate Results

The subsequent analysis is based on the *degree of cooperation*, which is defined, for a pair k in period t with average choice within pair denoted by $\bar{x}_{kt}$, as

$$\rho_{kt} = \frac{\bar{x}_{kt} - x_{NE}}{x_{JPM} - x_{NE}}. \tag{1}$$

The average degrees of cooperation in four treatments are reported in Figure 2 and Table 2. As is clearly seen in Figure 2, when communication is not allowed, complementarity induces more cooperation compared to substitution. This is in line with previous findings, particularly with PS.[13] Next, for both strategic environments, communication boosts the levels of cooperation. However, this shift leads to the disappearance of the strategic environment effect, *i.e.,* when communication is allowed, the degree of cooperation is the same across strategic environments.[14]

Table 2 delivers details and test results for all periods combined (1-30), first half of the experiment (1-15), second half of the experiment (16-30), first period, and last period. The $p-$values

[12] In the trial period, the payoff calculators were used twice to calculate hypothetical payoffs. In chat treatments, the chat box is tried out by typing "hello" (*bonjour*) after this and finally, a forced decision has been commanded. Payoffs in the trial period did not count in final earnings.

[13] Although overall comparison in between treatments is the same with PS, several observations should be noted. First, in PS, the average cooperation rates are higher (0.27 in substitution and 0.41 in complementarity). In both of their treatments, there seems to be a clear increasing trend of choices over the periods after first few. In case of complementarity, average choices increase as high as to the level of the JPM. Second, choices in PS are both higher than Nash equilibrium, whereas, in our data, substitution treatment has lower average choices than the NE. And finally, the end game effect in PS is stronger compared to our data for both treatments. These observations could be explained by differences in subject pools across studies. For instance, as noted by Al-Ubaydli et al. (2016), cognitive skills predict well the average cooperation rates in repeated prisoners' dilemma games, and Noussair et al. (2016) and Breaban et al. (2020) find that the average Cognitive Reflection Test score in Tilburg subject pool is around 1.8, whereas it is around 0.4 for the subject pool in Nice, as reported by Babutsidze et al. (2020).

[14] Figure 13 in Appendix C shows the comparison of payoffs. The average payoffs over all periods with (without) communication are: 35.1 (24.1) for complementarity and 36.9 (21.8) for substitution.

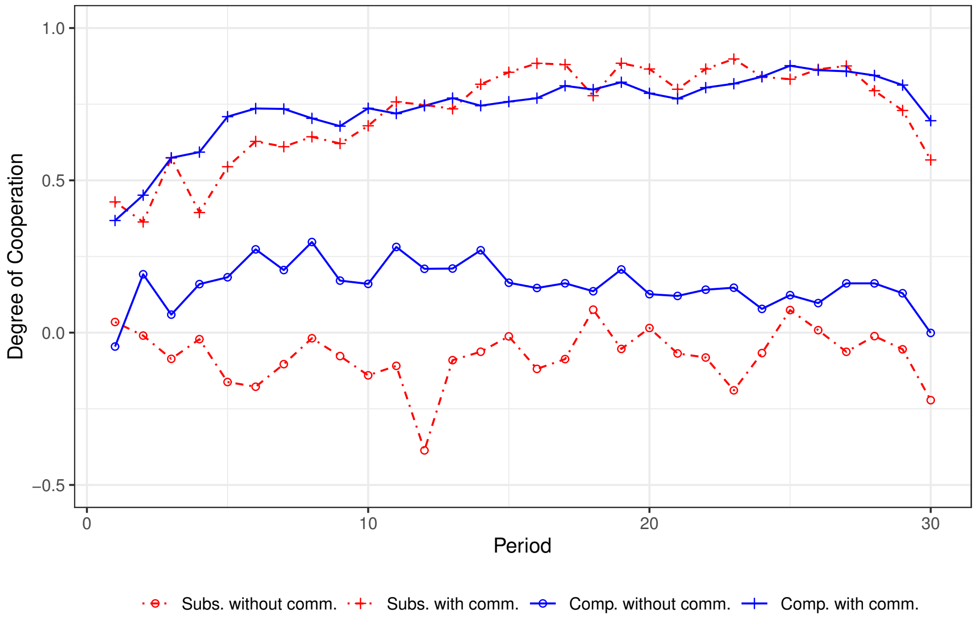


Figure 2. Average degree of cooperation.

	No Communication			*Communication*		
Periods	*Substitution*	*Complementarity*	*p−value*	*Substitution*	*Complementarity*	*p−value*
1-30	-0.07 (0.28)	0.16 (0.29)	0.034	0.72 (0.34)	0.74 (0.33)	0.538
1-15	-0.09 (0.24)	0.19 (0.31)	0.000	0.63 (0.43)	0.67 (0.37)	0.538
16-30	-0.06 (0.38)	0.13 (0.33)	0.018	0.82 (0.32)	0.81 (0.37)	0.240
1	0.03 (0.85)	-0.05 (0.72)	0.695	0.43 (0.90)	0.37 (0.70)	0.950
30	-0.22 (0.57)	0.00 (0.36)	0.046	0.57 (0.51)	0.70 (0.43)	0.104

Table 2. Average degrees of cooperation (standard deviations in parentheses). Standard deviations measure between-pair variability, except for first period, in which individual choices are used. Reported $p-$values are for alternative hypotheses in the WMW tests for higher degrees of cooperation under complementarity.

correspond to Wilcoxon-Mann-Whitney (WMW) tests of the null hypotheses that the degree of cooperation is the same in substitution and complementarity. When communication is not allowed, all the null hypotheses (except for the first period) are rejected in favor of the alternative hypotheses that the degree of cooperation is higher in complementarity than in substitution. However, when communication is allowed, we reject none of the null hypotheses. It is immediate to observe that the average degrees of cooperation are substantially higher when communication is allowed within a strategic environment.[15]

The end-game effect that is generally observed in finitely repeated social dilemma games (Selten and Stoecker, 1986) seems to take place in all our treatments, as seen in Figure 2. Let us define this effect as $|\rho^{30} - \rho^{16-30}|$ where ρ^{16-30} is the average degree of cooperation in the second half of the

[15] All WMW tests yield $p-$values of 0.000. We tested if this is due to the extra time given for chat, rather than the effect of communication itself by running two extra sessions with the same extra time (1 minute) but without the ability to communicate. The results can be found in Appendix C.2, which show that the extra time in communication treatments have only a very small effect.

experiment and ρ^{30} is the average degree of cooperation in the final period. We observe that the end-game effect is slightly stronger (0.16) under substitution compared to complementarity (0.13). This might partially be explained by the fact that optimal defection choice under substitution (10.6) is much lower than in complementarity (17.4), as noted by PS.

3.1.1 Full-cooperation behavior

We say the choice of a subject at any period is at JPM level if it lies in the interval $[25, 26]$, and we say the choices of a pair are at JPM level if both subjects play at JPM level simultaneously. When communication is not allowed, the number of pairs who have played JPM level as a pair at least once is 4 in both environments, which amounts to 12.5% of the pairs in substitution and 14% in complementarity.[16] However, out of these four pairs, none of them sustained JPM level choices for more than 5 periods in substitution, whereas in complementarity, three of them managed to cooperate fully from the first period they play at JPM level as a pair until the penultimate period.[17] We call a pair a JPM pair if their choices as a pair are at the JPM level for at least three periods until the last period, the last but one period, the last but two periods, or the last but three periods.[18] The rest of the pairs are called non-JPM.

We observe that more subjects make JPM level choices in substitution (47% compared to 34% in complementarity). One might conclude that subjects tend to unilaterally try out JPM strategies more in substitution, whereas only under complementarity we have pairs that succeed in sustaining cooperation for several periods.[19] It should be noted, however, that this difference is not statistically significant (Fisher's test yields a $p-$value of 0.193).

3.1.2 Reciprocity

With a regression model estimation, PS identify a higher level of reciprocity among subjects in the complementarity treatment. Table 3 shows the estimation results of the same model for our data (without communication):

$$\Delta x_{it} = \beta_0 + \beta_1 \Delta x_{jt-1} + \beta_2 COMP_i \Delta x_{jt-1} + u_{it},$$

[16]Figures 15 and 16 in the Appendix D show the evolution of choices within pairs.

[17]The first periods of mutual full-cooperation for these three pairs are: 4, 6, and 18. One other pair in complementarity plays at JPM level only once, at the 28th period. In substitution, two pairs play at JPM level only once (24th and 30th periods), one pair at 22nd and 24th periods, and another pair between 15th and 19th periods.

[18]The following results do not depend on the choice of the length of mutual cooperation. Details can be provided upon request.

[19]Mengel (2017), in her survey comprising 96 studies with 3500 subjects in total, finds that risk (loss from unilateral cooperation) and temptation (gain from unilateral defection) play a significant role on the levels of cooperation in prisoners' dilemma games. If we look at the restricted game with only NE and JPM strategies for respectively defection and cooperation, the value of the risk parameter is calculated to be approximately 2.6 for our complementarity treatment and 0.8 for our substitution treatment. Similarly, the value of the temptation parameter is calculated to be approximately 1.06 for our complementarity treatment and 1.22 for our substitution treatment. Mengel (2017) concludes that in repeated games with partner matching, temptation explains better the variation in cooperative behavior. As temptation is higher, sustaining cooperation is more difficult in substitution. On the other hand, as risk is higher in complementarity, fewer subjects tend to try out (jump to) JPM strategies. The latter follows from the argument that risk is crucial in determining short-run incentives (see Blonski et al., 2011).

β_1		β_2	
Estimate	*p−value*	*Estimate*	*p−value*
0.16	0.012	−0.04	0.554

Table 3. Regression results (with individual random effects) on changes in choices without communication. Standard errors are robust to within-pair dependency. Two-tailed $p-$values are reported. 3360 observations from 120 subjects (64 in substitution and 56 complementarity).

where $COMP$ is a dummy variable that takes the value 1 for choices in complementarity treatment and the value 0 for substitution, Δx_{it} is the change in the choice of subject i from period $t-1$ to t, and Δx_{jt-1} is the change in the choice of the partner from period $t-2$ to $t-1$. We observe significant reciprocity among our subjects, represented by the β_1 estimate in Table 3. However, there is no difference between strategic environments ($\hat{\beta}_2$ is not significantly different from zero). This is in contrast to what PS find. Specifically, PS observe that subjects in complementarity have significantly higher reciprocity ($\hat{\beta}_2 = 0.17$ with $p = 0.003$).

As differences in the degree of reciprocity between two strategic environments do not explain the higher degree of cooperation under complementarity in our data, in the next section we investigate whether a learning model can generate the result of our experiment.

3.2 Learning

We consider a simple reinforcement learning model (without communication) where learning is based on realized payoffs (see Erev and Roth, 1998). Let x_i^t denote the action agent i chooses in period t, s the step size used to discretize the action space, and $\mathcal{S}$ the discretized action space. Furthermore, $A_q^i(t)$ denotes the attraction associated with action x for agent i at period t. Given the attractions, the probability that i chooses x in period t is defined by

$$p_x^i(t) = \frac{e^{\lambda A_x^i(t)}}{\sum_{k\in\mathcal{S}} e^{\lambda A_k^i(t)}},$$

where $\lambda \geq 0$ is the parameter that governs the "sensitivity" of choice to the attraction. $\lambda = 0$ means uniformly random choice (thus, attractions play no role) and $\lambda \to \infty$ means that the quantity with the highest attraction for agent i in period t will be chosen with probability approaching 1.

We assume that each action has the same level of initial attraction, which is equal to the average payoff i can obtain if both i and j uniformly randomize their actions, *i.e.,*

$$A_x^i(0) = \sum_{(a,b)\in\mathcal{S}\times\mathcal{S}} \pi_i(a,b)/|\mathcal{S}|^2,$$

for all $x \in \mathcal{S}$. Furthermore, as in McAllister (1991) and Hanaki et al. (2005, 2018), we assume that the attraction for any $x \in \mathcal{S}$ evolves as a weighted average with

$$A_x^i(t+1) = \begin{cases} \omega A_x^i(t) + (1-\omega)\pi_i(x_i^t, x_j^t) & \text{if } x_i^t = x, \\ A_x^i(t) & \text{otherwise,} \end{cases}$$

for all $t \geq 0$, where ω is the "recency" parameter that indicates the speed at which past payoffs are

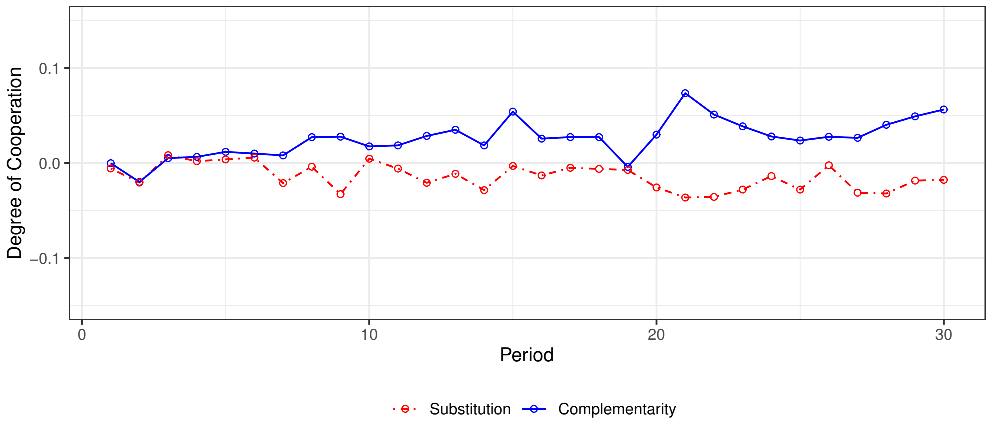


Figure 3. Simulated degree of cooperation for $\lambda^* = 0.2$ and $\omega^* = 0.88$.

forgotten: $\omega = 0$ when only the last period payoff is remembered and $\omega = 1$ implies that only the initial attractions are remembered. Thus, ω is higher when learning is slower.

Based on a maximum likelihood estimation, we obtained parameter values for our experimental data. In particular, we identified by a grid search over $\lambda \in \{0.1, 0.2, \ldots, 9.99\}$ and $\omega \in \{0.01, 0.02, \ldots, 0.99\}$ the maximizers of

$$\sum_{i \in N} \sum_{t \in \{1,\ldots,30\}} \log(p^i_{x=x^t_i}(t)). \tag{2}$$

Figure 3 shows the simulations based on 1000 pairs with the obtained parameter estimates, *i.e.*, $\lambda^* = 0.2$ and $\omega^* = 0.88$, which point to slow learning and noisy choices.

To show that the pattern we observe is dependent on the estimated parameters, we have computed simulations for $\lambda \in [0.1, 1.5]$ with increments of 0.2, and $\omega \in [0.05, 0.95]$ with increments of 0.05. For each set of parameter values, we have created 100 simulated pairs. We then computed, for each simulated pair, the average degree of cooperation within 30 periods. Namely, for pair k, the average degree of cooperation is defined as

$$\rho_k = \frac{1}{30} \sum_{t=1}^{30} \rho_{kt}.$$

We then took the average of ρ_k across all simulated pairs and obtained ρ^C for complementarity and ρ^S for substitution. Finally, we computed $\Delta\rho = \rho^C - \rho^S$ which summarizes the difference between complementarity and substitution, namely, the size of the strategic environment effect.

Figure 4 shows the relationship between $\Delta\rho$ and ω for four values of λ. The average degree of cooperation in complementarity is higher than in substitution when learning is slow enough ($\omega \geq 0.8$). When choices are less sensitive to attractions (λ is smaller), we observe the strategic environment effect for faster learning (smaller ω) as well.

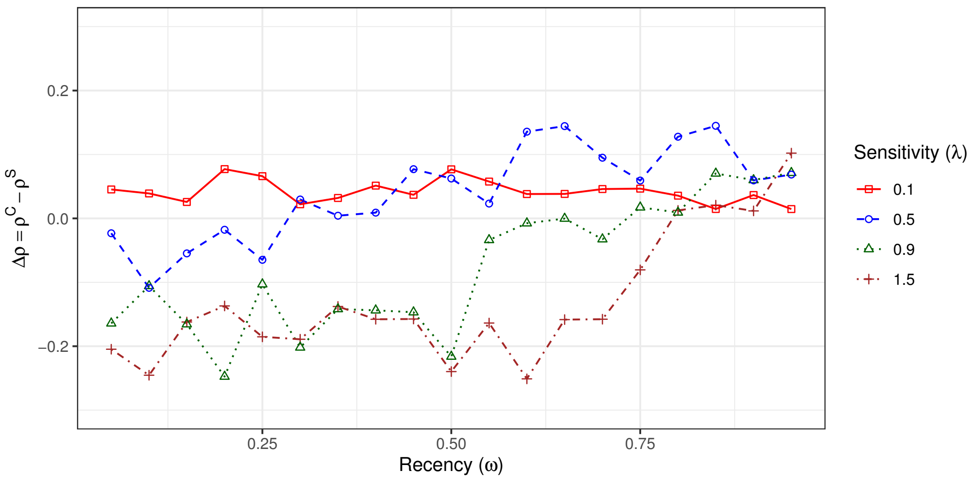


Figure 4. Simulated $\Delta\rho$ for various values of ω and four values of λ.

4 Communication

Many experimental studies include communication, and it is often implemented in free form, in which subjects are not restricted in the content of their messages, except for abusive words and identification purposes, as was the case in our experiments. It has been documented that free-form communication, as opposed to structured or restricted communication, has a larger impact on strategic interactions.[20] On the other hand, there is a big challenge facing the analyses of the impact of free-form communication on strategic behavior that pertains to the question of *how* it works.

Free-form communication is more and more prevalent in economic experiments that are implemented online and in laboratory, and has a distinctive power to reveal reasoning and deliberative processes in strategic decision-making. Naturally, however, assessment of this kind of data can be complex and are, most of the time, based on subjective judgment of researchers or research assistants. Current practices with regard to making sense of chat data coming from free-form communication in lab experiments include (*i*) self-classification of messages in order to relate the choice of words or messages to actual plays and outcomes (see Charness and Dufwenberg, 2006; Schotter and Sopher, 2007; Kimbrough et al., 2008), (*ii*) content analysis in which a few research assistants are recruited to be trained to code messages into categories formed by the researchers (see Cooper and Kagel, 2005; Sutter and Strassmair, 2009; Hennig-Schmidt et al., 2008), and (*iii*) classification coordination game *à la* Houser and Xiao (2011), in which coders are incentivized to

[20]Charness and Dufwenberg (2006, 2011) emphasize the effectivity of free-form communication in enhancing efficiency when equilibria can be Pareto ranked. Cooper and Kühn (2014) conclude that allowing a rich message space leads to persistent collusion in a two-person two-period matrix game resembling Bertrand price competition. Brandts et al. (2015) argue that restricted and unilateral communication is less effective compared to free-form communication in contract games. Andersson and Wengström (2012) argue that free-form communication increases the importance of social preferences as opposed to structured communication. Building on this argument, Cason and Mui (2015) deliver evidence for that rich communication is more effective in facilitating coordinated resistance modeled *à la* Weingast (1995). Cason et al. (2012), on the other hand, point to contest environments where free-form communication might damage efficiency. Finally, Wang and Houser (2019) find that in coordination games, free-form communication boosts coordination much more than restricted communication.

Periods	*Substitution*	*Complementarity*	*p−value*
1-30	1.97 (2.00)	1.57 (1.81)	0.000
1-15	2.05 (1.87)	1.85 (1.77)	0.000
16-30	1.88 (2.12)	1.30 (1.82)	0.000

Table 4. Average number of messages per period (*s.d.* in parentheses). The $p-$values are due to two-tailed WMW tests.

pay more attention through rewarding the codes that match the most popular evaluation among other coders' evaluations (see Corazzini et al., 2014; Ellingsen and Johannesson, 2008; Andersson et al., 2010).

In this paper, we propose the use of computerized techniques in analyzing experimental chat data in place of human labor. Advantages are that (*i*) they are less costly in terms of time and money as researchers devote less time to the analysis and do not have to hire coders or assistants, (*ii*) they may make language restriction redundant as many techniques in natural language processing are language-free, and (*iii*) they may rely on subjective assessments to a lesser extent. The latter two points are particularly relevant for unsupervised learning methods.

Before proceeding with the results of our NLP approach, *i.e.,* estimating a structural topic model (STM), we look at the general features of chat content, in relation to the strategic environment and full-cooperation behavior.

4.1 Number of messages sent

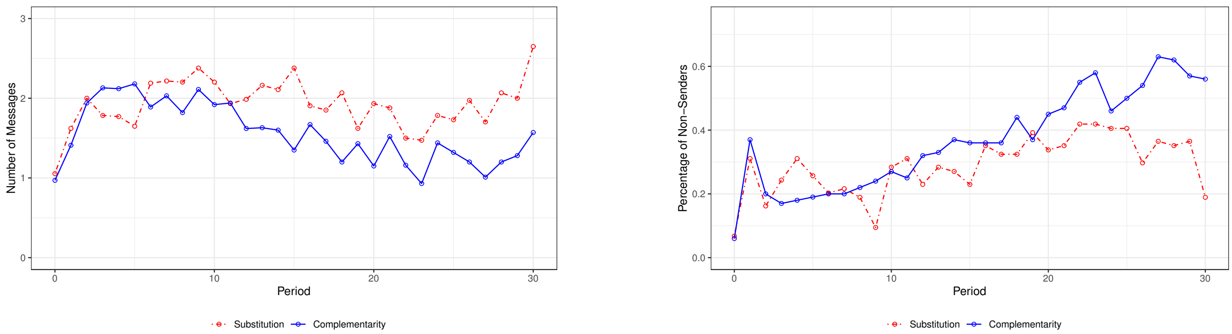
In this section we look at the number of messages sent by subjects.[21] All 174 subjects sent at least one message throughout the experiment. They sent, on average, 1.74 messages per period. In the first half of the experiment, the average is 1.93, which is significantly higher than the second half (1.55, with $p = 0.000$ in a WMW two-tailed test). As can be seen in Table 4, in complementarity average number of messages per period is 1.57, whereas it is 1.97 in substitution. Thus, we conclude that subjects sent more messages in substitution treatments, the difference being about one message in every two periods.

Figure 5a depicts the evolution of the number of messages over time by strategic environment, which confirms that, especially in the second half of the experiment, subjects in the substitution treatment sent more messages. The percentage of subjects who do not send any message is increasing in complementarity treatment, whereas there is no visible trend in substitution, as seen in Figure 5b. This might be explained in part with the fact that there are more pairs who manage to reach and sustain full-cooperation and may not need further communication in complementarity (see Table 5). In what follows, we look more closely at the messaging patterns in JPM and non-JPM pairs.

4.1.1 Full-cooperation and communication

Table 5 shows the number (percentage) of subjects and pairs who make JPM level choices at least once in both strategic environment with communication, together with JPM pairs. We do not

[21] This is based on the number of times subjects clicked the "send" button.



a. Average number of messages per period.

b. Percentage of subjects who do not send any message per period.

Figure 5. Average number of messages and percentage of subjects who do not send any message per period. The period 0 stands for the forced trial period.

	Substitution	*Complementarity*
JPM at least once individually	67 (90%)	94 (94%)
JPM at least once as pair	33 (90%)	44 (88%)
JPM pairs	27 (73%)	40 (80%)

Table 5. Number (percentage) of pairs and subjects that play at JPM level at least once and JPM pairs.

observe any significant difference between strategic environments (Fisher's tests yield $p-$values greater than 0.4).[22]

Figure 6 shows the evolution of the degree of cooperation for both JPM and non-JPM pairs in both strategic environments. The JPM pairs start at already high degrees of cooperation and gradually reach full cooperation in average. The average choice of non-JPM pairs in complementarity treatment is stable throughout the experiment, whereas there is a visible trend in substitution. In fact, the average degree of cooperation over all periods under substitution is much higher for non-JPM pairs when communication is allowed (0.28) compared to when communication is not allowed (-0.07). This difference is not as large for complementarity (0.25 for non-JPM with communication and 0.16 for without communication). We conclude that communication fosters cooperation in substitution to a greater extent, even if it does not lead to full cooperation.[23]

Considering two strategic environments together, subjects both in JPM and non-JPM pairs send on average 1.74 messages ($s.d. = 1.90$ and 1.91 respectively) per period. In the first half of the experiment, average number of messages is 1.96 ($s.d. = 1.80$) and 1.86 ($s.d. = 1.85$), respectively. The number of messages sent by non-JPM subjects is significantly higher compared to JPM subjects only in the second half of the experiment (1.62 ($s.d. = 1.96$) and 1.53 ($s.d. = 1.98$), respectively, with $p = 0.014$ from WMW two-tailed test). Table 6 shows these values for each strategic environment separately, together with $p-$values for corresponding tests.

Subjects sent more messages in substitution treatments regardless of if they manage to reach

[22] Figures 17 and 18 in the Appendix E show the evolution of choices within pairs.

[23] Also, there is no visible end-game effect in either of strategic environments, which might indicate that subjects in non-JPM pairs are not involved in the game strategically to the extent those in JPM pairs are, who show a substantial end-game effect.

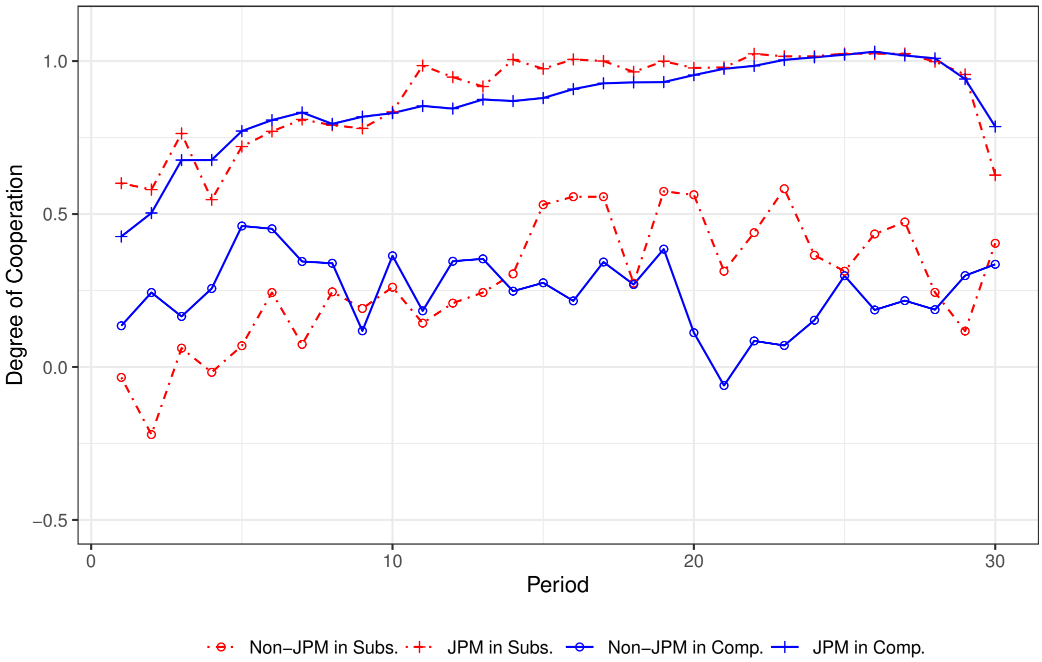


Figure 6. Average degree of cooperation by JPM and non-JPM pairs.

	Substitution			*Complementarity*		
Periods	*non-JPM pairs*	*JPM pairs*	*p−value*	*non-JPM pairs*	*JPM pairs*	*p−value*
1-30	2.12 (2.02)	1.91 (1.99)	0.000	1.36 (1.71)	1.63 (1.83)	0.000
1-15	2.07 (1.90)	2.05 (1.86)	0.897	1.66 (1.78)	1.89 (1.76)	0.009
16-30	2.18 (2.14)	1.76 (2.11)	0.000	1.05 (1.58)	1.36 (1.87)	0.010

Table 6. Average number of messages per period (standard deviations in parentheses). Reported $p-$values are for two-tailed WMW tests.

and sustain full cooperation or not. In complementarity, JPM subjects send more messages both in the first and second half of the experiment. In substitution, on the other hand, non-JPM subjects send more messages in the second half of the experiment and there is no difference in the first half.

The fact that non-JPM subjects send fewer messages in complementarity compared to JPM might indicate that the failure of cooperation in complementarity is due to failure in communication. On the other hand, non-JPM subjects send more messages in the substitution treatment, which might indicate that even when subjects communicate (*e.g.*, to find a common ground), communication may not lead to cooperation, which is harder.

In what follows, we explore chat content for a better understanding of how strategic environment affects cooperative behavior.

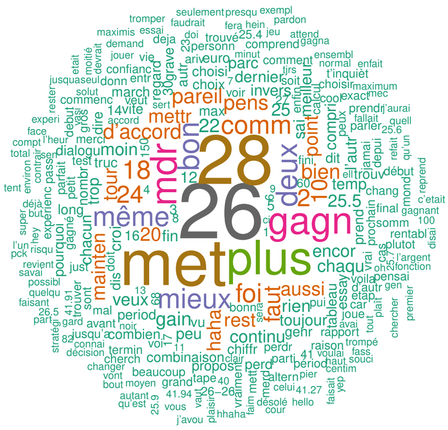


Figure 7. 298 stemmed terms that are used by subjects at least 10 times in total. Centrality, size, and colors reflect frequencies.

4.2 Message Content

We first look at the frequencies of the terms subjects used in their communication. The word cloud in Figure 7 shows the terms that appeared in chats at least ten times.[24] We build our analysis on chat records for each of 86 pairs.[25]

We first compare the most frequently used terms across treatments. To do so, we refer to the *relative rank differences* (r.r.d., *à la* Huerta, 2008) of 50 most frequent terms. For each term t, we compute r.r.d. for substitution as

$$\Delta r_S^C(t) = \frac{r_C(t) - r_S(t)}{r_S(t)},$$

where $r_C(t)$ stands for the rank of the word t in the decreasing order of the times it is used by the subjects in the complementarity treatment, and $r_S(t)$ stands for the substitution treatment. The relative rank difference for complementarity, $\Delta r_C^S(t)$, is symmetrically defined. We pay a particular attention to those words that have either $\Delta r_S^C(t) > 1$ or $\Delta r_C^S(t) > 1$, following Fischer and Normann (2019).

Figure 8 shows the ranks of the top 50 words in both treatments.[26] The shaded (green) area

[24] The proceeding analysis is executed with the R packages `quanteda` (Benoit et al., 2018) and `tm` (Feinerer, 2018). The stopwords we removed that may not be predefined in these packages are listed in the Appendix G.1. Details of our preparation for the content analysis, which includes a mild orthographical clean-up necessitated by common mistakes, will be provided in the online appendix.

[25] We exclude a pair in substitution treatment who did not communicate beyond first period. Some stopwords are removed after the word cloud in Figure 7. This removal emptied one other subject's chat content, thus we have 171 subjects, whose chat records are utilized.

[26] Three terms are not included as they did not appear more than 10 times in substitution although they were in the top 50 for complementarity. These are "period" (period), "tableau" (table), and "chiffr" (number), which are at 41st, 44th, and 45th ranks in complementarity, respectively.

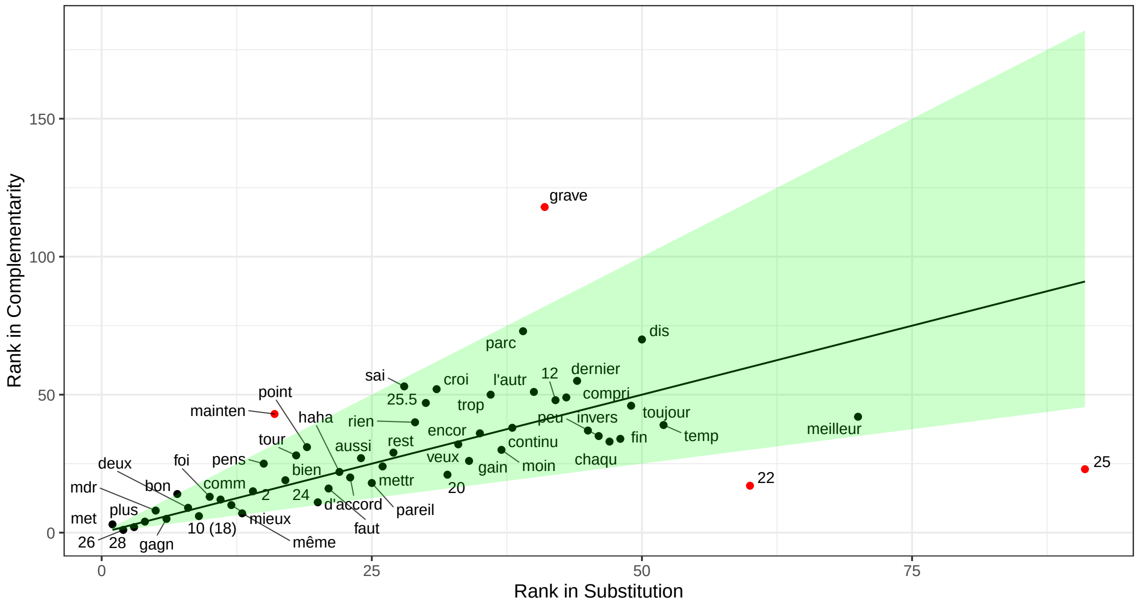


Figure 8. The frequency rankings of 50 most used words in both treatments. Within the shaded region we have $-1/2 \leq \Delta r_S^C(t) \leq 1$ and only outside this region we have either of the difference greater than 1. The term "10" in substitution is matched with the term "18" in complementarity as they are the corresponding optimal defection choices. Translations can be found in Table 9 in Appendix F.

indicates r.r.d. values smaller than or equal to 1.[27] The rankings of words are remarkably similar across treatments. This points to that communication is utilized in similar ways in the two strategic environments. Nevertheless, there are some observations we can make. For instance, there are two terms ("mainten" and "grave") that appear to be significantly more frequently used by subjects in substitution treatment.

The term "mainten" stands only for the word "maintenant", *i.e.*, "now" in English. A closer look into chat content and choices in the game reveals that this difference is due to the excessive usage of the word by subjects in a small set of pairs who try to sustain a sophisticated alternating strategy.[28] This alternating strategy involves playing the action pair $(28, 10)$ in one round, and $(10, 28)$ in the following. Thus, subjects remind each other quite frequently that "now" it is their turn to play, for instance, the action "10". And it is immediate to observe that this strategy is embraced by some pairs as the action pair $(28, 10)$ maximizes the payoff for the first player (although the two-period average payoff, 36.54, is lower than JPM, 41.94). The corresponding pair in complementarity is $(28, 18)$, which pays the same to first player. However, this strategy is observed only in substitution treatments as the reverse pays negative and much lower in complementarity (-7.56 *vs.* 4.87 in substitution). The choices of pairs (with IDs 298, 1894, 2091, and 2097) that employ this alternating strategy can be seen in the Figure 18 in Appendix E.

The difference in popularity of the term (word) "grave" indicates that under substitution, more subjects need to reassure and forgive the other one for maintaining full cooperation, as defections,

[27] Note that $\Delta r_S^C(t) = -\Delta r_C^S(t)/(\Delta r_C^S(t) + 1)$.

[28] Figure 19 in the Appendix F shows that this term is not outside the shaded region for JPM pairs. Figure 20 shows the same data for non-JPM pairs.

or mistakes, happen more.[29]

The terms that appear at higher ranks in complementarity, *i.e.,* "22" and "25" (together with "20" and "24", which also have relatively high r.r.d values, *i.e.,* higher than 0.8), point to that in complementarity the move towards full cooperation is more gradual, as discussions about interim cooperative choices are more prevalent. That "25.5", the exact value of JPM choice that is not in the payoff tables, is slightly more popular among subjects in substitution might indicate that the move is not as gradual but happens due to jumps to full cooperation.[30]

4.3 Structural topic modeling

The use of machine-assisted natural language processing techniques has not been considered until very recently in analyses of communication data coming from (lab) experiments (see the beginning of Section 4 for a review of common practices). Penczynski (2018) suggests, in the first ever published paper with such an approach, that computer classification can be employed to validate the consistency of previously used methods of content analyses and finds that a supervised learning approach can replicate to a considerable extent the human classification of written accounts of reasoning in terms of models of cognitive processes in experimental games of beauty contest, hide and seek, social learning, and coordination.[31] Georgalos and Hey (2019), on the other hand, employ a Bayesian classifier algorithm to classify messages exchanged in a production game. Here, we propose *topic modeling* for the analysis of chat data coming from lab experiments.

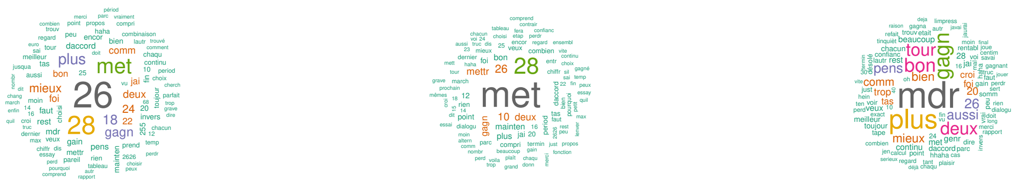
Topic models form an unsupervised method to recover generative underlying topics in a collection of documents (*corpora*) to exploit the co-occurrence of words towards a classification of documents. Structural topic models, which are logistic-normal mixed membership topic models, built on the early works in topic modeling such as the Latent Dirichlet Analysis (Blei et al., 2003) and the Correlated Topic Model (Blei and Lafferty, 2007), among others, allow researchers to integrate metadata (document-level covariates other than text) into the latent semantic analysis of documents (see Roberts et al., 2014).

Particularly, in an STM, a set of covariates are chosen to explain topical variation across documents, and even variation in the usage of different words within topics. Let there be D documents. A document $d \in \{1, \ldots, D\}$ is seen as beginning with a collection of N_d empty positions, each to be filled with a word. Assume there are K topics that exist in the whole corpora. Then, to fill a position, a topic $k \in \{1, \ldots, K\}$ will be chosen according to a distribution over topics firstly. The chosen topic is also a probability distribution, this time over words in the vocabulary (of the corpora), and it is according to this the choice of the particular word for each empty position is made. The metadata used in an STM estimation comes into play in recovering the probability distributions both over topics (*topic prevalence*) and words (*topical content*). Topical prevalence refers to how much of a document is associated with a topic. Topical content, on the other hand,

[29] The term appears as in "ce n'est pas grave", which translates as "it does not matter" in English, in the chat content of 7 (3) subjects in 5 (3) pairs in substitution (complementarity). They use this term as in this sentence to show forgiveness for a cheating attempt or a (self-declared) mistake by the opponent. Details can be provided upon request.

[30] Figure 19 in Appendix F supports this argument, as the differences between 25.5 and other interim values (such as 20, 22, 24) in terms of prevalence in different strategic environments seem to be more pronounced for JPM pairs.

[31] Arad and Penczynski (2018) employ the (random forest) method proposed in Penczynski (2018) for the analysis of reasoning in Blotto games.



a. Topic 1. **b.** Topic 2. **c.** Topic 3.

Figure 9. Word clouds for each topic.

refers to the words used in topics.[32]

We estimated a model with three topics, while topic prevalence is assumed to be dependent on the strategic environment and full cooperation behavior, without a topical content covariate. The basis of analysis is the chat content for each pair throughout the experiment. A detailed account of our procedures regarding model selection can be found in the Appendix G.

4.3.1 Topical content and prevalence

Figure 9 shows the word clouds for each topic separately. In the first topic, most used term is “26”, the JPM choice on the payoff table. In the second topic, it is the verb ”met” (“put” in English), and in the third topic, it is “mdr” (acronym for “mort de rire”, corresponding to “lol” or “laughing out loud” in English, although literally “dead from laughing”).

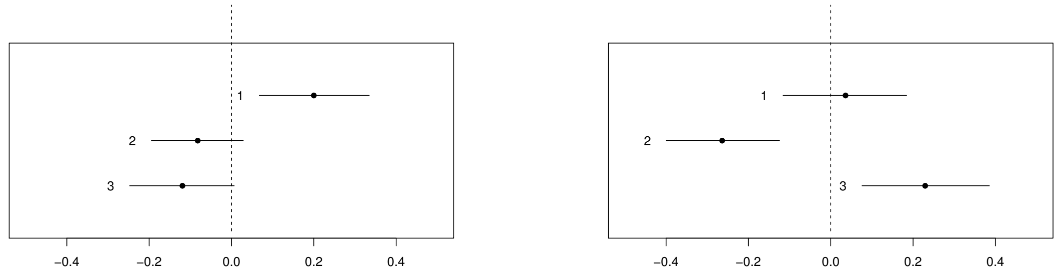
Figure 10 shows the results from a regression estimation where chat content in pairs are the units, the outcome is the proportion of each document devoted to a topic in an STM model, and the explanatory dummy variables indicate strategic environment and whether the pair is a JPM pair or not.[33] This estimation shows that in complementarity, Topic 1 is used relatively more and Topic 2 and 3 are used more in substitution. On the other hand, while non-JPM subjects use Topic 2 more, JPM subjects use Topic 3 more. In what follows we look at these patterns more closely.

We divide JPM pairs into *early* and *eventual* JPM pairs. We say that a JPM pair is an early JPM pair if both players in the pair choose 24 or higher for 7 or more times in the first 10 periods.[34] A JPM pair that is not an early JPM pair is called an eventual JPM pair. The percentage of early JPM subjects are the same in both treatments (Pr[early JPM$|SUBS$] = 0.44

[32] We refer the reader to Roberts et al. (2016) for the formal aspects of the estimation procedure. In short, model estimation uses a fast semi-collapsed, variational expectation maximization algorithm where Laplace approximations are used for the non-conjugate portions of the model.

[33] This procedure incorporates measurement uncertainty from the STM model using the method of composition (see Roberts et al., 2019, for details). Appendix G.3 contains the estimated topic proportions for each pair in both treatments and Appendix G.4 delivers a set of examples of chat contents together with estimated topic proportions.

[34] Symmetric strategy pairs that are higher than 24 pay very similar to what JPM pays. For instance $\pi^S(28, 28) = \pi^S(28, 28) = 41.272$ and $\pi^C(24, 24) = \pi^S(24, 24) = 41.696$, whereas $\pi^C(25.5, 25.5) = \pi^S(25.5, 25.5) = 41.94$. Thus, subjects may not be able to coordinate on the most efficient cooperation although they intend to in the first few periods. Our subsequent observations are robust to small changes in the choice of this interval. We believe the choice of 7 periods (instead of 5 or 6) would not be of significant importance for the purpose of this discussion. Details can be provided upon request.



a. Effect of strategic environment. Positive values indicate higher prevalence in the chat content of subjects in complementarity treatment.

b. Effect of JPM behavior. Positive values indicate higher prevalence in the chat content of subjects in JPM pairs.

Figure 10. Mean differences in topic proportions for strategic environment and JPM behavior together with 95% confidence intervals.

Topics		*All*	*Non-JPM*	*JPM*	$p-value$	*Early*	*Eventual*	$p-value$
1	Comp	0.46	0.32	0.49	0.199	0.39	0.60	0.012
	Subs	0.25	0.33	0.22	0.424	0.19	0.28	0.283
	$p-$value	0.001	0.948	0.000		0.009	0.001	
2	Comp	0.23	0.48	0.17	0.034	0.14	0.20	0.278
	Subs	0.33	0.51	0.27	0.081	0.24	0.31	0.412
	$p-$value	0.078	0.855	0.049		0.134	0.173	
3	Comp	0.31	0.20	0.34	0.241	0.47	0.20	0.001
	Subs	0.42	0.16	0.51	0.002	0.57	0.41	0.154
	$p-$value	0.106	0.739	0.020		0.271	0.032	
#	Comp	49	9	40		21	19	
	Subs	36	9	27		16	11	

Table 7. Mean topic proportions. $p-$values are due to two-sided $t-$tests with null hypotheses that topic proportions do not differ.

and Pr[early JPM|$COMP$] = 0.43). This indicates that jumping to JPM is equally likely in both strategic environments. However, it appears that among the pairs who do not reach and sustain full cooperation early on, eventual cooperation is less likely under substitution (Pr[JPM|not early, $SUBS$] = 0.55 and Pr[JPM|not early, $COMP$] = 0.68).

Table 7 shows the mean topic proportions. Note that Topic 1 is more popular among eventual JPM pairs in complementarity. As interim choices (such as 20, 22, and 24) appear with relatively higher frequencies in this topic, we conclude that these pairs reach full cooperation by agreeing on gradual moves towards cooperation. On the other hand, we do not see any significant difference between early and eventual JPM pairs in the substitution. Finally, Topic 3 is used more by JPM pairs in both treatments. While the difference is significant in substitution, in complementarity, it is not. However, this topic is significantly more frequently used by early JPM pairs than eventual JPM pairs in complementarity. These differences point to a possibility that those pairs who managed to reach and sustain full cooperation switch to a more collegial conversation, not necessarily related to the game anymore, reflected by the large weight of the term “mdr”.

5 Conclusion

Social dilemmas are prevalent in economic decision-making processes and strategic environment is argued to have a significant impact on how they are resolved.[35] Our results confirm previous findings, which are clearly identified by PS, that in the absence of communication, aggregate behavior is more cooperative under complementarity as opposed to substitution. Our results beyond this point differ from that of PS, however, in that the higher degree of cooperation under complementarity is not due to the higher degree of reciprocity in our data. Rather, it can be explained by noisy choices and slow learning. Differences in subject pools, as discussed in Footnote 13, can account for these differences.

Our major findings relate to the impact of communication in interaction with the strategic environment. Firstly, communication boosts cooperation levels in both strategic environments. Secondly, communication has an ironing effect regarding the impact of strategic environment, in that the degree of cooperation in two strategic environments becomes the same with communication. Considering many instances in which eliminating communication completely may not be viable, our findings point to that the strategic environment would not matter in terms of cooperation levels (or collusion levels as in oligopoly markets).[36] However, there remain some differences. Communication is more effective in helping participants to cooperate, even if not at the efficient level, in substitution than in complementarity. Also, reaching efficient cooperation happens in a more gradual fashion under complementarity. Our results from the structural topic model estimation show that the use of machine learning techniques can be promising for the content analysis of experimental chat data. Through our estimations, we are able to automatically categorize the topics subjects talk about in their chats according to their cooperative behavior and the strategic environment they are in.

Acknowledgments

We are grateful to Colin Camerer, Jernej Čopič, Charles Holt, Kenan Huremović, Yukio Koriyama, Nikhil Kotecha, Antonin Macé, Aidas Masiliūnas, Paul Pezanis-Christou, Charles Plott, Kirill Pogorelskiy, Jan Potters, Owen Powell, Erik Wengström, Sevgi Yuksel, and participants in Murat Sertel Workshop in Paris, Economic Science Association World Meeting in San Diego, Southwest Experimental and Behavioral Economics Workshop in Santa Barbara, Istanbul Bilgi University Experimental Economics Seminars, Economic Design Workshop at CNAM in Paris, GATE-LSE seminars in Lyon, LAMETA seminars in Montpellier, Behavioral and Experimental Analyses in Macro-finance Workshop in Nice, Theory, Organization, and Markets seminar at Paris School of Economics, CREST Workshop in Experimental Economics, and T&C Chen Center lab meetings at Caltech. We are grateful to Erina Hanaki for translations from French to English.

[35] See Eaton (2004) for an overview of the prevalence of strategic environment effects in social dilemma situations in economic studies. These include patent races, international trade policies, arms races, team productions, public goods, and so on.

[36] Similar conclusions can be drawn for team production instances, in which skills of the members of team might be complements or substitutes, R&D competition in which high spillovers would induce complementarity whereas lower spillovers would induce substitution, and public good production processes, in which the nature of returns to scale would imply complementarity or substitution, among others.

References

Airoldi, E. M. and J. M. Bischof (2016): "Improving and Evaluating Topic Models and Other Models of Text," *Journal of the American Statistical Association*, 111, 1381–1403.

Al-Ubaydli, O., G. Jones, and J. Weel (2016): "Average player traits as predictors of cooperation in a repeated prisoner's dilemma," *Journal of Behavioral and Experimental Economics*, 64, 50–60.

Andersson, O., M. M. Galizzi, T. Hoppe, S. Kranz, K. Van Der Wiel, and E. Wengström (2010): "Persuasion in experimental ultimatum games," *Economics Letters*, 108, 16–18.

Andersson, O. and E. Wengström (2012): "Credible communication and cooperation: experimental evidence from multi-stage games," *Journal of Economic Behavior & Organization*, 81, 207–219.

Arad, A. and S. Penczynski (2018): "Multi-Dimensional Reasoning in Competitive Resource Allocation Games: Evidence from Intra-Team Communication," Working paper.

Arora, S., R. Ge, Y. Halpern, D. Mimno, A. Moitra, D. Sontag, Y. Wu, and M. Zhu (2013): "A practical algorithm for topic modeling with provable guarantees," in *International Conference on Machine Learning*, 280–288.

Awaya, Y. and V. Krishna (2016): "On communication and collusion," *The American Economic Review*, 106, 285–315.

Babutsidze, Z., N. Hanaki, and A. Zylbersztejn (2020): "Nonverbal content and swift trust: An experiment on digital communication," *Available at SSRN 3540258*.

Benoit, K., K. Watanabe, H. Wang, P. Nulty, A. Obeng, S. Müller, and A. Matsuo (2018): "quanteda: An R package for the quantitative analysis of textual data," *Journal of Open Source Software*, 3, 774.

Bigoni, M., J. Potters, and G. Spagnolo (2018): "Frequency of interaction, communication and collusion: an experiment," *Economic Theory*, 1–18.

Blei, D. M. and J. D. Lafferty (2007): "A correlated topic model of science," *The Annals of Applied Statistics*, 17–35.

Blei, D. M., A. Y. Ng, and M. I. Jordan (2003): "Latent dirichlet allocation," *Journal of machine Learning research*, 3, 993–1022.

Blonski, M., P. Ockenfels, and G. Spagnolo (2011): "Equilibrium selection in the repeated prisoner's dilemma: Axiomatic approach and experimental evidence," *American Economic Journal: Microeconomics*, 3, 164–192.

Brandts, J., D. J. Cooper, and C. Rott (2019): "21. Communication in laboratory experiments," *Handbook of Research Methods and Applications in Experimental Economics*, 401.

Brandts, J., M. Ellman, and G. Charness (2015): "Let's talk: How communication affects contract design," *Journal of the European Economic Association*, 14, 943–974.

Breaban, A., C. N. Noussair, and A. V. Popescu (2020): "Contests with money and time: Experimental evidence on overbidding in all-pay auctions," *Journal of Economic Behavior & Organization*, 171, 391–405.

Cason, T. N. and V.-L. Mui (2015): "Rich communication, social motivations, and coordinated resistance against divide-and-conquer: A laboratory investigation," *European Journal of Political Economy*, 37, 146–159.

Cason, T. N., R. M. Sheremeta, and J. Zhang (2012): "Communication and efficiency in competitive coordination games," *Games and Economic Behavior*, 76, 26–43.

Charness, G. and M. Dufwenberg (2006): "Promises and partnership," *Econometrica*, 74, 1579–1601.

——— (2011): "Participation," *The American Economic Review*, 101, 1211–1237.

Cooper, D. J. and J. H. Kagel (2005): "Are two heads better than one? Team versus individual play in signaling games," *The American economic review*, 95, 477–509.

Cooper, D. J. and K.-U. Kühn (2014): "Communication, renegotiation, and the scope for collusion," *American Economic Journal: Microeconomics*, 6, 247–278.

Corazzini, L., S. Kube, M. A. Maréchal, and A. Nicolo (2014): "Elections and deceptions: an experimental study on the behavioral effects of democracy," *American Journal of Political Science*, 58, 579–592.

Crawford, V. P. (2019): "Experiments on Cognition, Communication, Coordination, and Cooperation in Relationships," *Annual Review of Economics*, 11, 167–191.

Eaton, B. C. (2004): "The elementary economics of social dilemmas," *Canadian Journal of Economics/Revue canadienne d'économique*, 37, 805–829.

Echenique, F. (2004): "Extensive-form games and strategic complementarities," *Games and Economic Behavior*, 46, 348–364.

Ellingsen, T. and M. Johannesson (2008): "Anticipated verbal feedback induces altruistic behavior," *Evolution and Human Behavior*, 29, 100–105.

Embrey, M., G. R. Fréchette, and S. Yuksel (2017): "Cooperation in the finitely repeated prisoner's dilemma," *The Quarterly Journal of Economics*, 133, 509–551.

Erev, I. and A. E. Roth (1998): "Predicting how people play games: Reinforcement learning in experimental games with unique, mixed strategy equilibria," *American economic review*, 848–881.

Farrell, J. and M. Rabin (1996): "Cheap talk," *The Journal of Economic Perspectives*, 10, 103–118.

Feinerer, I. (2018): “Introduction to the tm Package Text Mining in R,” *Retrieved March*, 1, 2019.

Fischbacher, U. (2007): “z-Tree: Zurich toolbox for ready-made economic experiments,” *Experimental economics*, 10, 171–178.

Fischer, C. and H.-T. Normann (2019): “Collusion and bargaining in asymmetric Cournot duopoly – An experiment,” *European Economic Review*, 111, 360–379.

Fonseca, M. A. and H.-T. Normann (2014): “Endogenous cartel formation: Experimental evidence,” *Economics Letters*, 125, 223–225.

Gentzkow, M., B. Kelly, and M. Taddy (2019): “Text as data,” *Journal of Economic Literature*, 57, 535–74.

Gentzkow, M. and J. M. Shapiro (2010): “What drives media slant? Evidence from US daily newspapers,” *Econometrica*, 78, 35–71.

Georgalos, K. and J. Hey (2019): “Testing for the emergence of spontaneous order,” *Experimental Economics*, 1–21.

Gomez-Martinez, F., S. Onderstal, and J. Sonnemans (2016): “Firm-specific information and explicit collusion in experimental oligopolies,” *European Economic Review*, 82, 132–141.

Grajzl, P. and P. Murrell (2019): “Toward understanding 17th century English culture: A structural topic model of Francis Bacon’s ideas,” *Journal of Comparative Economics*, 47, 111–135.

Greiner, B. (2015): “Subject pool recruitment procedures: organizing experiments with ORSEE,” *Journal of the Economic Science Association*, 1, 114–125.

Hanaki, N., A. Kirman, and P. Pezanis-Christou (2018): “Observational and reinforcement pattern-learning: An exploratory study,” *European Economic Review*, 104, 1–28.

Hanaki, N., R. Sethi, I. Erev, and A. Peterhansl (2005): “Learning strategies,” *Journal of Economic Behavior & Organization*, 56, 523–542.

Hansen, S. and M. McMahon (2016): “Shocking language: Understanding the macroeconomic effects of central bank communication,” *Journal of International Economics*, 99, S114–S133.

Hennig-Schmidt, H., Z.-Y. Li, and C. Yang (2008): “Why people reject advantageous offers: Non-monotonic strategies in ultimatum bargaining: Evaluating a video experiment run in PR China,” *Journal of Economic Behavior & Organization*, 65, 373–384.

Holt, C. A. (1993): “Industrial organization: A survey of laboratory research,” *The handbook of experimental economics*, 349, 402–03.

Houser, D. and E. Xiao (2011): “Classification of natural language messages using a coordination game,” *Experimental Economics*, 14, 1–14.

Huerta, J. M. (2008): "Relative rank statistics for dialog analysis," in *Proceedings of the Conference on Empirical Methods in Natural Language Processing*, Association for Computational Linguistics, 965–972.

Kimbrough, E., V. L. Smith, and B. J. Wilson (2008): "Historical property rights, sociality, and the emergence of impersonal exchange in long-distance trade," *The American Economic Review*, 98, 1009–1039.

McAllister, P. H. (1991): "Adaptive approaches to stochastic programming," *Annals of Operations Research*, 30, 45–62.

Mengel, F. (2017): "Risk and Temptation: A Meta-Study on Prisoner's Dilemma Games," *The Economic Journal*.

Mermer, A. G., W. Müller, and S. Suetens (2016): "Cooperation in Indefinitely Repeated Games of Strategic Complements and Substitutes," *University of Vienna, Department of Economics*, Working paper.

Mimno, D., H. M. Wallach, E. Talley, M. Leenders, and A. McCallum (2011): "Optimizing semantic coherence in topic models," in *Proceedings of the conference on empirical methods in natural language processing*, Association for Computational Linguistics, 262–272.

Mueller, H. and C. Rauh (2018): "Reading between the lines: Prediction of political violence using newspaper text," *American Political Science Review*, 112, 358–375.

Noussair, C. N., S. Tucker, and Y. Xu (2016): "Futures markets, cognitive ability, and mispricing in experimental asset markets," *Journal of Economic Behavior & Organization*, 130, 166–179.

Penczynski, S. P. (2018): "Using machine learning for communication classification," *Experimental Economics*, 1–28.

Potters, J. and S. Suetens (2009): "Cooperation in experimental games of strategic complements and substitutes," *The Review of Economic Studies*, 76, 1125–1147.

——— (2013): "Oligopoly experiments in the current millennium," *Journal of Economic Surveys*, 27, 439–460.

Roberts, M., B. Stewart, and D. Tingley (2019): "stm: An R Package for Structural Topic Models," *Journal of Statistical Software, Articles*, 91, 1–40.

Roberts, M. E., B. M. Stewart, and E. M. Airoldi (2016): "A model of text for experimentation in the social sciences," *Journal of the American Statistical Association*, 111, 988–1003.

Roberts, M. E., B. M. Stewart, D. Tingley, C. Lucas, J. Leder-Luis, S. K. Gadarian, B. Albertson, and D. G. Rand (2014): "Structural Topic Models for Open-Ended Survey Responses," *American Journal of Political Science*, 58, 1064–1082.

Sabarwal, T. and H. VuXuan (2018): "Two Stage 2x2 Games with Strategic Substitutes and Strategic Heterogeneity," *Available at SSRN 3322176*.

Schotter, A. and B. Sopher (2007): "Advice and behavior in intergenerational ultimatum games: An experimental approach," *Games and Economic Behavior*, 58, 365–393.

Selten, R. and R. Stoecker (1986): "End behavior in sequences of finite Prisoner's Dilemma supergames A learning theory approach," *Journal of Economic Behavior & Organization*, 7, 47–70.

Suetens, S. and J. Potters (2007): "Bertrand colludes more than Cournot," *Experimental Economics*, 10, 71–77.

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

Taddy, M. (2012): "On estimation and selection for topic models," in *International Conference on Artificial Intelligence and Statistics*, 1184–1193.

Vives, X. (2009): "Strategic complementarity in multi-stage games," *Economic Theory*, 40, 151–171.

Waichman, I., T. Requate, et al. (2014): "Communication in Cournot competition: An experimental study," *Journal of Economic Psychology*, 42, 1–16.

Wallach, H. M., I. Murray, R. Salakhutdinov, and D. Mimno (2009): "Evaluation methods for topic models," in *Proceedings of the 26th annual international conference on machine learning*, ACM, 1105–1112.

Wang, S. and D. Houser (2019): "Demanding or deferring? an experimental analysis of the economic value of communication with attitude," *Games and Economic Behavior*, 115, 381–395.

Weingast, B. R. (1995): "The economic role of political institutions: Market-preserving federalism and economic development," *Journal of Law, Economics, & Organization*, 1–31.

Whinston, M. D. (2008): "Lectures on antitrust economics," *MIT Press Books*.

A Instructions for treatments with chat

Authors' note: The following were read aloud and distributed in the beginning of the sessions within chat treatments, for both complementarity and substitution. Aside from these instructions, subjects also received payoff tables.

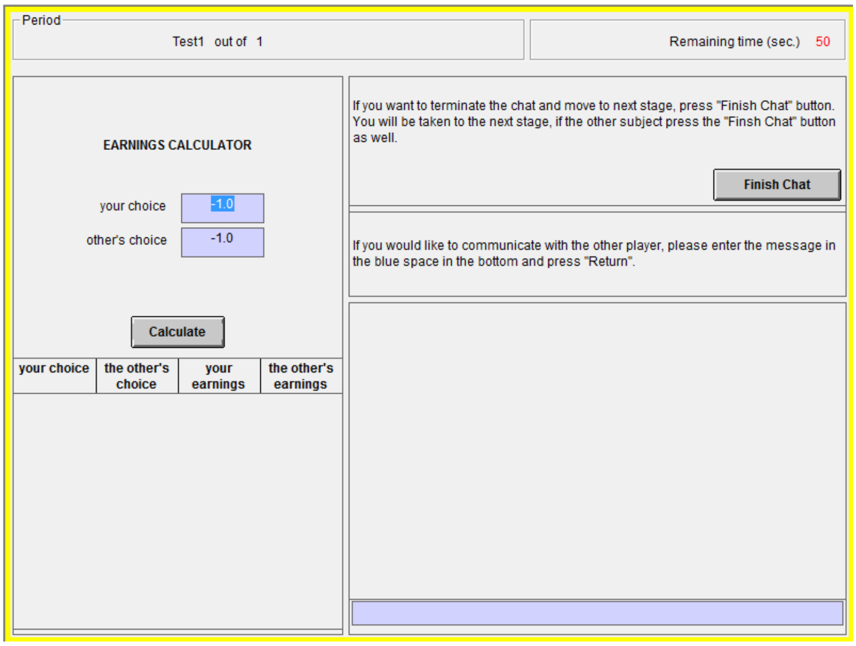
You are participating in an experiment on economic decision-making and will be asked to make a number of decisions. If you follow the instructions carefully, you can earn a considerable amount of money. At the end of the experiment, you will be paid your earnings in private and in cash.

During the experiment you are not allowed to talk to other participants. You can ask your questions after the instructions and before we start the experiment.

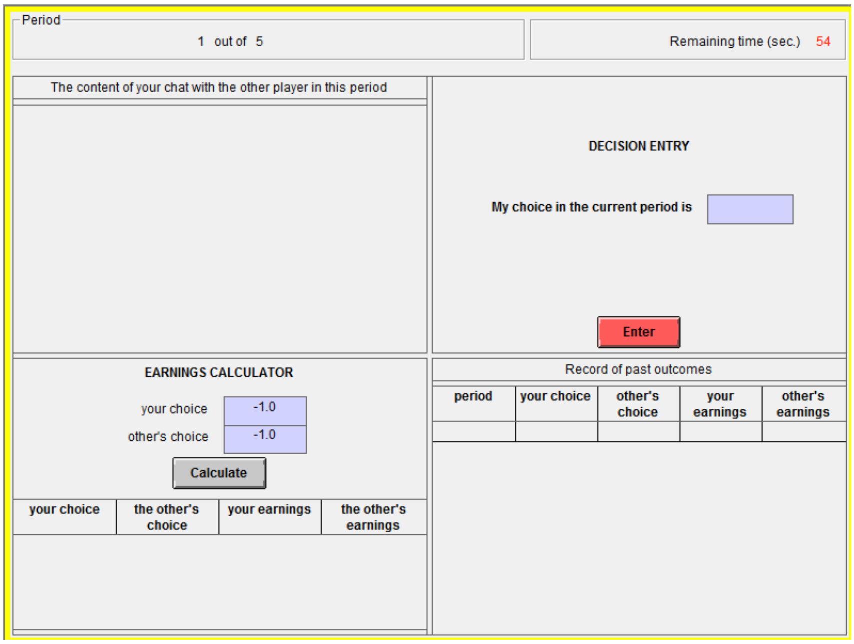
Your earnings depend on your own decisions and on the decisions of one other participant. The identity of the other participant will not be revealed. The other participant remains the same during the entire experiment and will be referred to as "the other" in what follows.

The experiment consists of 30 periods. In each period you have to choose a number between 0.0 and 28.0 (in increments of 0.1 points). The other also chooses a number between 0.0 and 28.0. Your earnings in points depend on your choice and the other's choice. The table you have received gives information about your earnings for some combinations of your choice and the other's choice. The other gets the same table.

At each period there will be two stages. In the first stage you are allowed to communicate with the other. In the second stage you will make a decision. In the first stage, your screen will look like the picture below.



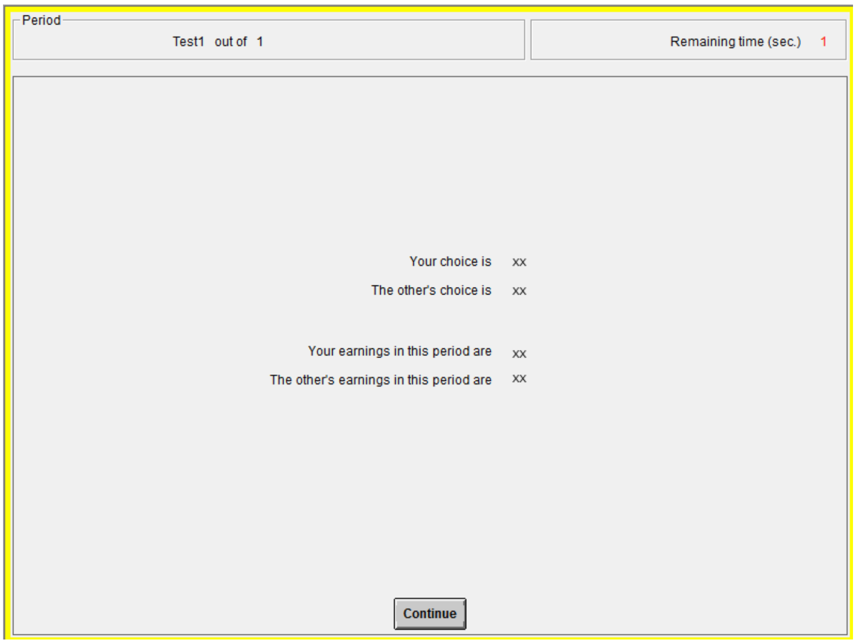
In this first stage, you can calculate your and the other's earnings in more detail (for choices that are not multiples of 2 for instance) by using the EARNINGS CALCULATOR on the left of your screen. On the right, you can communicate with the other through a chat box, during 1 minute. You can type your message in the bar at the bottom right and hit "Return". Only you and the other will be able to see the messages you send and you are allowed to post as many messages as you like. The same is true for the other. The messages you send should not identify yourself (e.g., name, age, gender, location, etc.) in any case and you may not use offensive language. If you want to finish chat before 1 minute, you can click “Finish Chat” button at the top right. If the other also clicks this button, communication will end and you will move to next stage.



In the second stage, your screen will look like the picture below.

In this stage you will not communicate but you will make your decision. You will see the message history at the top left of the screen. At the bottom left, you can use the Earnings Calculator, same as before. At the top right you are asked to type in your choice and click “Enter”. In each period you have about 1 minute to enter your decision. A history of your and the other’s past choices and earnings is available at the bottom right of your screen.

At the end of each period you are informed about the other’s choice and your and the other’s earnings in that period as in the picture below.



Your total earnings in points are the sum of your earnings in points over the 30 periods. Your earnings in points will be converted into EUR according to the rate: 100 points = 1 EUR.

Now we move to the trial period. The result of the trial period will not be counted into your earnings. Please follow our instructions in the trial period.

B Payoff Tables

		Choix de l’ autre ➔														
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0
	0.0	−28.00	−27.96	−27.87	−27.74	−27.57	−27.35	−27.09	−26.78	−26.43	−26.04	−25.60	−25.12	−24.59	−24.02	−23.41
	2.0	−18.16	−17.46	−16.72	−15.93	−15.09	−14.21	−13.29	−12.33	−11.32	−10.26	−9.16	−8.02	−6.84	−5.61	−4.33
	4.0	−10.55	−9.19	−7.78	−6.33	−4.84	−3.30	−1.72	−0.09	1.58	3.29	5.05	6.85	8.70	10.59	12.52
	6.0	−5.16	−3.14	−1.08	1.03	3.19	5.39	7.63	9.91	12.24	14.62	17.04	19.50	22.00	24.55	27.15
	8.0	−2.00	0.68	3.41	6.18	8.99	11.85	14.75	17.70	20.69	23.72	26.80	29.92	33.09	36.30	39.55
	10.0	−1.06	2.28	5.67	9.10	12.57	16.09	19.65	23.26	26.91	30.60	34.34	38.12	41.95	45.82	49.73
Votre	12.0	−2.34	1.66	5.70	9.79	13.93	18.11	22.33	26.59	30.90	35.26	39.66	44.10	48.58	53.11	57.69
choix	14.0	−5.85	−1.19	3.52	8.27	13.06	17.90	22.78	27.71	32.68	37.69	42.75	47.85	53.00	58.19	63.42
➔	16.0	−11.58	−6.26	−0.90	4.51	9.97	15.47	21.01	26.59	32.22	37.90	43.62	49.38	55.18	61.03	66.93
	18.0	−19.54	−13.56	−7.53	−1.46	4.65	10.81	17.01	23.26	29.55	35.88	42.26	48.68	55.15	61.66	68.21
	20.0	−29.72	−23.08	−16.39	−9.66	−2.89	3.93	10.79	17.70	24.65	31.64	38.68	45.76	52.89	60.06	67.27
	22.0	−42.12	−34.82	−27.48	−20.09	−12.65	−5.17	2.35	9.91	17.52	25.18	32.88	40.62	48.40	56.23	64.11
	24.0	−56.75	−48.79	−40.78	−32.73	−24.64	−16.50	−8.32	−0.09	8.18	16.49	24.85	33.25	41.70	50.19	58.72
	26.0	−73.60	−64.98	−56.32	−47.61	−38.85	−30.05	−21.21	−12.33	−3.40	5.58	14.60	23.66	32.76	41.91	51.11
	28.0	−92.68	−83.40	−74.07	−64.70	−55.29	−45.83	−36.33	−26.78	−17.19	−7.56	2.12	11.84	21.61	31.42	41.27

Figure 11. Payoff table for the complementarity treatments. Horizontal axis shows the partner’s choices.

		Choix de l’ autre ➔														
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0
	0.0	−28.00	−22.88	−17.57	−12.09	−6.42	−0.57	5.47	11.68	18.08	24.66	31.42	38.37	45.49	52.80	60.29
	2.0	−22.39	−17.46	−12.35	−7.06	−1.58	4.07	9.91	15.93	22.14	28.52	35.09	41.84	48.77	55.89	63.19
	4.0	−17.43	−12.70	−7.78	−2.69	2.59	8.06	13.70	19.53	25.54	31.73	38.11	44.66	51.40	58.32	65.43
	6.0	−13.13	−8.59	−3.87	1.03	6.12	11.39	16.84	22.47	28.29	34.29	40.47	46.83	53.37	60.10	67.01
	8.0	−9.48	−5.14	−0.61	4.10	8.99	14.07	19.32	24.76	30.38	36.19	42.17	48.34	54.69	61.23	67.94
	10.0	−6.49	−2.34	2.00	6.51	11.21	16.09	21.15	26.40	31.83	37.43	43.23	49.20	55.36	61.70	68.22
Votre	12.0	−4.15	−0.19	3.95	8.27	12.77	17.46	22.33	27.38	32.61	38.03	43.63	49.41	55.37	61.51	67.84
choix	14.0	−2.46	1.30	5.24	9.37	13.68	18.17	22.85	27.71	32.75	37.97	43.37	48.96	54.72	60.67	66.81
➔	16.0	−1.43	2.14	5.89	9.82	13.94	18.24	22.72	27.38	32.22	37.25	42.46	47.85	53.43	59.18	65.12
	18.0	−1.06	2.32	5.88	9.62	13.54	17.64	21.93	26.40	31.05	35.88	40.90	46.10	51.48	57.04	62.78
	20.0	−1.33	1.85	5.21	8.76	12.49	16.40	20.49	24.76	29.22	33.86	38.68	43.68	48.87	54.24	59.79
	22.0	−2.26	0.72	3.89	7.25	10.78	14.49	18.39	22.47	26.74	31.18	35.81	40.62	45.61	50.78	56.14
	24.0	−3.85	−1.05	1.92	5.08	8.42	11.94	15.64	19.53	23.60	27.85	32.28	36.90	41.70	46.68	51.84
	26.0	−6.09	−3.49	−0.71	2.26	5.40	8.73	12.24	15.93	19.81	23.86	28.10	32.52	37.13	41.91	46.88
	28.0	−8.98	−6.57	−3.99	−1.22	1.73	4.87	8.18	11.68	15.36	19.22	23.27	27.50	31.91	36.50	41.27

Figure 12. Payoff table for the substitution treatments. Horizontal axis shows the partner’s choices.

C Payoff evolution and extra sessions

C.1 Payoff evolution

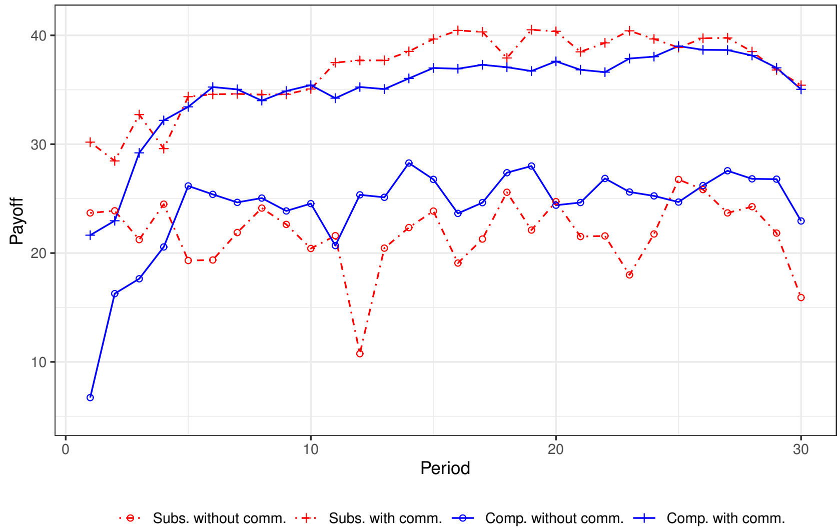


Figure 13. Average payoffs per period for complementarity and substitution treatments with and without chat.

C.2 Communication or extra time?

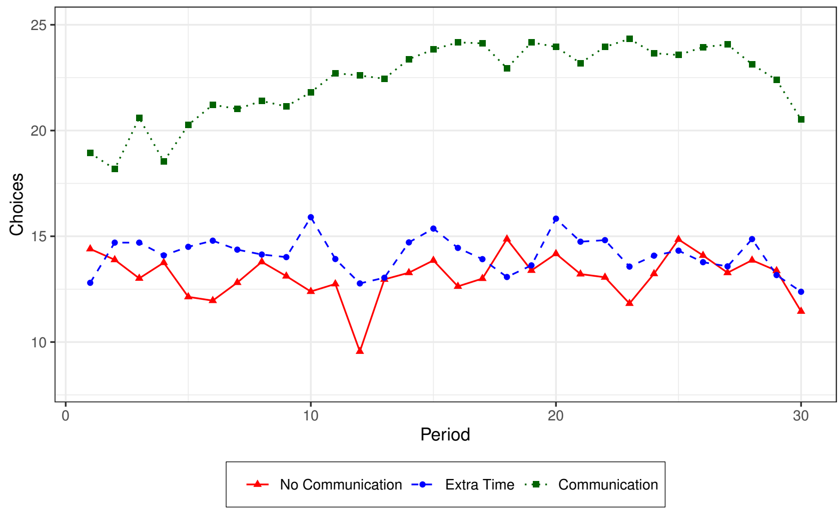


Figure 14. Average choices within each substitution treatment, including extra sessions with extra time without communication.

Here, we provide comparisons with the extra sessions we have run to check if the observed effect of communication is due to the extra time in the communication treatments. Figure 14 shows the average choices for each of the substitution treatments, including extra sessions where

	No Communication	*Extra Time*	*Communication*
Choices	13.13 (7.31)	14.13 (7.47)	22.34 (7.28)
Subjects	64	48	74

Table 8. Average choices within each substitution treatment, including extra sessions with extra time without communication. The WMW test for any pair yield a $p-$value of approximately zero. Tests are run over all periods, thus, cover number of subjects $\times$ 30 observations.

subjects were given the same amount of time as in the communication treatments but were not able to communicate. As can be seen in the figure, choices are very close to the case without extra time and much lower than the treatment with communication. Table 8 shows the average choices (standard deviations) for each treatment.

D Choices in treatments without communication

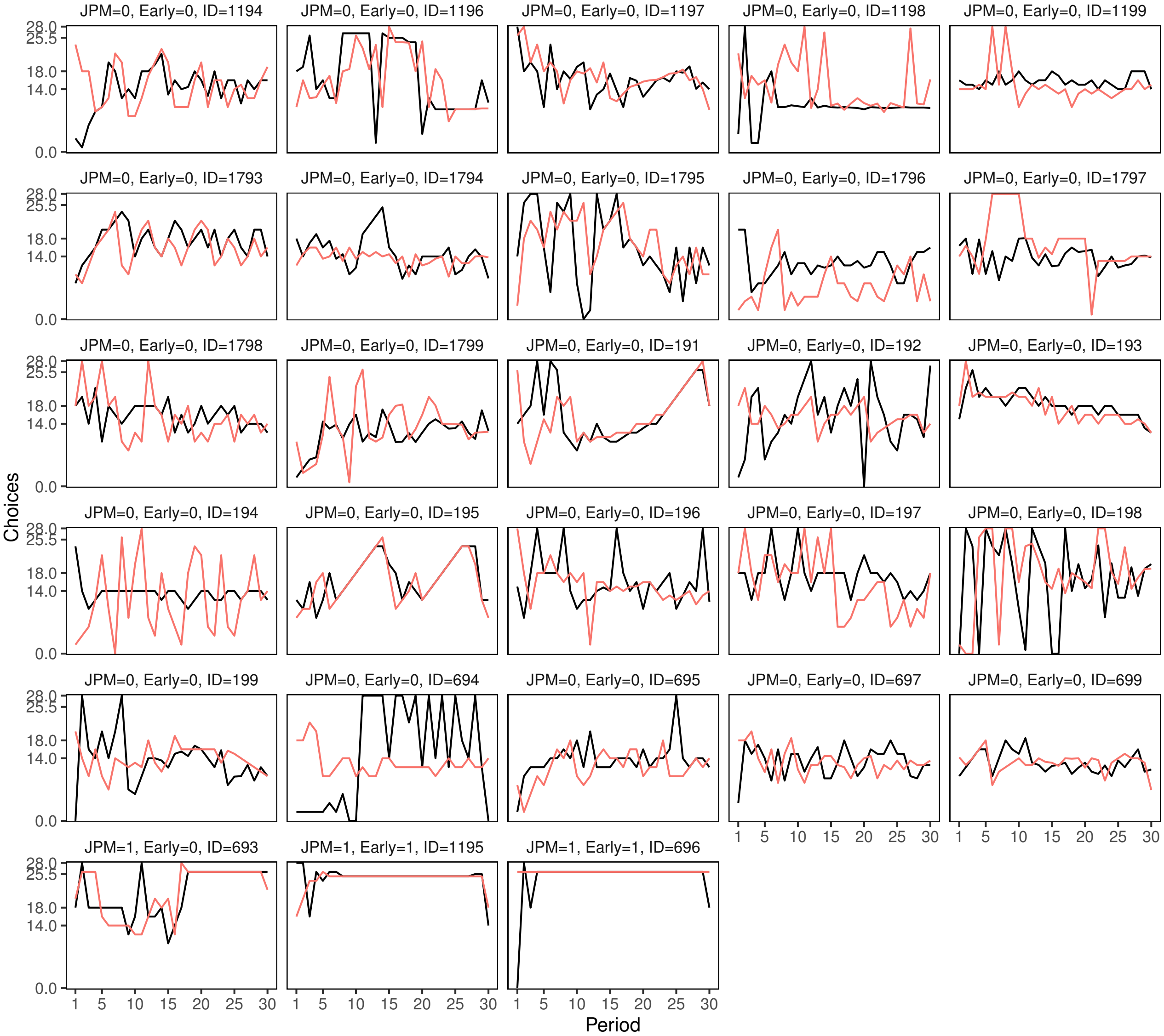


Figure 15. The evolution of choices in pairs under complementarity without communication. Pair IDs are printed on top of each plot next to if the pair is a JPM pair (1, if not 0), and if the pair is an early JPM pair (1, if not 0). The definitions of early and eventual JPM pairs are given in Section 4.3.1. The plots are confined to the strategy space, *i.e.,* the interval $[0, 28]$. Nash equilibrium is 14 and JPM is 25.5 for both strategic environments and the optimal defection choice is 18 for complementarity.

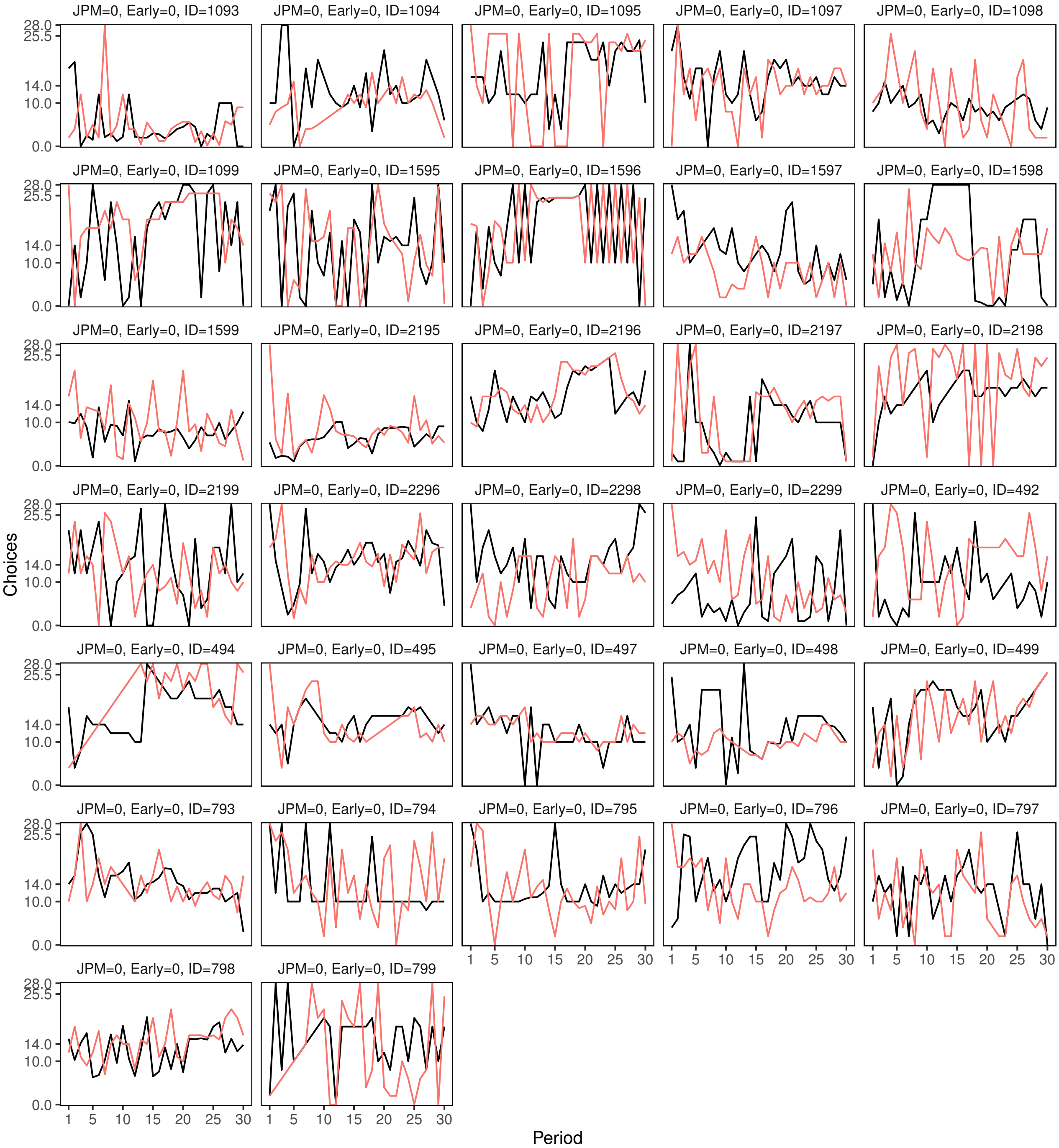


Figure 16. The evolution of choices in pairs under substitution without communication. Pair IDs are printed on top of each plot next to if the pair is a JPM pair (1, if not 0), and if the pair is an early JPM pair (1, if not 0). The definitions of early and eventual JPM pairs are given in Section 4.3.1. The plots are confined to the strategy space, *i.e.,* the interval $[0, 28]$. Nash equilibrium is 14 and JPM is 25.5 for both strategic environments and the optimal defection choice is 10 for substitution.

E Choices in treatments with communication

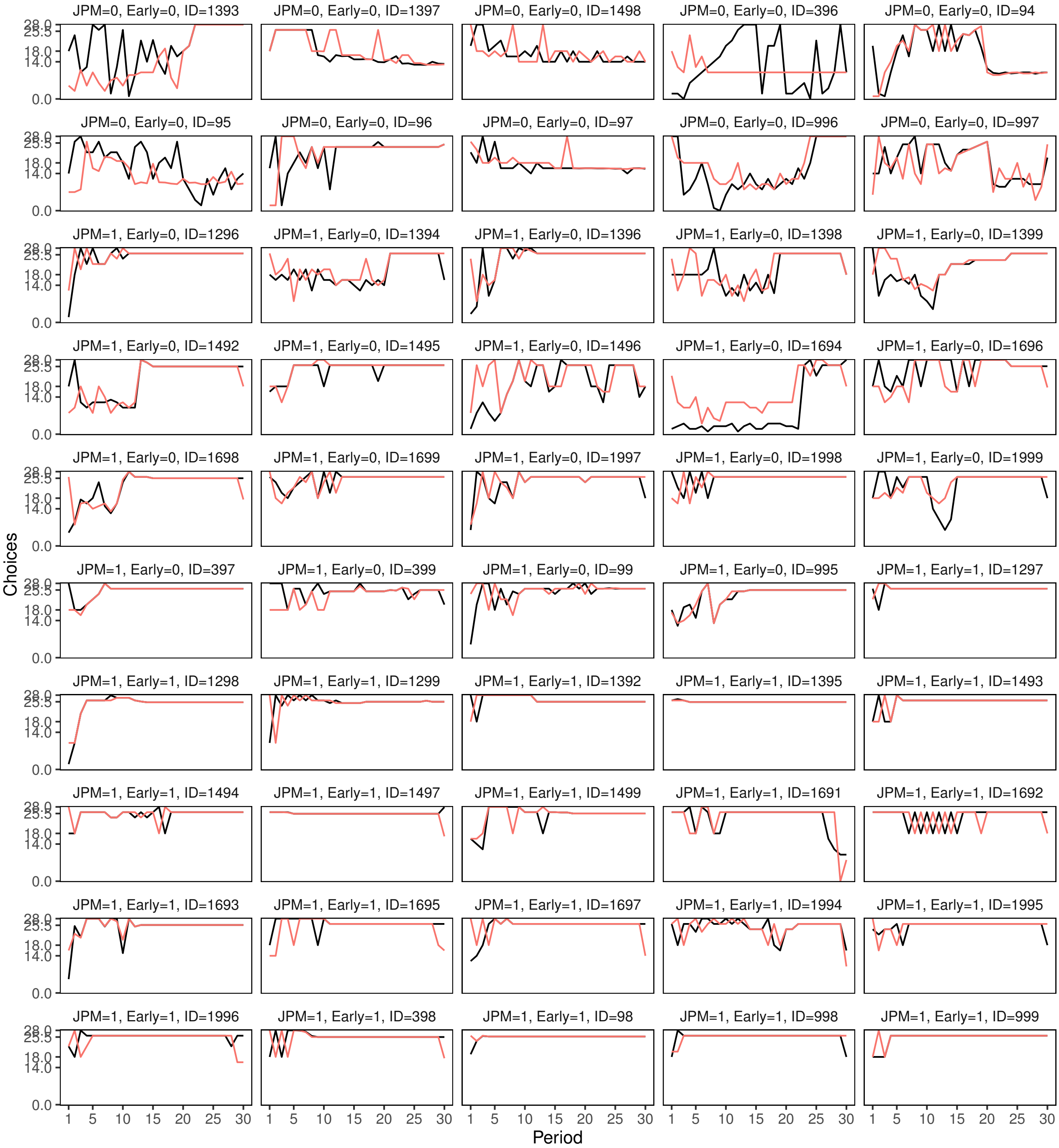


Figure 17. The evolution of choices in pairs under complementarity with communication. Pair IDs are printed on top of each plot next to if the pair is a JPM pair (1, if not 0), and if the pair is an early JPM pair (1, if not 0). The definitions of early and eventual JPM pairs are given in Section 4.3.1. The plots are confined to the strategy space, *i.e.*, the interval $[0, 28]$. Nash equilibrium is 14 and JPM is 25.5 for both strategic environments and the optimal defection choice is 18 for complementarity.

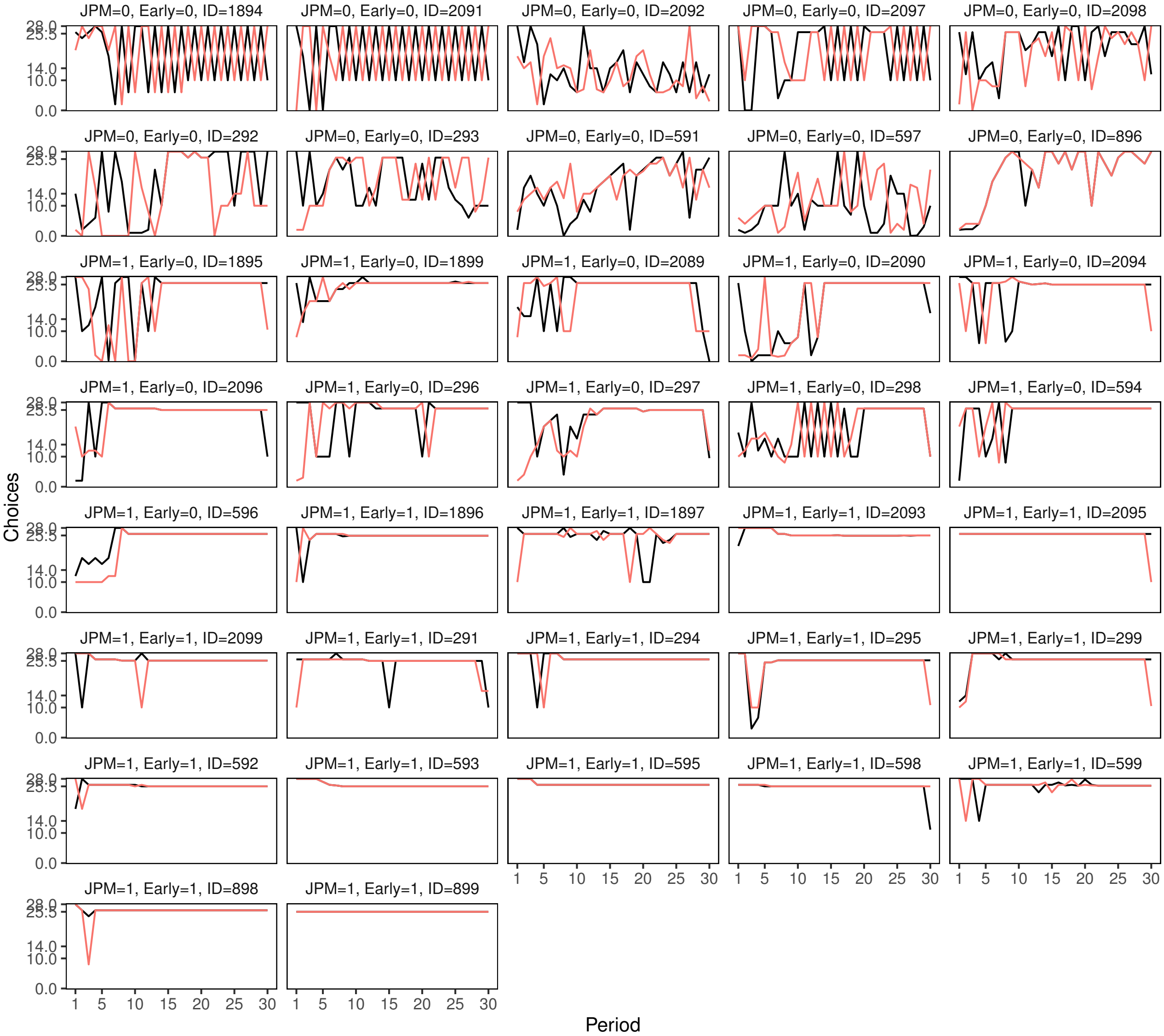


Figure 18. The evolution of choices in pairs under complementarity with communication. Pair IDs are printed on top of each plot next to if the pair is a JPM pair (1, if not 0), and if the pair is an early JPM pair (1, if not 0). The definitions of early and eventual JPM pairs are given in Section 4.3.1. The plots are confined to the strategy space, *i.e.*, the interval $[0, 28]$. Nash equilibrium is 14 and JPM is 25.5 for both strategic environments and the optimal defection choice is 10 for substitution.

F Further content analysis data

Term	*Translation*	*Rank Subs*	*Rank Comp*	*Term*	*Translation*	*Rank Subs*	*Rank Comp*
met	put	1	3	sai	know	28	53
26	26	2	1	rien	nothing	29	40
28	28	3	2	25.5	25.5	30	47
plus	more	4	4	croi	believe	31	52
mdr	lol	5	8	20	20	32	21
gagn	win	6	5	veux	want	33	32
bon	good	7	14	gain	earn	34	26
deux	two	8	9	encor	again	35	36
10 (18)	10 (18)	9	6	trop	too much	36	50
foi	time	10	13	moin	less	37	30
comm	like	11	12	continu	continue	38	38
mieux	better	12	10	parc	because	39	73
même	same	13	7	l'autr	the other	40	51
2	2	14	15	grave	serious	41	118
pens	think	15	25	12	12	42	48
mainten	now	16	43	compri	understood	43	49
bien	good	17	19	dernier	last	44	55
tour	turn	18	28	invers	inverse	45	37
point	point	19	31	peu	little	46	35
24	24	20	11	chaqu	each	47	33
faut	must	21	16	fin	end	48	34
haha	haha	22	22	toujour	always	49	46
d'accord	agreed	23	20	dis	said	50	70
aussi	too	24	27	22	22	60	17
pareil	same	25	18	25	25	91	23
mettr	to put	26	24	temp	time	52	39
rest	rest	27	29	meilleur	best	70	42

Table 9. Most frequent (stemmed) terms depicted in Figure 8 with English translations and ranks in both treatments.

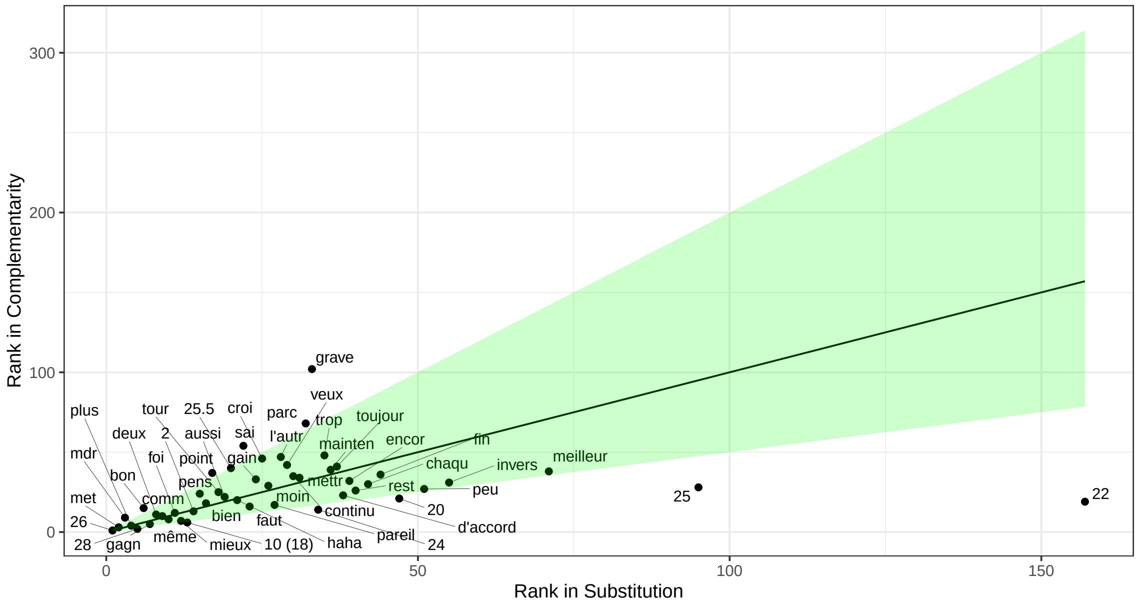


Figure 19. The ranks of 40 most frequently used words by JPM pairs in both treatments.

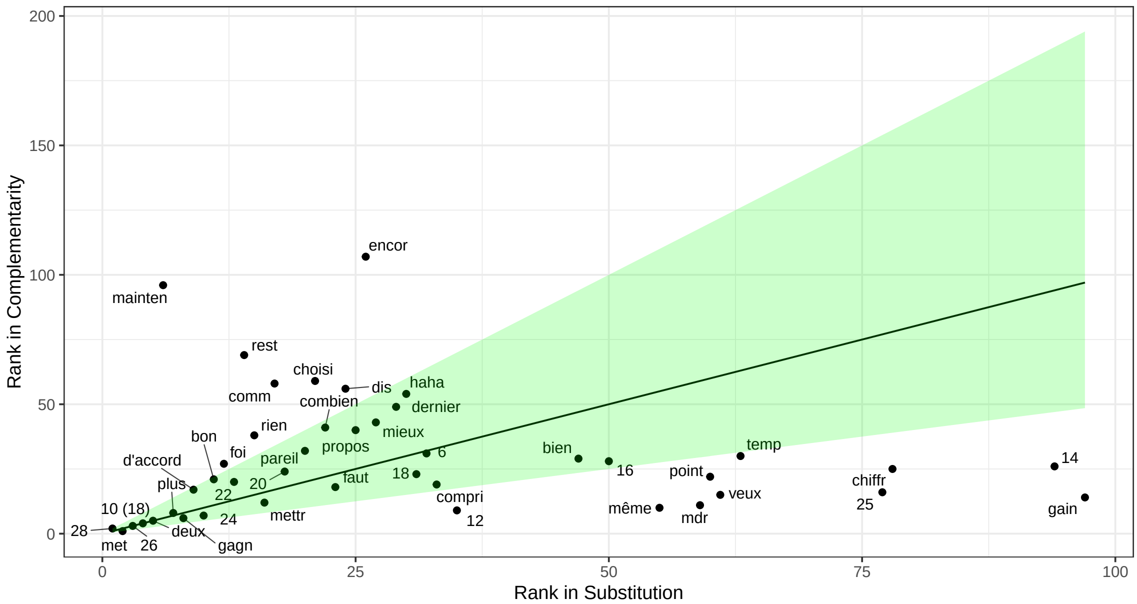


Figure 20. The ranks of 30 most frequently used words by non-JPM pairs in both treatments.

G STM Specifications

G.1 Removed stopwords

"a, à, ah, ai, aie, aient, aies, ait, aller, allez, alors, apres, après, as, au, aura, aurai, auraient, aurais, aurait, auras, aurez, auriez, aurions, aurons, auront, aux, avaient, avais, avait, avec, avez, aviez, avions, avoir, avons, ayant, ayez, ayons, bah, bjr, bonjour, c, c'est, c'était, ca, ça, cb, ce, ceci, cela, celà, ces, cest, cet, cette, chose, coup, d, dans, de, des, donc, dsl, du, e, elle, en, es, est, et, étaient, étais, était, étant, été, êtes, étiez, étions, etre, être, eu, eue, eues, eûmes, eurent, eus, eusse, eussen, eusses, eussiez, eussions, eut, eût, eûtes, eux, fai, fair, faire, fais, fait, fûmes, furent, fus, fusse, fussent, fusses, fussiez, fussions, fut, fût, fûtes, ici, il, ils, j, j'avais, j'en, je, l, la, là, le, les, leur, leurs, lui, m, m'a, m'as, ma, mais, me, même, mes, mis, mm, moi, mon, n, nan, ne, nn, non, nos, notre, nous, o, ok, on, ont, ou, ouai, ouais, oui, ouii, p, par, pas, pas, peut, pour, pr, q, qu, qu'il, qu'ils, qu'on, quand, que, quel, quelle, quelles, quels, qui, quoi, quon, re, s, s'il, sa, salut, sans, se, sera, serai, seraient, serais, serait, seras, serez, seriez, serions, serons, seront, ses, si, sinon, soi, soient, sois, soit, sommes, son, sont, sous, soyez, soyons, suis, sur, t, t'en, t'es, ta, te, tes, toi, ton, tous, tout, tres, très, tt, tu, un, une, va, vais, vas, vera, viens, vos, votre, vous, x, xd, y, ya"

G.2 Model Selection

As is necessary for any mixed-membership topic model, STM entails multi-modal estimation that may depend on starting values of parameters such as the distribution over words for a particular topic. In this paper we utilize an initialization method that is known as spectral initialization, which based on the method of moments that is deterministic and globally consistent under reasonable assumptions (see Arora et al., 2013). Under spectral initialization, the only remaining choice pertains to the number of topics to estimate, which involves, in general, evaluating outcomes of estimations for different numbers according to some criteria. In our exercise, we followed the methodology suggested by Roberts et al. (2019). We paid particular attention to four criteria. The first one is *semantic coherence* developed by Mimno et al. (2011), which is maximized when the most probable words in a given topic frequently co-occur together. As shown by Mimno et al. (2011), the criterion correlates well with human judgment of topic quality. Formally, let $D(v, v')$ be the number of times that words v and v' appear together in a document. Then given the number of topics K in the model, for the list of M_k^K most probable words in topic k, the semantic coherence for topic k, C_k^K, is computed as

$$C_k^K = \sum_{i=2}^{M_k^K} \sum_{j=1}^{i-1} \log\left(\frac{D(v_i, v_j) + 1}{D(v_j)}\right).$$

Second, it is desirable to have topics that can be distinguishable, *i.e.,* they are *exclusive* to topics. For this purpose, another criterion called *FREX* is proposed by Roberts et al. (2019) (following Airoldi and Bischof, 2016), which assesses the degree to which high probability words across topics coincide. FREX, what we denote by ϕ, is a weighted harmonic mean of the word's

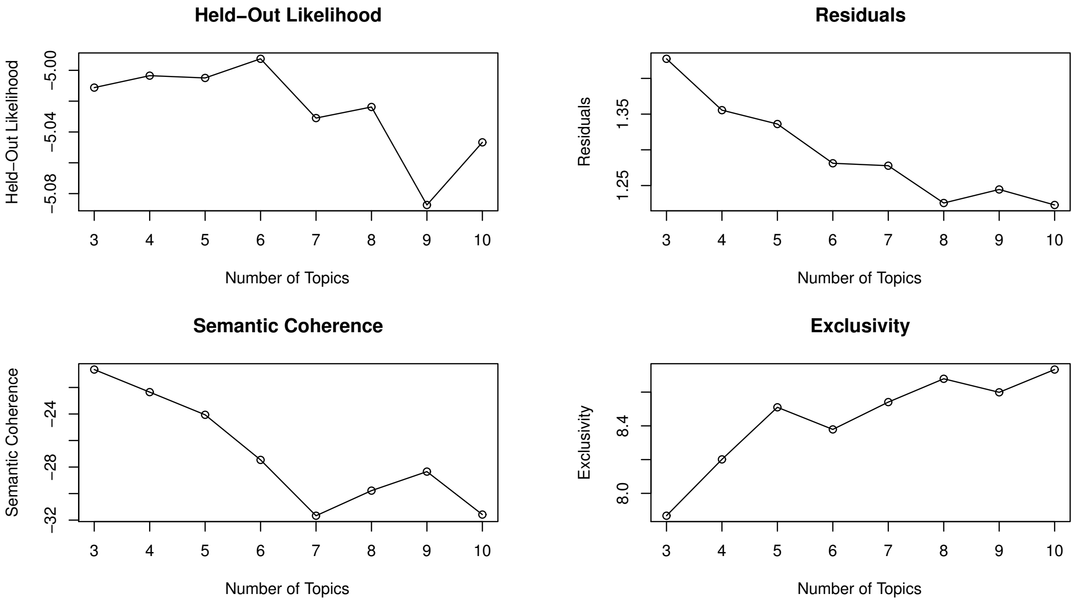


Figure 21. Diagnostics.

rank in terms of exclusivity and frequency. Formally,

$$\phi_{k,v}^{K} = \left(\frac{\omega}{ECDF(\beta_{k,v}/\sum_{j=1}^{K}\beta_{j,v})} + \frac{1-\omega}{ECDF(\beta_{k,v})} \right)^{-1},$$

where $\beta_{k,v}$ is the probability of the word v in topic k, ECDF is the empirical CDF, and ω is the weight given to exclusivity.[37] For a topic k, the *exclusivity* of the topic, ϕ_k^K, is calculated as the average of the top M_k^K words.

A topic that is both cohesive in its words and exclusive is more likely to be semantically relevant. Furthermore, we check *residual dispersion* (Taddy, 2012) and *held-out likelihood* (Wallach et al., 2009) values. Computing these measures are straightforward within the `stm` package. Taddy (2012) proposes the following residual analysis. First, the sample dispersion of the residuals is obtained by dividing the mean of the squared adjusted residuals by the degrees of freedom parameter, which itself is obtained by approximating the parameter $\hat{N}$ by the number of expected counts exceeding a tolerance level (set to 100). When the model is correctly specified, the multinomial likelihood implies that dispersion of residuals is 1. Hence, if the computed sample dispersion is greater than this, the number of topics might be too low, because the latent topics are not able to account for the variation. We also computed the document-completion held-out likelihood that is the estimation of the probability of words being used by a subject when those words have been removed in the estimation.[38] Figure 21 shows relationship between these measures and the number of topics.

We have chosen three topics as this gives the highest semantic coherence without a significant

[37] We take $\omega = 0.7$, following Roberts et al. (2019).
[38] 50% of the content of 10% of documents are held out.

loss in terms of held-out likelihood. Both the residual analysis and exclusivity naturally point to higher number of topics. As the residuals constraint can never be satisfied within our topic number interval, and exclusivity may not be a major concern in a specific context such as our experiment, we are not worried about the low performance of the three-topic model on these measures. We believe including more topics in the estimation would not add to our analysis.

G.3 Estimated topic proportions within pairs

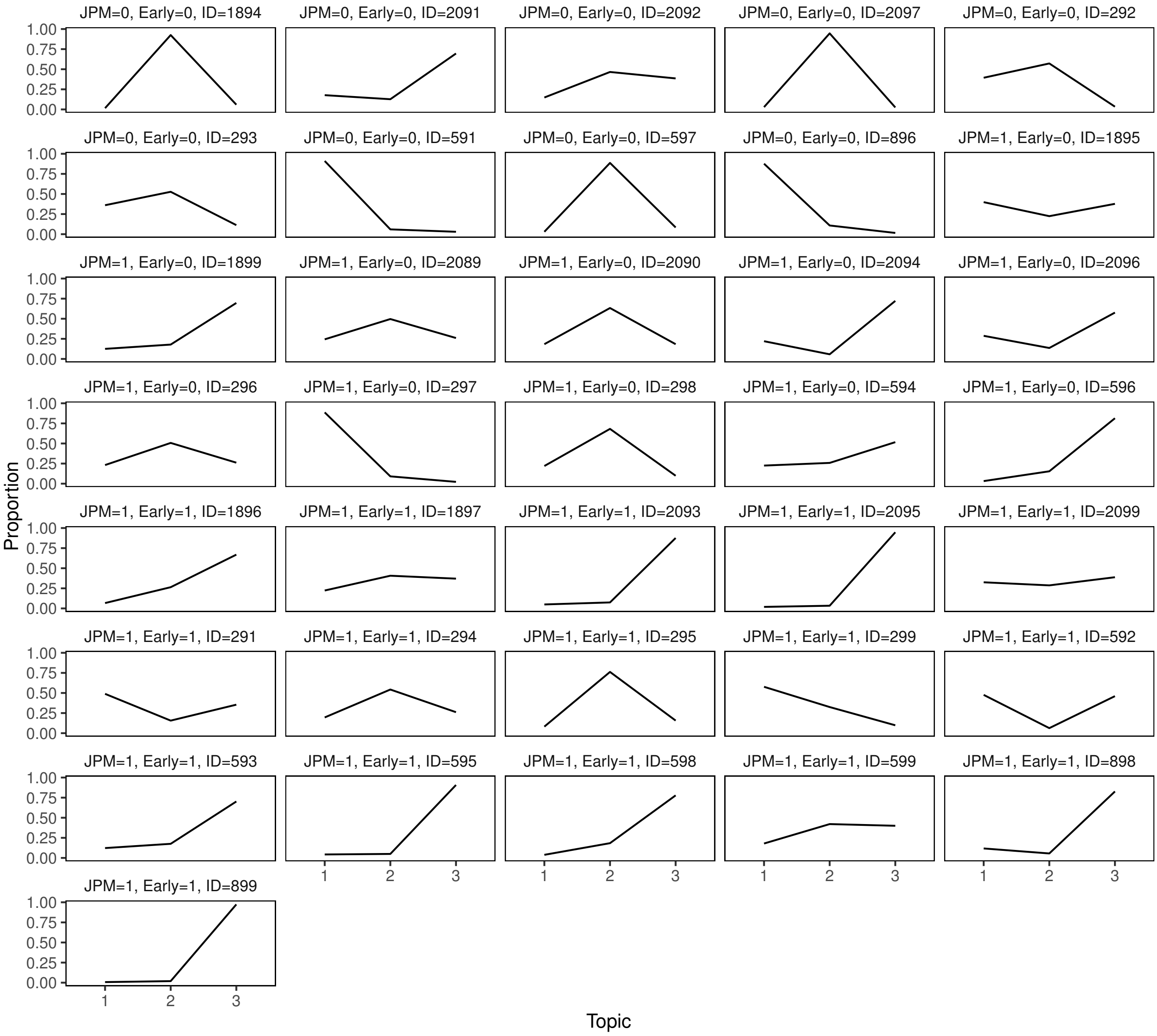


Figure 22. Estimated topic proportions within pairs in substitution treatment.

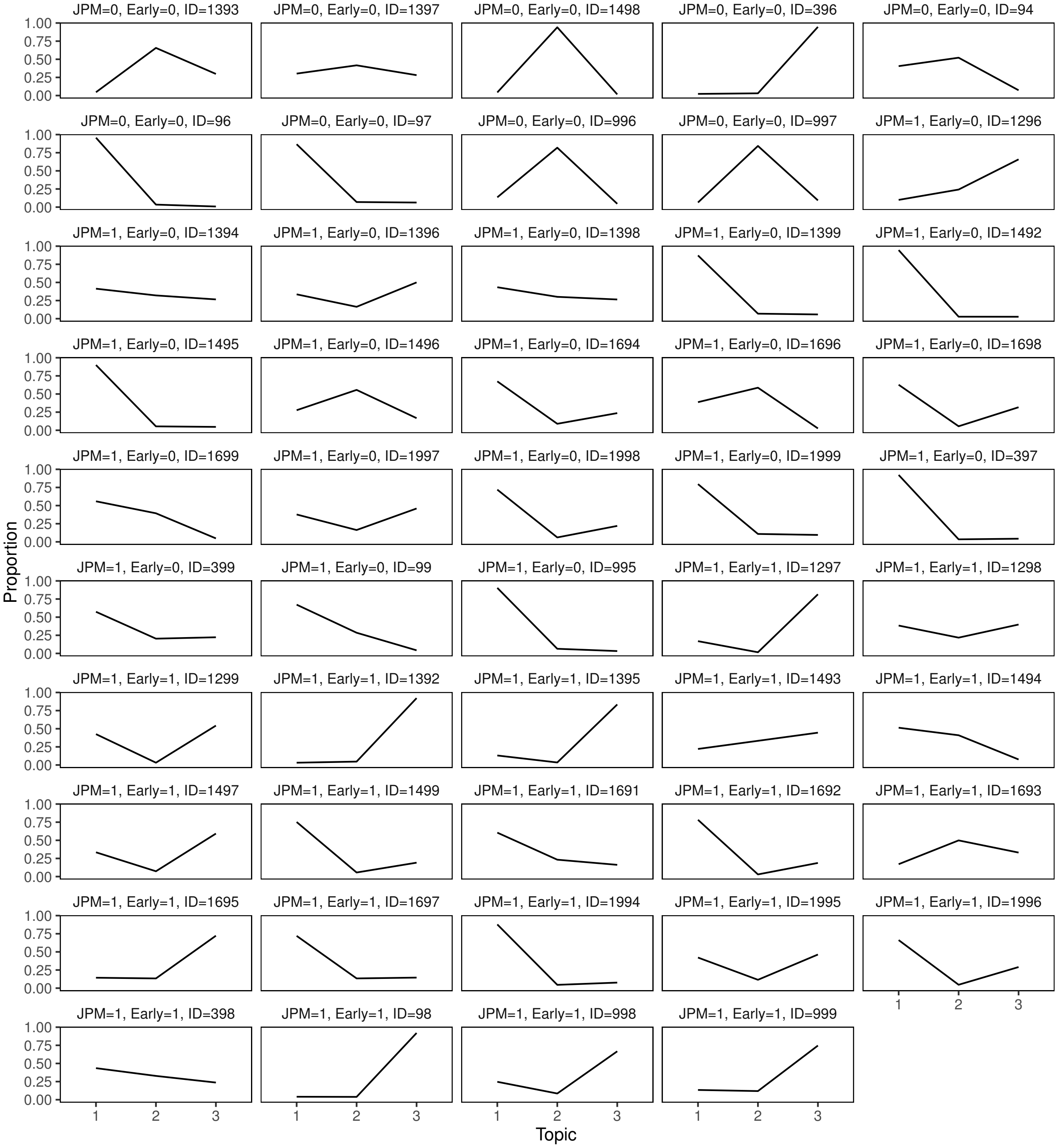


Figure 23. Estimated topic proportions within pairs in complementarity treatment.

G.4 Chat record examples

1	*2*	*3*
0.92	0.03	0.04

Table 10. Estimated topic proportions in Pair 397.

Period	*Player*	*Message*	*English translation*
0	1	bonjour	hello
1	1	je propose de choisir 18.0	I propose to choose 18.0
1	2	ca marche	alright
2	1	choisir 18.0	choose 18.0
2	2	nous sommes censés choisir le mm nombre?	Are we suppose to choose the same number ?
2	2	??	??
3	1	18.0	18.0
3	2	moi 16	me 16
4	1	?	?
4	2	je cherche un peu sur le tableau pr voir la meilleure combinaison pr nous 2	I'm looking a little bit on the table to see the best combination for us two
4	2	20 pr ns 2	20 for us two
5	2	22 pr nous 2	22 for us two
6	2	tu penses qu on est sur la b onne voie ?	Do you think that we're on right track ?
6	1	OUI	YES
6	2	24 pr ns 2	24 for us two
6	1	OK	OK
7	2	propose	propose
7	1	28.0 POUR NS	28 for us
7	2	ok	ok
8	2	26 ?	26 ?
8	1	OK	OK
9	1	ON CONTINUE COMME ÇA	We keep doing like this
9	2	si tu vx on reste sur le 26	We keep 26 if you want
9	1	OUI	YES
9	1	C MIEUX	It's better
9	2	ok ca marche	Ok alright
10 -14			
15	2	tu penses que c ce qu il faut faire :d ?	Do you think that it's what we have to do ?
15	1	OUI	YES
15	1	JE CROIS	I THINK
15	2	okk	Ok
16 - 19			
20	2	c ennuyeux	It's boring
20	1	C VRAI	it's true
21 - 30			

Table 11. Chat record of Pair 397 in time order within periods.

1	*2*	*3*
0.05	0.66	0.30

Table 12. Estimated topic proportions in Pair 1393.

Period	*Player*	*Message*	*English translation*
0	2	Bonjour	Hello
0	1	bonjour	Hello
1	1	faut qu'il y en ai un qui mettre des chiffres entre 18 et 20 et l'autre entre 26 et 28?	There has to be one who puts a number between 18 and 20 and the other between 26 and 28 ?
1	2	J'ai pas trop compris le bus de la boite de dialogue, je rentre le chois 6.0	I didn't quite understand the bus (*purpose*) of the box of the dialogue, I put in the choice 6.0
1	2	Je ne sais pas	I don't know
2	1	on met quoi,	What do we put in ?
2	2	Il faut être en fonction du tableau pour avoir le plus de gains possibles c'est ca?	It has to be that accorded to the table, to have the biggest gain hasn't it ?
2	2	je mets 26?	Do I put in 26 ?
2	1	JE PENSE	I THINK
2	1	MOI 24	ME 24
2	1	oklm	Cosy
2	2	on brasse	Let's do it
3	2	je mets 28	I put in 28
3	2	c quoi le but de la periode ?	What's the purpose of the period?
3	1	mois 10	month (*me*) 10
3	1	rien compris je suis a mopins la	I don't understand anything
3	1	moins	minus
3	2	moi non mais je comprends pas pq	Not me but I don't understand why
3	1	t'as mis 3 au dernier truc?	Did you put 3 in the last thing ?
3	2	oui	yes
3	2	et toi	and you
3	1	24	24
4	2	moi 13 c ca?	me 13 is it ?
4	1	moi 12	me 12
4	1	si tu veux	If you want
4	2	ca marche	alright
4	2	faut etre en fonction des colonnes donc toi tes horizontale ou verticale ?	We have to be by the columns so are you horizontal or vertical ?
4	1	je sais pas chacun sa colonne	I don't know each one his column
5	2	on emet tous les deux 28?	We both put 28 ?
5	2	met	put
5	1	oui on essaye voir c'que ca fait	Yes we try to see what it does
5	2	tu veux verticale ou horizontale pour la suite ?	Do you want horizontal or vertical for the rest?
5	1	28 tous les deux ca devrait faire 41.27	28 for us two should make 41.27
5	2	c'est bon ca	This is good
5	1	c'est pareil mdr j'essaye de comprendre leur truc la	It's the same lol I'm trying to understand their thing now
5	2	moi je comprensd pas	I don't understand it
5	1	j'crois j'comprend kla	I think I understand now

Table 13. Chat record of Pair 1393 in time order within periods.

Period	*Player*	*Message*	*English translation*
6	2	je mets 12 toi 28?	I put 12 and you put 28?
6	1	j'ai pris -45	I took -45
6	1	mdrrr	lol
6	2	je sais mdr	I know lol
6	2	12 48?	12 48?
6	1	les escroc et toi t'as gagne	The scammers and you won
6	2	cest ca le style	That's cool
6	1	atyt j'essay un chiffe garde le 28	Wait I try a number, keep the 28
6	2	je mtes 28?	Do I put 28?
6	1	oui	Yes
7	2	dis moi ton chiffre j'aui du mettre au hasard	Tell me your number that I probably put randomly
7	1	mais serieux	Seriously
7	2	mdrrrrrr	lol
7	2	on met quoi	What do we put
7	2	s	s
7	2	je te suit	I follow you
7	1	j'met 28 met au hasard toi	I'm putting 28, you put randomly
7	2	moi je mets 12	I put 12
7	1	ok	12
7	1	j'vais finir a -1000	I am going to end at -1000
7	2	pas beaucoup de sous tout ca	That's not a lot of money
7	2	mdr c toi qui va devoir payer	lol it's you who will have to pay it
8	2	MAIS JE COMPRENDS PAS	BUT I DON'T UNDERSTAND
8	2	je mets 22 toi 44 ?	I put 22 and you put 44 ?
8	1	j'suis tellement en negatif qu'ils vont me demander de l'argent a la fin	I am so much in the minus that they will ask me money at the end
8	2	cest hyper bizarre	It's so strange
8	2	mdrrrr oui c'est c	lol yes exactly
8	2	a	a
8	1	moi je met 3	I put 3
8	2	mais pq les impairs c pas dans le tableau ?	But why aren't the odd numbers in the table ?
8	1	au point ou j'en suis je tente de toucher le jackpot	At the situation I am I'm trying to touch the jack-pot
9	2	tableauuuuuuuu	Tableeeeeee
9	1	faut qu'on retente le 12 13	We have to try 12 13 again
9	2	la periode on est d'accord c totalement au hasard ?	We agree that the period is completely random ?
9	1	je met 12 et toi 13	I put 12 and you put 13
9	1	oui	yes
9	2	pa 12 et 13	Not 12 and 13
9	2	j'aime pas 13	I dont like 13
9	2	je peux pas mettre 14 ?	Can't I put 14 ?
9	1	si tu veux	If you want
9	2	periode au hasard ?	random period ?
9	1	quand tu calculs dans leur truc tu gagnes a chauqe fois et le rien	If you calculate in their thing you win every time and the nothing
10	2	On essaie meme chiffre meme periode ?	Do we try same number same period ?
10	1	j'ai des pointqs!!!!!!!	I have points!!!!!
10	2		
10	2	BRAVO	CONGRATULATION
10	1	oui si tu veux	Yes if you want
10	2	on met quoi	What do we put
10	1	quel chiffre?	Which digit ?
10	1	mdrr meme question	lol same question
10	2	26	26
10	1	ok	ok
10	2	et periode...... decide	and period...... decide
10	1	tu vas gagner des points toi et(moi negatif	You are going to win points and (me negative
10	2	si on gagne pas pareil c cheloui	If we don't win in the same way it's weird
10	2	pourquoi	Why

Table 14. Chat record of Pair 1393 in time order within periods.

Period	*Player*	*Message*	*English translation*
11	2	ok mauvauise technique	Okay bad technique
11	2	mdr	lol
11	2	je t'écoute mtnt	I'm listening to you now
11	1	STOPPPP	STOPPPP
11	2	donne moi tes instructions	Give me your instructions
11	1	mais pk tu gagnes toujours et pas moi	But why do you always win and not me
11	2	pacq je suis trop fraiche	Because I'm too fresh
11	1	meme quand on met les memes resultats moi j'perd -50 et toi +	Even when we put the same answersI lose -50 and you +
11	2	trop trop bizarre	so so weird
11	1	y a un truc la	There's something here
11	2	je mets quoi tu mets quoi	Why do I put and what do you put
11	2	dis moi	tell me
11	2	10 sec	10 seconds
11	1	viens on met hasqard	Let's put randomly
12	2	moi je pense c la periode qui fait tout	I think that it's the period which does everything
12	1	et allez encore	and again
12	2	le reste c du baratin	the others are spiels
12	1	ca change qsuoi la periode	What does the period change
12	2	Jsais pas regarde on met les mm chiffres et une periode différente	I don't know look we put the same numbers and a different period
12	2	résultat : t'es en moins	result : you are in minus
12	2	moi en plus	me in plus
12	2	donc bon...	So yes
12	1	vas y on met 10 et 12	Let's put 10 and 12
12	2	periode : 9	period : 9
12	2	moi 10	me 10
12	1	9 alors	9 then
13	2	ok donc on fait en fonction du tableau	Ok so we do based on the table
13	1	t'as mis 9?	Did you put 9?
13	2	acvec les meme periodes	With the same periods
13	2	oui en periode jai mis 9	yes I put 9 as a period
13	1	on met 10?	do we put 10?
13	2	en periode ?	as a period ?
13	2	et en chiffre on met 22 22	and as numbers we put 22 22
13	2	?	?
13	1	on voit ou la periode?	where do we see the period?
13	2	c la deuxieme etape	it is the second step
13	1	si tu veux	if you want
13	2	ok 22 periode 10	ok 22 period 10
13	2	deterr	decided
14	2	t'aqs mis la meme periode ?????	Did you put the same period ?????
14	1	c'est quoi la periode????	What's the period????
14	2	la 2e etape la	the second step now
14	1	c'est ou que t'ecris la periode??	Where do you write the period??
14	2	jappelle ca periode	I call it period
14	2	en haut a droite apres ca	On the top at the right after this
14	1	j'ai qu'une etape moi c'est ecrire un chiffre	I only have one step and it is to write a number
14	2	oui c ca	yes it is that
14	1	moi j'ai ecris 22 c'zest tout	I wrote 22 and that's all
15	1	t'as mis cb?	How many did you put?
15	1	moi 14	me 14
15	2	EN FAIT C MIEUX QUAND Y A PAS DE STRATEGIE ET QU'on met au hasard	ACTUALLY IT'S BETTER WHEN THERE IS NO STRATEGY AND THAT we put randomly
15	2	moi 10	me 10
15	1	oui voila	yes that's right
15	2	la je mets 26 fais ta life	here I put 26 and you do whatever you want
15	1	ok	ok

Table 15. Chat record of Pair 1393 in time order within periods.

Period	*Player*	*Message*	*English translation*
16	2	jai pas compris	I didn't understand
16	1	hello	hello
16	2	salut	hi
16	1	on fait notre life mtn	we do whatever we want now
16	2	ca marche	alright
16	1	c'est cheaté	it is cheating
16	2	je capte rien ca me gave	I don't get anything I'm enough
16	2	encore 1h.....	still 1 hour.....
16	1	pareil	same
17	1	rien compris	I understand nothing
17	2	bah moi non plus	well me neither
17	2	mais y a rien a comprendre a mon avis	but I think that there's nothing to understand
17	2	ils testent notre facon de reflechir	they are testing our way of thinking
17	2	et la ils captent qu'on est pas tres intelligents	and now they understand that we are not very smart
17	1	mais quand tu fais dans le calculateur de gain ca donne jamais al meme chose	but when you do in the calculator of the gain it never gives the same thing
17	2	bah nan c ca qui est bizarre	well that's what's weird
17	1	c'est quoi le delire laaa	What's the problem hereee
18	2	on fait quoi	what do we do
18	2	concretement la	concretely now
18	2	ca m'agace	it annoys me
18	1	ils ont peur qu'on gagne trop le l'experience est truquée mdr	they are afraid that we win too much the experiment is tricked lol
18	2	mdrrrrr c surement ca	lol it's certainly that
18	2	je mets tt le tps pareil mtnt	I always put the same now
19	1	gavaoooo	I'm enooouugh
19	2	et encore 1h	and still 1 hour
19	2	on va se faire 1 euro	we are going to make 1 euro
19	1	jamais	never
19	2	c cool :)	it's cool
19	2	garrooooo	
19	1	t'facon ils vont me demander de l'argent avec mon score negatif j'me barre en courant	they are going to ask me money anyway with my minus score I will run to escape
19	2	mdrrrr la fuite	lol the escape
20	2	dans les previsions ils disaient que j'avais 20 points et toi 18	In the previsions they were saying that I had 20 points and you 18
20	2	bah que dal	well nothing
20	2	donc nashav	so a lie
20	1	fakeeee	fake
20	1	18	18
20	1	et 18	and 18
20	2	oki	ok
21	2	28 28	28 28
21	1	pk ca a marche la????????????????	why does it work now???????????
21	1	non 20 et 20	no 20 and 20
21	2	26 26 même	26 26 same
21	2	ok	ok
21	2	28 28 ca fait plus de points	28 28 it makes more points
21	1	mdrrrrrrr 28 caz porte malheur depuis le debut	lol 28 is bad luck from the beginning
21	2	mdrrrr j'avoue	lol it's true
21	1	20	
21	2	donc 20	so 20
21	1	yessssss	yes
21	2	mais je viens de coprendre en fait	wait I just understood now actually
22	2	test 28 28	try 28 28

Table 16. Chat record of Pair 1393 in time order within periods.

Period	*Player*	*Message*	*English translation*
23	2	28 le sang	28 the life
23	1	on prend les memes et on recommence	we take the same and we do it again
23	2	que 28	only 28
23	2	c le meilleur	it's the best
23	2	ca fait 41 points	it makes 41 points
23	2	on aurait du faire ca depuis le début	we should've done this since the beginning
23	1	oui	yes
24	1	same	same
24	2	c le best	it's the best
24	2	tu vois ca porte pas malheur	see it's bad luck
24	2	plus que 6 etapes	only 6 steps left
24	2	allelujah	hallelujah
24	1	gogoggogogogo	go
25	1	26?	26?
25	2	bah nan c pas equitable quand on met pas les mêmes nombres	well no because it's not even if we don't put the same numbers
25	1	26 et 26	26 and 26
25	2	genre si je mets 20 toi 26 jai 60 pointe et toi 14	if I put 20 and you 26 I get 60 points and you 14
25	2	on va gagner moins que 28 avec 26	we will win less than 28 with 26
25	2	donc restons sur 28	so let's stay on 28
25	1	o	o
26	2	a coup de -60 pour toi au début	so -60 for you at the beginning
26	2	on est débiles	we are stupid
26	2	on aurait du garder 28	we should've kept 28
26	1	ouiiiiii	yeeees
26	2	dans tous les cas ca va nous payer le paquet de garr	it'll pay us the packet of Garr anyway
27	1	xd	lol
27	2	XHD même	same
27	1	ca va meme pas me payer le paquet de garr stp	it won't even pay me the packet of gar
27	2	mais si	yes it will
27	2	t'as cash 5 euros	do you have 5 euros in cash
27	2	et t'zuras bien gagné 2 euros	and you would have well won 2 euros
27	1	non j'ai pris trop de malus au debut	no I took so many bad things at the beginning
27	2	ah oui merde	oh yes sh*t
27	2		
27	2		
27	2	moi j'en ai presque pas eu en scred	I got almost nothing in secret
27	2	mais je sais pas pq	but I don't know why
27	1	non ils vont me raquetter a la fin avec tous les moins que j'ai eu	no they will ask me for money with all the minus I got
28	1	en vrai j'espere prochaine experience c'est individuel	actually I hope that the next experiment will be individual
28	2	mdr pourquoi	lol why
28	1	et pas avec des chiffres tout mort	and without dead numbers
28	2	ah oui	ah yes
28	2	trop bizarreeeee	so weird
28	2	ca me laisse perplexe leurs logiciels la	their software leaves me confused
28	1	parceque tout seul au moins jt'e ferais pas perdre de lovés	because alone I won't make you lose
28	2	:$	:$

Table 17. Chat record of Pair 1393 in time order within periods.

Period	*Player*	*Message*	*English translation*
29	2	2 séances et basta	two sessions and that's all
29	2	gavao a max	let's do it
29	1	on finis sur les chapeaux de roues	we end on a good way
29	2	28 28 28 28 28 28 28 8 28	28 28 28 28 28 28 28 8 28
29	2	nsm	
29	1	prochainer seance je fais peter la banque mdrr	in the next session I will make the bank explode
29	2	mdrrrrr voila	yes that's it
29	2	q15 euros minimum q	15 euros minimum
29	2	LOL	LOL
29	1	minimum le mimi prochaine seance	the next little session at least
30	2	THE LAST ONE	THE LAST ONE
30	2	YEAH	YEAH
30	1	prochaine seance minimum 2 paquet de garro	the next session minimum 2 packets of garro
30	1	enfinnnnnnn fini	finally finished
30	2	mdr c'est l'objectif	lol it't the objective
30	1	yes paquet souple biensur	yes a flexible packet of course
30	2	tu penses y a des strategies ?	do you think there's strategy ?
30	2	mdr pour avoir la classe	lol to be cool
30	1	pour faire l'bg	to act the cool guy
30	1	non y a rien j'pense dfaut etrze bete etr discipline	no there's nothing I think we have to be stupid and have discipline
30	1	et travauiller en equipe	and work with the team

Table 18. Chat record of Pair 1393 in time order within periods.

1	*2*	*3*
0.04	0.05	0.91

Table 19. Estimated topic proportions in Pair 595.

Period	*Player*	*Message*	*English translation*
0	1	bonjour	hello
0	2	bonjour	hello
1	1	tu veux prendre quel chifffre	which number do you want to take
1	2	il faut faire quoi là ?	what do we have to do here ?
1	1	tape 28	pat in 28
1	1	fait moi confiance	trust me
2	1	ta vu on a gagne tout les deux 40 centimes	you see we win both 40 cents
2	2	on continu comme ça tout le long ?	we keep doing like this all along ?
2	1	continue de tape 28	keep putting 28 in
2	2	d'acc	okay
2	1	oui a la fin en tout on aura chacun 14euros	yes at the end we will have both 14 euros
2	2	ok	ok
2	1	ok	ok
3			
4	1	cette fois ci tape 26.0	this time put 26 in
4	1	on aura chacun encore plus	we will both have even more
4	2	si on met tout les deux 26 on gagne plus	if we put both 26 we will win more
4	1	on va passe de 41.27 à 41.97	we are going to go from 41.27 to 41.97
4	2	ah bin voilà on a vu la même chose	ah yes we saw the same thing
4	1	oui ok	yes ok
5 - 8			
9	1	c troooooooooooop long la ...	it's too long ...
9	2	ouais ça m'a soulé !!	yes it annoys me
9	2	mdr	lol
9	1	ennuie.......	bored
9	1	lol	lol
9	2	on est seulement au tiers en plus	and we are only at one-third
10	1	jai pas eu le temps de lire ce que tu a ecrit tout a l'heur?	I didn't have time to read what you wrote earlier
10	2	qen plus on a fait seulement un tiers q	and even more that we have only done one-third
11	1	oui seulement 1/3...	yes only 1/3
11	1	pour la derniere partie trahis pas ton amie virtuel du jour mdr	for the last game where you have been betrayed by your virtual friend lol
11	2	mdr	lol
11	2	pareil pour toi...	same for you...
12	1	non pour 20centimes en plus sa se fait pas je prefere que	no for 20 cents that's just wrong I prefer that
12	1	l'on gagne tout les deux 40 centimes	we both win 40 cents
13	2	ouais ça sert à rien	yes it's no use
13	1	oe lol	yes lol
13	2	et en plus ça fait perdre des sous à l'autre	and even you can't make the other loose money
13	1	oui en effet	yes exactly
14			
15	2	−_	

Table 20. Chat record of Pair 595 in time order within periods.

Period	*Player*	*Message*	*English translation*
16 - 20			
21	2	J'ai l'impression que ça fait 3 heures qu'on est dessus	I feel like it has been 3 hours since we started this
22 - 24			
25	1	plus que 6 parties !	only 6 sessions left !
25	2	enfin !	finally !
25	2	je m'endors	I'm falling asleep
25	1	continue a dormire alors mdr	keep sleeping then
25	2	mdr	lol
26	1	c'est domage que l'experience est aussi longue sinon elle est tres interressante	it's unfortunate that this experiment is that long but apart from that it's interesting
26	2	ouais c'est vrai	yes true
26	2	c'est ta première ?	Is it your first one ?
26	1	non du tout	not at all
27	2	ça te fait combien de fois alors?	How many times have you done it then?
28	1	6/7 fois je crois et toi ?	6/7 times I think and you ?
28	2	ah ouais quand même	oh wow
28	2	moi c'est ma première	me it's my first time
28	1	tu t'en sort bien pour un nouveau lol	you do it well for a new arrival
28	2	et à chaque fois tu fais cette stratégie ?	and you do this strategy every time ?
29	2	Je te fais confiance hein...	I trust you ok...
29	1	oui j'adopte toujours la strategie de q je fais 50/50 avec	Yes I always use the strategy when I do 50/50 with
29	1	l'autre q je trouve que c la meilleur	the other I think is the best
29	1	apres t pas toujours avec d gens desfois c avec l'ordi	you are not always with other people sometimes you are with computers
29	2	ouais c'est sûr	yes it's true
29	1	oui tkt	yes don't worry
29	2	ah bon ?	is that so ?
30	1	sa a etait un plaisir de jouer avec toi mdrr	it was a pleasure to play with you lol
30	2	mdr	lol
30	2	Un plaisir pour moi aussi	it was a pleasure for me too
30	1	bonne continuation	good luck
30	2	toi aussi ;-)	you too
30	1	enrevoir lol	goodbye lol

Table 21. Chat record of Pair 595 in time order within periods.