Strategic Environment Effect and Communication*

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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 and replicate previous findings that point to higher levels of tacit cooperation under strategic complementarity than under strategic substitutability. We find that this is not because of differences in the levels of reciprocity as previously suggested. Instead, we demonstrate that slow learning coupled with noisy choices may drive this effect. When subjects are allowed to communicate in free-form online chats 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 then shows how the content of communication is dependent on the strategic environment and cooperative behavior, and indicates that subjects in complementarity games reach full cooperation by agreeing on gradual moves toward it.

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JEL Codes: C7 · C8 · C9 · D83 · L13

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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 this dilemma can be resolved in favor of cooperation on 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 (dilemma) games with Pareto-inefficient Nash equilibria (NE). Particularly, we study the effect of communication in interaction with the strategic environment, *i.e.,* whether strategic interactions exhibit complementarity or substitutability.

Theoretically, provided that interactions are to be repeated a certain commonly known number of times, cooperation unravels in equilibrium due to backward induction, when communication is not possible.[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 goods, as in Holt (1993), who notes in a context of Bertrand price competition that the sellers who compete on the prices of substitute goods may find it easier to (tacitly) collude than sellers who compete on the prices of complement goods.[3] The former is a case of strategic complementarity, and the latter one of strategic substitutability, hence they represent different strategic environments.

In situations that are described with dilemma games, communication is either desired and facilitated (*e.g.*, in cooperation problems) or hard to avoid (*e.g.*, in collusion problems). Thus, it is important to understand the workings of communication in this context. Although there are studies about the strategic environment effect, there was no preceding study investigating if this

[1]Our focus is on finitely repeated games. See Mermer et al. (2021) for an analysis on indefinitely repeated games. Furthermore, we note that the strategic environment definitions are based on 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 of how cooperation is reached and sustained in repeated social dilemma games. Crawford (2019) provides a recent review of determinants of cooperation, including the role of communication.

[3]The intuition is that in the case of substitute goods (from the consumer's perspective), 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 the price toward the collusive outcome. It should be noted that Cournot competition is typically modeled with strategic substitutability and negative externality, whereas Bertrand competition is usually modeled with strategic complementarity and positive externality. However, as in Anderson et al. (2010, 2015), both Cournot and Bertrand competitions can be modeled with either complementarity or substitutability. See Suetens and Potters (2007) for a discussion and review of results on the strategic environment effect and Potters and Suetens (2013) for a survey on oligopoly experiments.

effect is dependent on the presence of (free-form) communication. This paper contributes to the literature in two ways: we build on previous findings by first exploring the behavioral underpinnings of the effect of the 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) (henceforth PS), by focusing 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 substitutability.[4] We find that under complementarity, choices are higher than equilibrium levels, *i.e.,* more cooperative, which, in turn, are higher than the choices under substitutability. Conversely, we find that reciprocity, as suggested by PS, does not explain this effect: changes in the partner's choices are followed to the same extent under both strategic environments. However, we demonstrate using 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 implement 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 to better understand how the strategic environment affects subjects' reasoning about the game by looking into chat content. Although communication is generally found to enhance cooperation in the existing literature, its effect on the levels of cooperation is not definitive and is known to depend on the type, duration, and content of communication, as well as the game specifics.[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 of

[4] It is important to note that under market framing, Anderson et al. (2010, 2015) observe collusion among firms under Cournot competition with substitute goods (hence, strategic substitutability) and under Bertrand competition with complement goods (also with strategic substitutability), whereas there is no collusion in the opposite cases (Cournot competition with complement goods or Bertrand competition with substitute goods, both leading to strategic complementarity). Barthel et al. (2019) implement a simple design with 3×3 games of complements and substitutes without market framing, where the NE coincides with the joint payoff maximization strategy pair. Similarly, they observe higher frequencies of NE play under complementarity.

[5] Andersson and Wengström (2012) find, for instance, that more communication possibilities do not necessarily lead to more cooperation in two-stage games. Instead, they find that adding the possibility of communicating intra-play communication can reduce the cooperation boost induced by pre-play communication. Furthermore, Lee and Hoffman (2020) observe that the frequency of the possibility to communicate (pre-play) correlates with the levels of cooperation. Finally, Fonseca and Normann (2012) find that the possibility of communication improves outcomes for any number of firms, but that this gain from communicating is nonmonotonic in the number of firms.

different sizes, and conclude that, free-from communication helps to obtain higher profits and that firms will succesfully continue collusion after communication is disabled. They note (Fonseca and Normann, 2012), however, referring to Farrell and Rabin (1996) and Whinston (2008), that the effect of communication on dilemma games is subject to debate among theorists. Waichman et al. (2014) note that there is 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 70 to 80 % of the 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 to avoid collusion in oligopolies, for instance, our finding points to the idea that the strategic environment may not be as 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 substitutability than in complementarity. Secondly, under complementarity, efficient cooperation is more likely to be reached by gradual moves.

We then aim at seeking an understanding about how communication works towards cooperation and if the strategic environment is relevant in this regard. To that end, we employ a set of text analysis methods, including analyses of the 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 have not been considered in analyses of communication

[6]Gomez-Martinez et al. (2016) study the effect of the revelation of firm-specific data in a Cournot game with multiple firms, and reveal that communication helps to reach collusive agreements in both individual and aggregate information treatments. Awaya and Krishna (2016) investigate, in their theoretical study 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 examine the effect of flexibility (the ability to respond quickly) on cooperation, and observe rapid convergence to very low levels of cooperation, regardless of flexibility. Finally, Fonseca et al. (2018) discover an increasing and concave relationship between the number of firms and the additional profit firms make from the opportunity to communicate free form in Cournot oligopolies.

[7]Recent works include, among others, Hansen and McMahon (2016), which assesses the impact of content in central bank communication on real economic variables, Gentzkow and Shapiro (2010), which investigates the demand for like-minded news as a reason behind bias in newspapers, Mueller and Rauh (2018), which suggests implementing topic models in the analysis of newspaper articles to predict timing of political violence, and Grajzl and Murrell (2019),

records in experimental games until very recently.[8]

We refer to an unsupervised learning method, a novel approach in the experimental economics literature, for content 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 depends on the strategic environment and whether 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 also reveal evidence in chat content that subjects in complementarity treatment reach efficient cooperation by agreeing on gradual moves towards it, in case they do not start cooperating from the very beginning. Alternatively, in substitutability treatment, subjects either do not reach efficient cooperation or they may jump to it later.

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

2 The Experiment

Our central experimental questions are as follows. First, we question if tacit cooperation levels are higher under strategic complementarity compared with substitutability and if so, 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 how chat content relates to the strategic environment. Our experimental design that we describe in the following section builds on these three questions. Importantly, it is constructed in a way to single out the strategic environment effect, by avoiding possible confounds (such as the market frame) and holding constant most of the properties across games (such as full cooperation strategies, Nash equilibrium, and so on).

which employs a structural topic model to study the features of Francis Bacon's writings to gauge their importance in the history of economic thought.

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

2.1 Design

We designed treatments with strategies as substitutes and complements, both with and without communication, based on PS. Thus, we have a 2×2 between-subjects design, in which subjects play the stage game repeatedly 30 times in fixed pairs (with 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, called the joint profit maximization (JPM) outcome. In both strategic environments, there is positive externality, *i.e.*, one's own payoff is increasing in the 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 payoff, and the absolute value of the slope of the reaction curve are identical across strategic environments. The latter makes the best-reply dynamics generate the same speed of convergence. Figure 1 graphically summarizes the similarities and the differences between the 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 $x \in [0, 28]$, and thus, our treatments without communication are exact replicas of the 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 and -0.3 under substitutability.

[9] PS find no difference between the degrees of cooperation under positive and negative externality cases within strategic environments and pool them for their analyses of strategic environments. Therefore, we focus on only one of the externality cases, *i.e.,* positive externality.

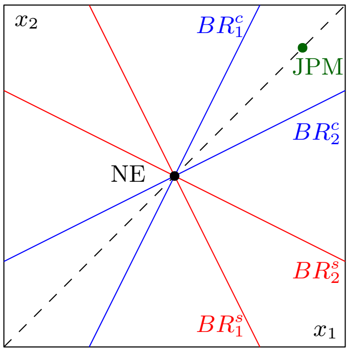


Figure 1. Best-response functions and NE and JPM choices.

	Without communication	*With communication*
Complementarity	102 (7)	100 (8)
Substitutability	112 (9)	104 (7)

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

2.2 Procedure

All our computerized sessions were conducted at the Laboratory of Experimental Economics of Nice.[10] In total, 418 student subjects participated in the experiment. Table 1 details the number of subjects (sessions) per treatment.[11]

Instructions with screenshots were distributed and read aloud at the beginning of each session (see Appendix A). The instructions were the same for complementarity and substitutability and subjects were told that their earnings were going to be based on their own decisions and the decisions 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 their own payoff corresponding to choices in even numbers between 0 and 28 (see Appendix B). Along with the payoff table, subjects were provided a payoff calculator for hypothetical numbers that they could type in on their screen. The number of decimal points for both the calculator and the decisions was restricted to one. In sessions with communication, subjects could communicate voluntarily through a chat box for one minute before moving to the decision stage. Offensive language and identifying

[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 because of variation in show-up rate across our prescheduled sessions that took place at different times of the school semester.

messages were prohibited, but there was no further restriction on the content of communication. The subjects' communication language occurred to be exclusively French, although it was not restricted as such.

The stage game was repeated for 30 periods, starting after a trial period with forced decisions.[12] The history of past decisions and payoffs was provided for 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 the total payoffs earned throughout the session. Subjects earned on average 15.1 euros in treatments with communication and 12.2 euros in treatments without communication, including 5 euro appearance fee. The average duration of a session without communication was 88 minutes and 100 minutes for sessions with communication.

2.3 Hypotheses

As mentioned above, our questions in this study pertain to the strategic environment effect with and without communication. Based on previous findings, particularly PS, we predict higher tacit cooperation degrees under strategic complementarity compared to strategic substitutability. We formulate this as the following hypothesis.

Hypothesis 1: The average degree of cooperation is higher under strategic complementarity compared to strategic substitutability when communication is not allowed.

Based on previous literature that we discuss in the Introduction (and further in Section 4) and that points to a boost in the degree of cooperation due to communication, we predict that communication possibility can increase the level of cooperation in both strategic environments to a level so that there is no difference anymore.

Hypothesis 2: When communication is allowed, there is no strategic environment effect.

[12] In the trial period, the payoff calculators were used twice to calculate hypothetical payoffs. In chat treatments afterwards, the chat box was trialed by typing "hello" (*bonjour*) and then a forced decision was required. Payoffs in the trial period did not count in the final earnings.

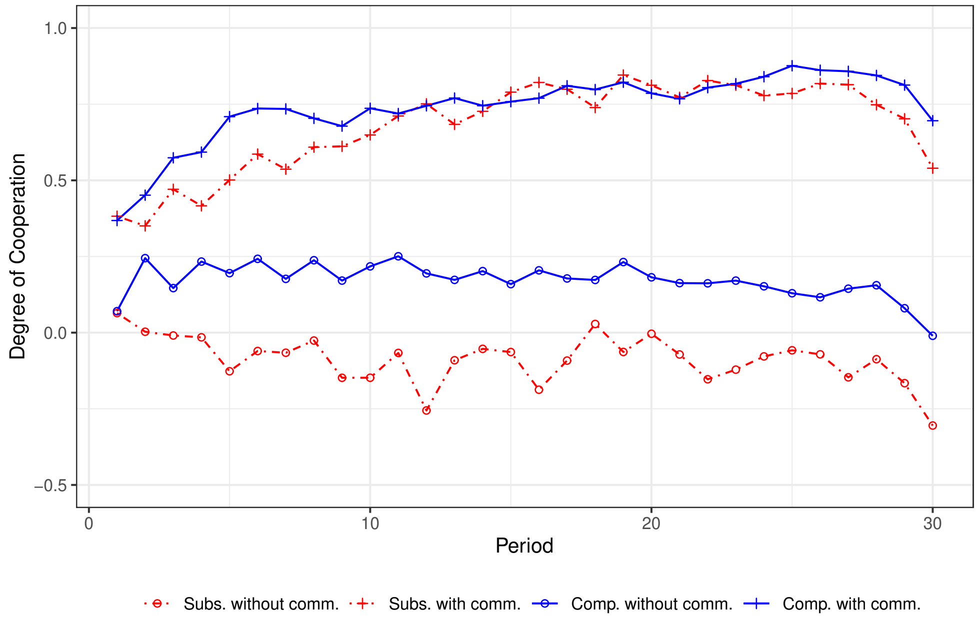


Figure 2. Average degree of cooperation.

Our last hypothesis is about reciprocity. PS found that under strategic complementarity there is a higher level of reciprocity, which can explain the observed strategic environment effect. We formulate the corresponding hypothesis as follows.

Hypothesis 3: The level of reciprocity is higher under strategic complementarity.

3 Experimental Results

3.1 Aggregate results

The following analysis is based on the *degree of cooperation*, which is defined, for a pair k in period t with average choice within the 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 the four treatments are variously reported in Figure 2 and Table 2. As clearly shown in Figure 2, when communication is not allowed, complementarity induces more cooperation compared with substitutability, thus, we find support for hypothesis 1.

	No Communication			*Communication*		
Periods	*Substitutability*	*Complementarity*	*p−value*	*Substitutability*	*Complementarity*	*p−value*
1-30	-0.09 (0.37)	0.17 (0.30)	0.000	0.68 (0.44)	0.74 (0.33)	0.397
1-15	-0.07 (0.33)	0.19 (0.33)	0.000	0.59 (0.47)	0.67 (0.37)	0.368
16-30	-0.11 (0.45)	0.15 (0.33)	0.000	0.77 (0.48)	0.81 (0.37)	0.283
1	0.06 (0.83)	0.07 (0.73)	0.485	0.43 (0.90)	0.38 (0.87)	0.850
30	-0.30 (0.58)	-0.01 (0.36)	0.001	0.54 (0.60)	0.70 (0.44)	0.124

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

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] Thus, hypothesis 2 is supported by the data.

Table 2 provides the details and test results for all periods combined (periods 1–30), the first half of the experiment (periods 1–15), the second half of the experiment (periods 16–30), the first period, and the last period. The $p-$values correspond to Wilcoxon–Mann–Whitney (WMW) tests of the null hypotheses that the degree of cooperation is the same in substitutability and complementarity. When communication is not allowed, all the null hypotheses (except that for the first period) are rejected in favor of the alternative hypotheses that the degree of cooperation is higher in complementarity than in substitutability. However, when communication is allowed, we reject none of the null hypotheses. It is immediately observed that the average degrees of cooperation are substantially higher when communication is allowed within a given strategic environment.[15]

[13] Although the overall comparison between treatments is the same with PS, several observations should be noted. First, in PS, the average cooperation rate is higher (0.27 in substitutability and 0.41 in complementarity). In both of their treatments, there appears to be a clearly increasing trend in choices after the first few periods. In the case of complementarity, average choices increase as high as to the level of the JPM. Second, choices in PS are both higher than the NE, whereas, in our data, the substitutability treatment has lower average choices than the NE. Finally, the end game effect in PS is stronger than with 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 well predict 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 the Tilburg subject pool is around 1.8, whereas it is around 0.4 for our subject pool in Nice, as reported by Babutsidze et al. (2021).

[14] Figure 14 in Appendix C depicts the comparison of payoffs. The average payoffs over all periods with (without) communication are: 35.1 (25.5) for complementarity and 35.3 (20.7) for substitutability, which align with the findings regarding choices.

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

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 shown 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 experiment and ρ^{30} is the average degree of cooperation in the final period. We observe that the end-game effect is slightly stronger (0.19) under substitutability compared with complementarity (0.16). This might be explained in part by the fact that optimal defection choice under substitutability (10.6) is much lower than in complementarity (17.4), as noted by PS.

3.1.1 Full-cooperation behavior

We say that the choice of a subject at any period is at JPM level if it lies in the interval $[25, 26]$, and we say that 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 that have played at JPM level as a pair at least once is 8 (7) in complementarity (substitutability), which amounts to 15.7% (12.5%) of all pairs in complementarity (substitutability).[16] Of these pairs, only two reached and sustained JPM-level choices in substitutability, whereas in complementarity, four managed to reach and sustain full cooperation. We refer to a pair as a JPM pair if their choices as a pair are at the JPM level for at least three consecutive periods until the last period, the last but {one, ..., or four} period(s).[17] The remaining pairs are called non-JPM.

We observe that more subjects make JPM-level choices in substitutability (45.5% compared with 38.2% in complementarity). One might conclude that subjects tend to unilaterally try out JPM strategies more in substitutability, whereas only under complementarity do we have pairs that succeed in sustaining cooperation for several periods.[18] It should be noted, however, that this

[16] Figures 16 and 17 in Appendix D show the evolution of choices within pairs.

[17] The following results do not depend on the choice of the length of mutual cooperation. Details available upon request. That these choices do not have a bite can be confirmed with an inspection of the evolution of choices in Figures 16 –19 in Appendices D and E.

[18] Mengel (2017), in a survey comprising 96 studies with 3,500 subjects in total, finds that risk (loss from unilateral cooperation) and temptation (gain from unilateral defection) play a significant role in the levels of cooperation in prisoners' dilemma games. If we look at the restricted game with only NE and JPM strategies for defection and cooperation, respectively, the value of the risk parameter is approximately 2.6 for our complementarity treatment and 0.8 for our substitutability treatment. Similarly, the value of the temptation parameter is approximately 1.06 for our complementarity treatment and 1.22 for our substitutability treatment. Mengel (2017) concludes that in repeated games with partner matching, temptation better explains the variation in cooperative behavior. When temptation is higher, sustaining cooperation is more difficult in substitutability. In contrast, 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).

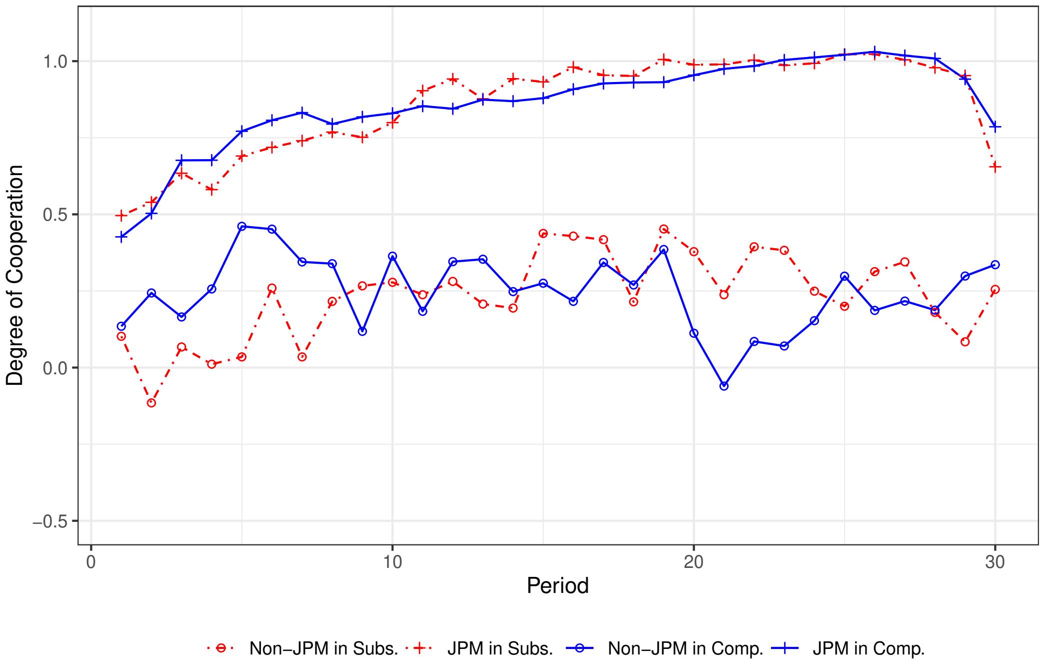


Figure 3. Average degree of cooperation by JPM and non-JPM pairs when communication is allowed.

difference is not statistically significant (Fisher's test yields a $p-$value of 0.332).

When communication is allowed, the JPM pairs start at already high degrees of cooperation and gradually reach full cooperation (Figure 3). The average choice of non-JPM pairs is stable throughout the experiment, in both strategic environments. We conclude that although communication fails to deliver full cooperation, it eliminates the strategic environment effect.[19]

3.1.2 Reciprocity

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

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

[19]In addition, there is no visible end-game effect in either of strategic environments, which could indicate that subjects in non-JPM pairs are not strategically involved in the game to the same extent as those in JPM pairs and which show a substantial end-game effect.

Δx_{it}	Coeff.	Rob. St. Err.	z	$p-$value	95% Conf. Int.	
Constant	-0.108	0.024	-4.36	0.000	-0.157	-0.059
Δx_{jt-1}	0.166	0.047	3.52	0.000	0.073	0.258
$COMP_i \Delta x_{jt-1}$	-0.058	0.055	-1.06	0.290	-0.167	0.050

$R-$squared	=	0.0238	Number of observations	=	5992
Obs. per group	=	28	Number of groups	=	214

Table 3. Regression results (generalized least squares with individual random effects) on changes in choices without communication. Standard errors are robust to within-pair dependency (107 clusters; 56 pairs in substitutability and 51 pairs in complementarity). Two-tailed $p-$values reported.

where $COMP$ is a dummy variable that takes a value of 1 for choices in the complementarity treatment and 0 for substitutability, 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 partner from period $t-2$ to $t-1$. We observe significant reciprocity among our subjects, as 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, thus, we do not find support for our hypothesis 3). This contrasts with what PS find. Specifically, PS observe that subjects in complementarity have significantly higher reciprocity ($\hat{\beta}_2 = 0.17$ with $p = 0.003$).

We now turn to learning as an explanation for the observed strategic environment effect. In complex strategic situations, assuming full knowledge of the environment and the ability to anticipate others' behaviors may not be viable. Learning-based models are used to provide insights about observed behavior in such contexts, with more plausible assumptions on abilities and behavior (see Bergin and Bernhardt, 2009, for instance, show that sustained cooperation is to be expected in repeated games with strategic substitutability or complementarity if agents are learning with a memory). In the next section, we investigate within a simple reinforcement learning modeling approach, the conditions under which a strategic environment effect can be observed and if our experimental data are in alignment with these conditions.

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, $A^i_q(t)$ 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

$$p^i_x(t) = \frac{e^{\lambda A^i_x(t)}}{\sum_{k\in\mathcal{S}} e^{\lambda A^i_k(t)}},$$

where $\lambda \geq 0$ is the parameter that governs the "sensitivity" of choice to the attraction. $\lambda = 0$ is the uniformly random choice (thus, attractions play no role) and $\lambda \to \infty$ is 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.,*

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

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

$$A^i_x(t+1) = \begin{cases} \omega A^i_x(t) + (1-\omega)\pi_i(x^t_i, x^t_j) & \text{if } x^t_i = x, \\ A^i_x(t) & \text{otherwise,} \end{cases}$$

for all $t \geq 0$, where ω is the "recency" parameter indicating the speed at which past payoffs are forgotten: $\omega = 0$ when only the last period payoff is remembered and $\omega = 1$ when 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 4 depicts the simulations based on 1,000 pairs with the obtained parameter estimates, *i.e.,* $\lambda^* = 0.1$ and $\omega^* = 0.8$,which point to slow learning and noisy choices.

To show that the pattern we observe is dependent on the estimated parameters, we conducted

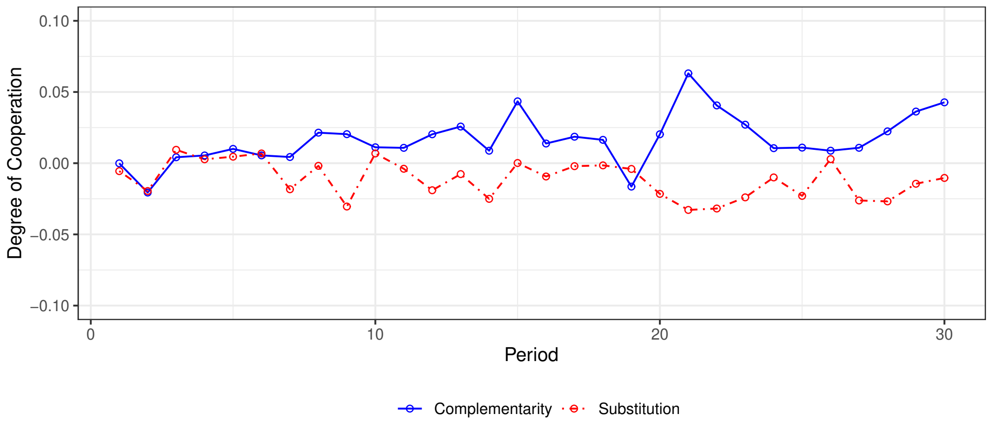


Figure 4. Simulated degree of cooperation for $\lambda^* = 0.1$ and $\omega^* = 0.8$.

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 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 substitutability. Finally, we computed $\Delta\rho = \rho^C - \rho^S$ which summarizes the difference between complementarity and substitutability, namely, the size of the strategic environment effect.

Figure 5 illustrates the relationship between $\Delta\rho$ and ω for four values of λ. The average degree of cooperation in complementarity is higher than in substitutability when learning is sufficiently slow ($\omega \geq 0.8$). When choices are less sensitive to attractions (λ is smaller), we also observe the strategic environment effect for faster learning (smaller ω).

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 for 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

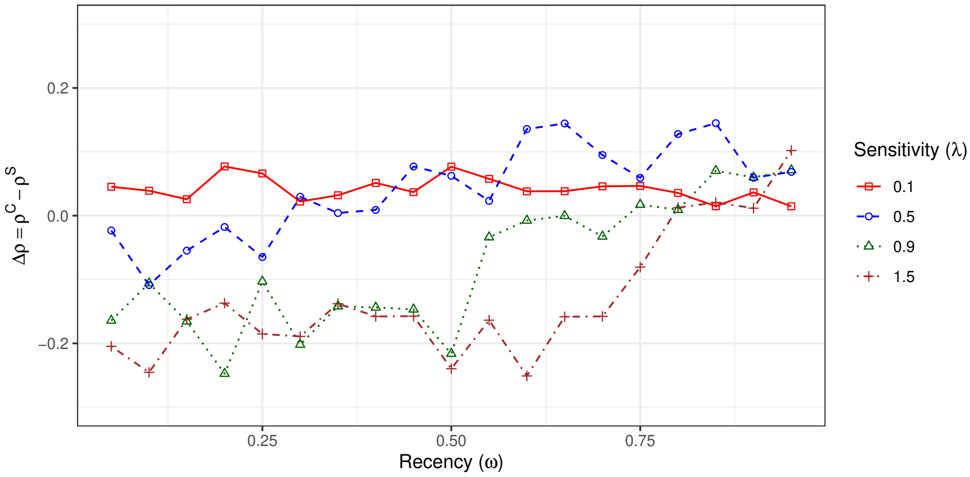


Figure 5. Simulated $\Delta\rho$ for various values of ω and four values of λ.

on strategic interactions.[20] Nonetheless, there is a significant challenge facing the analyses of the impact of free-form communication on strategic behavior pertaining to the question of *how* it works.

Free-form communication has a distinctive power to reveal reasoning and deliberative processes in strategic decision-making. Assessments of free-form chat data are commonly based on the subjective judgment of researchers or their 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 games *à la* Houser and Xiao (2011), in which coders are incentivized to pay more attention through rewarding the codes that match the most popular evaluation among other coders' evaluations (see Corazzini et al., 2014;

[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 with 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 suggesting that rich communication is more effective in facilitating coordinated resistance modeled *à la* Weingast (1995). Alternatively, Cason et al. (2012) point to contest environments where free-form communication could damage efficiency. Finally, Wang and Houser (2019) find that in coordination games, free-form communication boosts coordination much more than restricted communication. See Brandts et al. (2019) for an extensive survey of laboratory studies using communication.

Periods	*Substitutability*	*Complementarity*	*p−value*
1-30	1.71 (1.96)	1.57 (1.81)	0.033
1-15	1.81 (1.84)	1.85 (1.77)	0.197
16-30	1.61 (2.07)	1.30 (1.82)	0.000

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

Ellingsen and Johannesson, 2008; Andersson et al., 2010).

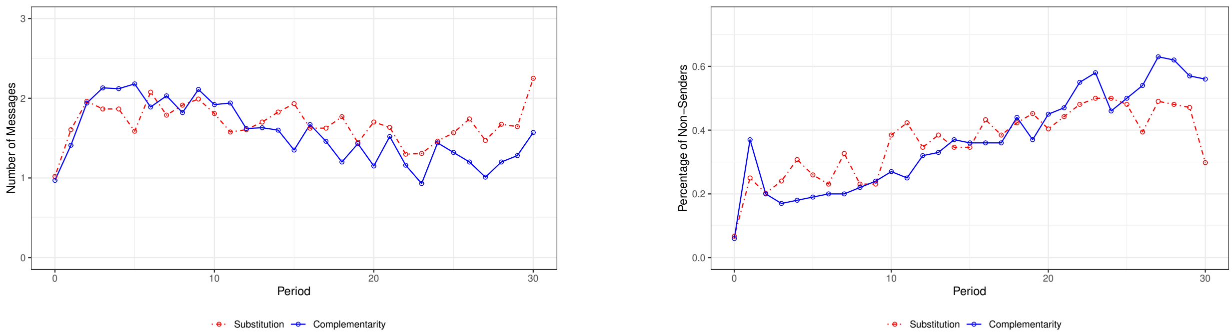
In this paper, we propose the use of computerized techniques in analyzing experimental chat data in place of human labor. The advantages are that (*i*) they are less costly in terms of time and money as researchers devote less time to the analysis and do not need to hire coders or assistants, (*ii*) they may make language restriction redundant as many techniques in natural language processing are language free, and (*iii*) they may rely less on subjective assessments. The latter two points are particularly relevant for unsupervised learning methods in that these methods do not require any semantic to knowledge or manually set clustering to be integrated thus, are more accessible, less costly, and possibly less subjective. There are also certain limitations of this approach. In terms of the method we implement, one immediate limitation is that it ignores that chat contents are dialogues construed through a dynamic interaction. Further, the current deployment of the technique does not make it automatically possible to consider the dynamics of chat content (which terms become more used by who over time, and so on).

Before proceeding with the results of our NLP approach, *i.e.,* by estimating a structural topic model (STM), we consider 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 assess the number of messages sent by subjects.[21] All but one of the 204 subjects sent at least one message throughout the experiment (including the trial period) sending, on average, 1.64 ($s.d.$ = 1.89) messages per period (beyond the trial period). In the first half of the experiment, the average was 1.83, which is significantly higher than in the second half (1.46, with $p = 0.000$ for a WMW two-tailed test). As detailed in Table 4, subjects in the substitutability treatment sent

[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 that do not send any message per period.

Figure 6. Average number of messages and percentage of subjects that did not send any message per period. In the forced trial period (0), subjects are told to send the message "Hello."

more messages on average, particularly in the second half of the experiment. This can be clearly seen in Figure 6a, which depicts the evolution of the number of messages over time by strategic environment. There is no visible difference in terms of the percentage of subjects that did not send any message across the treatments (Figure 6b). In what follows, we look at the messaging patterns for the JPM and non-JPM pairs.

4.1.1 Full cooperation and communication

Considering the two strategic environments together, the subjects in the JPM and non-JPM pairs send on average 1.67 and 1.57 messages ($s.d. = 1.89$ for both, with $p = 0.101$ in a WMW two-tailed test), respectively, per period. In the first half of the experiment, the average number of messages is 1.88 ($s.d. = 1.79$) and 1.65 ($s.d. = 1.83$), respectively, and the difference is statistically significant ($p = 0.000$ for WMW two-tailed test).[22] Table 5 shows these values for each strategic environment separately, together with $p-$values for the corresponding tests.

In the first half of the experiment, there is no difference between strategic environments: the JPM pairs send more messages than the non-JPM pairs. However, in the second half, we have a reversal in the substitutability treatments, in that, the non-JPM pairs send more messages than the JPM pairs, and both types of pairs send more messages when compared with the complementarity

[22]The number of messages sent by non-JPM subjects in the second half of the experiment (1.49, with $s.d. = 1.96$) is not statistically significantly different when compared with the JPM subjects (1.45, with $s.d. = 1.95$ and $p = 0.116$ for WMW two-tailed test).

Periods	*Substitutability* non-JPM pairs	JPM pairs	$p-$value	*Complementarity* non-JPM pairs	JPM pairs	$p-$value
1-30	1.71 (1.99)	1.71 (1.95)	0.524	1.36 (1.71)	1.63 (1.83)	0.000
1-15	1.64 (1.87)	1.87 (1.83)	0.006	1.66 (1.78)	1.89 (1.76)	0.009
16-30	1.78 (2.11)	1.55 (2.05)	0.000	1.05 (1.58)	1.36 (1.87)	0.010
# Subjects	30	74		20	80	

Table 5. Average number of messages per period (standard deviations in parentheses). Reported $p-$values are for two-tailed WMW tests.

treatment.[23] The fact that non-JPM subjects send fewer messages in complementarity compared with JPM subjects might indicate that the failure of cooperation in complementarity is due to a failure in communication. Then again, non-JPM subjects send more messages in the substitutability 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. As shown in Figure 3, however, the strategic environment effect is not present among the non-JPM subjects.

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

4.2 Message content

We first look at the frequencies of the terms subjects use in their communication. The word cloud in Figure 7 indicates the terms that appeared in chats at least 10 times.[24] We build our analysis on chat records of 100 pairs (50 per treatment).[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 the 50 most frequent terms. For each term t,

[23]These observations point to the idea that communication benefits subjects in the substitutability treatment more, as they make greater use of it, which could imply that under restricted communication, *e.g.,* regarding the number of messages, we might observe that the strategic environment effect could persist.

[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 Appendix G.1. The details of our preparation for the content analysis, which includes a mild orthographical clean-up necessitated by common mistakes, is provided in the replication package.

[25]We exclude a pair in the substitutability treatment that did not communicate beyond the first period. Some stopwords are removed after the word cloud in Figure 7 (see Appendix G.1). This removal emptied one other subject's chat content, so we have 201 subjects, thus, 100 pairs, whose chat records could be utilized.

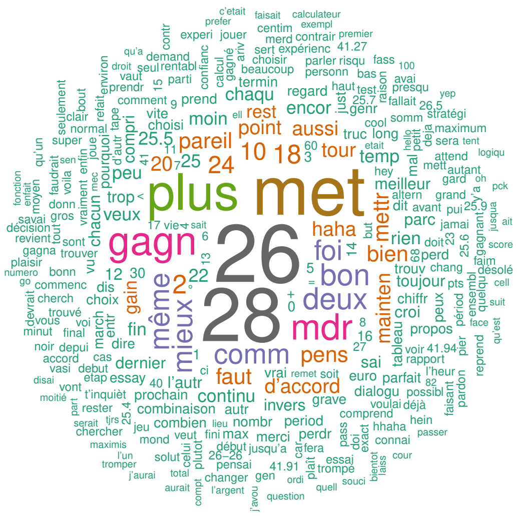


Figure 7. Three hundred and twenty-seven stemmed terms used by subjects at least 10 times in total. Centrality, size, and color reflect frequencies.

we compute the r.r.d. for substitutability as

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

where $r_C(t)$ is the rank of the word t in decreasing order of the number of times it is used by the subjects in the complementarity treatment, and $r_S(t)$ stands for the substitutability treatment. The relative rank difference for complementarity, $\Delta r_C^S(t)$, is symmetrically defined. We pay particular attention to those words that have either $\Delta r_S^C(t) > 1$ or $\Delta r_C^S(t) > 1$, following Fonseca et al. (2018) and Fischer and Normann (2019).

Figure 8 depicts the ranks of the top 50 words in both treatments.[26] The shaded (green) area indicates r.r.d. values smaller than or equal to 1.[27] The rankings of words are remarkably similar across treatments. This points to the fact 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

[26]Three terms are not included as they did not appear within the 125 top-ranked terms for substitutability although they were in the top 50 for complementarity. These are "period" (period), "tableau" (table), and "chiffr" (number), which rank 41st, 44th, and 45th in complementarity, respectively.

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

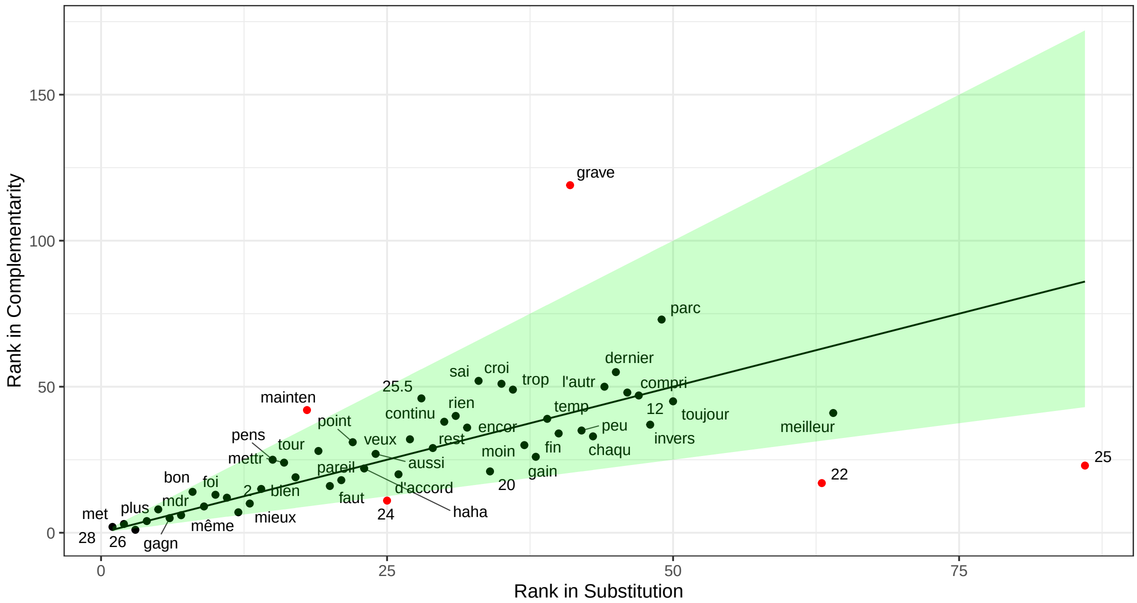


Figure 8. The frequency rankings of the 50 most used words in both treatments. Within the shaded region, we have $-1/2 \leq \Delta r_S^C(t) \leq 1$ and only outside this region is either of the differences greater than 1. The term "10" in substitutability is matched with the term "18" in complementarity as they are the corresponding optimal defection choices. English language translations are available in Table 7 in Appendix F.

by subjects in the substitutability treatment.

The term "mainten" stands for "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 attempting 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 round. Thus, subjects remind each other quite frequently that "now" it is their turn to play, for instance, the action "10". And it is immediately observable 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 the first player. However, this strategy is observed only in substitutability treatments as the reverse results in negative and much lower payments in complementarity (-7.56 *vs.* 4.87 in substitutability). The choices of pairs (with IDs 298, 1894, 2091, 2097, 2997, and 3093) that employ this alternating strategy are shown in Figure 19 in Appendix E.

[28]This difference regarding "mainten" is not observed when the analysis is confined to JPM pairs, whereas it is stronger in non-JPM pairs. Details available upon request.

The difference in popularity of the term (word) "grave" indicates that under substitutability, more subjects need to reassure and forgive the other one for maintaining full cooperation, as defections, or mistakes, happen more often.[29]

The terms that appear at higher ranks in complementarity, *i.e.,* "22," "24," and "25" (together with "20", which also has a relatively high r.r.d value, *i.e.,* higher than 0.8), point to the fact 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 the JPM choice that is not in the payoff tables, is more popular among subjects in substitutability might indicate that the move is not as gradual but happens because of 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 from (lab) experiments (see the beginning of Section 4 for a review of common practices). Penczynski (2018), in the first-ever published paper with such an approach, argues 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.[32]

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 early works in topic modeling such as the Latent Dirichlet Analysis (Blei et al., 2003)

[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 9 (5) pairs in substitutability (complementarity). They use this term as in this sentence to indicate forgiveness for a cheating attempt or a (self-declared) mistake by the opponent. Details available upon request.

[30] The term "25.5" is used 50 times by the subjects in substitutability as opposed to 36 times in complementarity.

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

[32] See Andres et al. (2021), where another topic modeling application is implemented following our approach.

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).

In particular, in an STM, a set of covariates is 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 first be chosen according to a distribution over topics. 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 word for each empty position is made. The metadata used in an STM estimation come 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. In contrast, topical content refers to the words used in topics.[33]

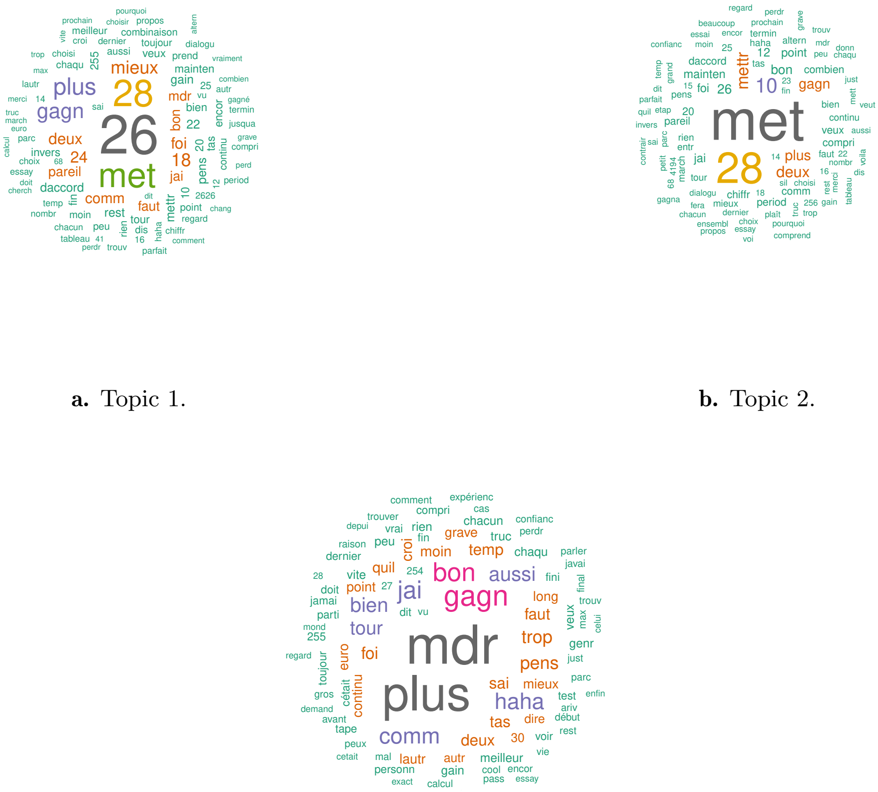
We estimated a model with three topics, where topic prevalence is assumed to be dependent on the strategic environment and full cooperation behavior, without a topical content covariate. The basis of analysis is the chat content for each pair throughout the experiment. A detailed account of our procedures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

4.3.1 Topical content and prevalence

Figure 9 illustrates the word clouds for each topic separately. In the first topic, the most used term is "26", being the JPM choice in 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 the literal translation from French is "dead from laughing").

Figure 10 shows the results from a regression estimation where chat contents in pairs are the units, the outcome is the proportion of each document devoted to a topic in an STM model, and

[33] We refer the interested reader to Roberts et al. (2016) for 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 nonconjugate portions of the model.



a. Topic 1.

b. Topic 2.

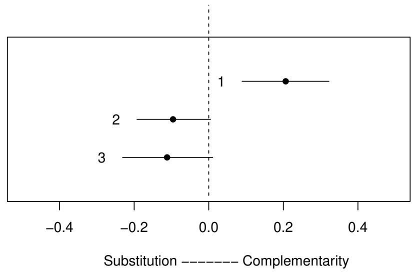
c. Topic 3.

Figure 9. Word clouds for each topic.

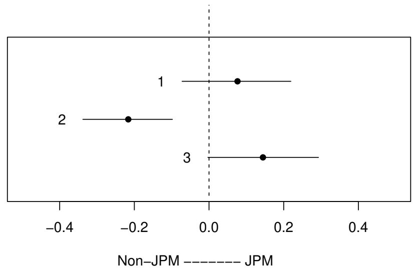
the explanatory dummy variables indicate strategic environment and whether the pair is a JPM pair or not.[34] This estimation shows that in complementarity, Topic 1 is used more, whereas Topics 2 and 3 are used more in substitutability. Alternatively, while non-JPM subjects use Topic 2 more, JPM subjects use Topic 3 more. In what follows we look at these patterns more closely.

Among the JPM pairs, some reach full cooperation early on, and some towards the end of the session. We believe that early cooperation reflects a distinctive synergy that makes a pair manage to reach an agreement rapidly when they start interacting. To identify these, we looked at the evolution of choices JPM pairs made and denoted those that made cooperative choices more than

[34]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.



a. Effect of strategic environment. Positive values indicate higher prevalence in the chat content of subjects in the 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 the strategic environment and JPM behavior together with 95% confidence intervals.

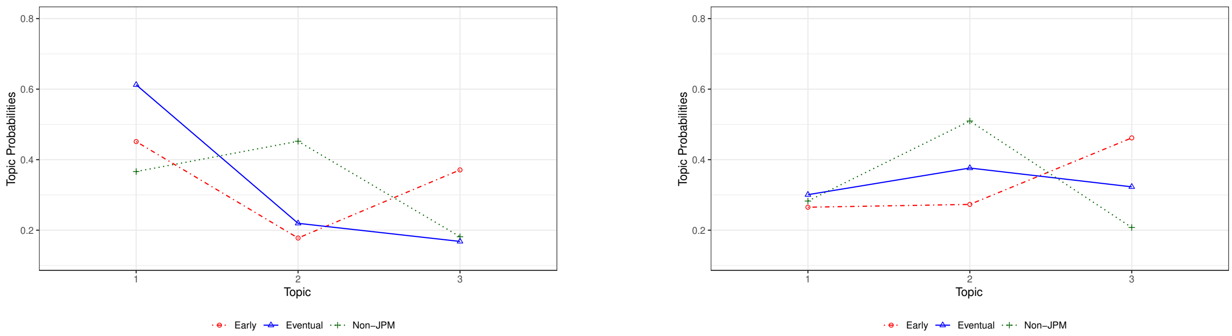
60% of the time in the first third of the experiment as "early JPM". To account for the fact that cooperating on the exact value of the JPM choice (25.5) might be difficult at the beginning of the experiment, we took any choice at least as high as 24 as full cooperation.[35]

The percentages of early JPM subjects are the same in both treatments (Pr[early JPM$|SUBS$] $=$ 0.40 and Pr[early JPM$|COMP$] $=$ 0.42). This indicates that jumping to JPM is equally likely in both strategic environments. However, it appears that among the pairs that do not reach and sustain full cooperation early on, eventual cooperation is less likely under substitutability (Pr[JPM|not early, $SUBS$] $= 0.52$ and Pr[JPM|not early, $COMP$] $= 0.65$ with the Fisher exact test statistic value 0.141).

Figure 11 shows the topic proportions within the three types (Early, Eventual, and Non-JPM). Note that we find that Topic 1 assigns about three times greater probability (11.67% vs. 4.25%) to interim choices ($14 < x < 25.5$) compared with Topic 2, whereas Topic 3 assigns zero probability.[36] Looking closer, we find that interim choices are mentioned in chat records of complementarity subjects more (on average 12.06 times vs. 8.2 times in substitutability, where the $p-$value in the two-sided WMW test is 0.016) and this is more pronounced when we compare JPM pairs (11.73 vs

[35]Note that this identification is done among JPM pairs, thus, they manage to cooperate fully eventually. Furthermore, 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 even though they intend to in the first few periods. Our subsequent observations are robust to small changes in the choice of this interval or the choice of 60% of the periods in the first third of the experiment (instead of 50% for instance), as shown in Figures 18 and 19 in Appendix E.

[36]Note that the terms that are used less than five times are excluded from the chat records in the STM estimation.



a. Complementarity.

b. Substitutability.

Figure 11. Average topic probability per JPM type in both strategic environments.

6.92 with $p-$value $= 0.002$). Thus, based on these observations coupled with a close inspection on the evolution of choices (see Figures 18 and 19 in Appendix E), we conclude that in complementarity, pairs reach full cooperation levels by discussing and agreeing on gradual movements. An example of how this dynamic works out can be seen in the chat content of Pair 397 in Table 9 in Appendix G.4, which predominantly consists of Topic 1. We do not observe any such dynamic in the substitutability treatment. Finally, as shown in Figure 11, Topic 3 is used relatively more by early JPM pairs, which indicates that those pairs that managed to reach and sustain full cooperation early on switch to a more collegial conversation, not necessarily related to the game anymore, as reflected by the large weights for the terms such as "mdr" and "haha."

5 Conclusion

Social dilemmas are prevalent in economic decision-making processes and the strategic environment is argued to have a significant impact on how they are resolved.[37] 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 substitutability. However, our results beyond this differ from that of PS, in that the higher degree of cooperation under complementarity does not arise from 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.

[37]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.

Our major findings relate to the impact of communication in interaction with the strategic environment. First, communication boosts cooperation levels in both strategic environments. Second, 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 the idea that the strategic environment does not matter in terms of cooperation levels (or collusion levels as in oligopoly markets).[38] However, there remain some differences. Communication is more effective in helping participants to cooperate, even if not at the efficient level, in substitutability than in complementarity. Also, reaching efficient cooperation arises 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 that subjects talk about in their chats according to their cooperative behavior and the strategic environment they are in.

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

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A Instructions for treatments with chat

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

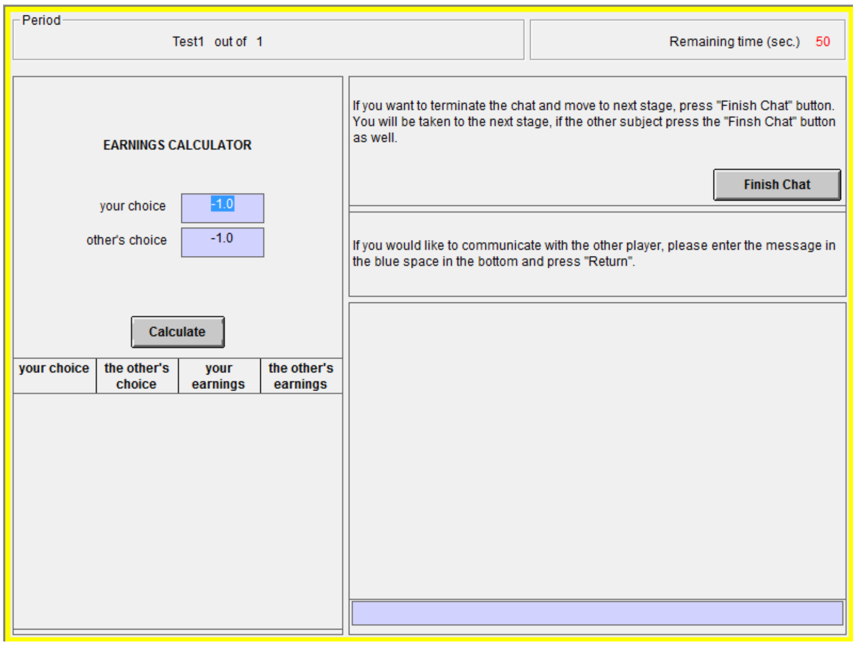
You are participating in an experiment on economic decision-making and will be asked to make several decisions. If you follow the instructions carefully, you can earn a considerable amount of money. At the end of the experiment, you will be paid your earnings in private and in cash.

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.

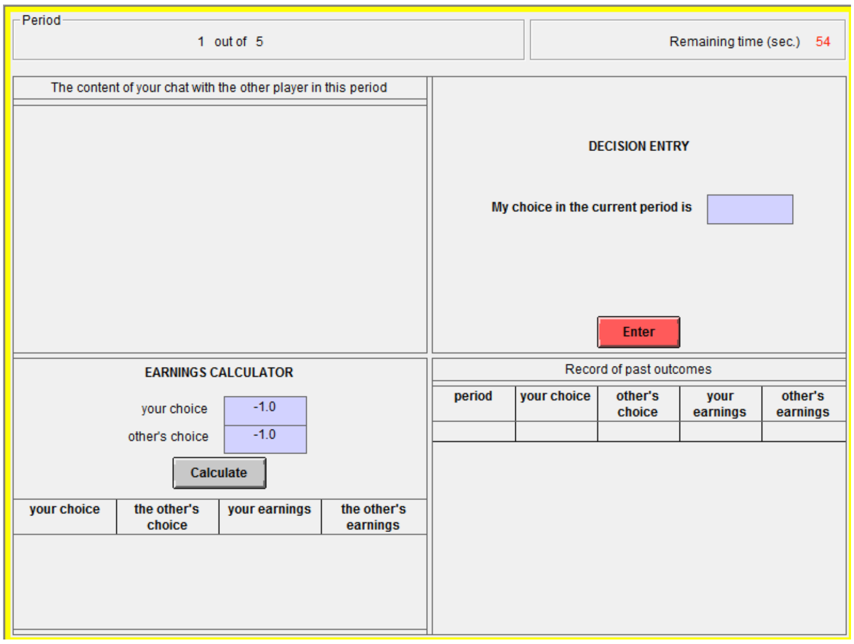
Your earnings depend on your own decisions and on the decisions of one other participant. The identity of the other participant will not be revealed. The other participant remains the same during the entire experiment and will be referred to as "the other" in what follows.

The experiment consists of 30 periods. In each period you must 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.

In 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.



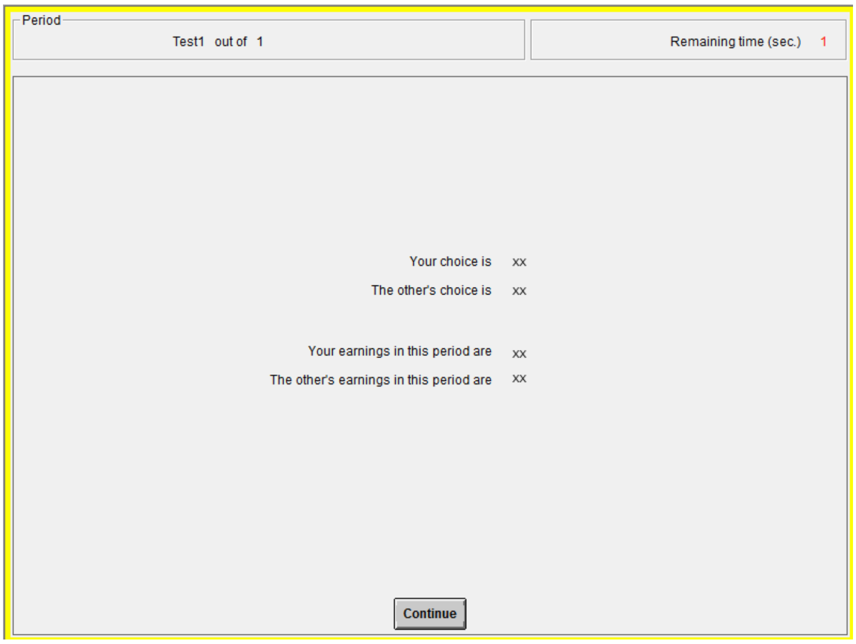
In this first stage, you can calculate your and the other's earnings in more detail (for choices that are not multiples of two for instance) by using the EARNINGS CALCULATOR on the left of your screen. On the right, you can communicate with the other through a chat box, for one minute. You can type your 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 your chat before the end of one minute, you can click the "Finish Chat" button at the top right. If the other also clicks this button, communication will end, and you will move to the 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, which is the same as before. At the top right you are asked to type in your choice and click “Enter”. In each period you have about one 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 in 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 12. 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 13. Payoff table for the substitutability treatments. Horizontal axis shows the partner’s choices.

C Payoff evolution and extra sessions

C.1 Payoff evolution

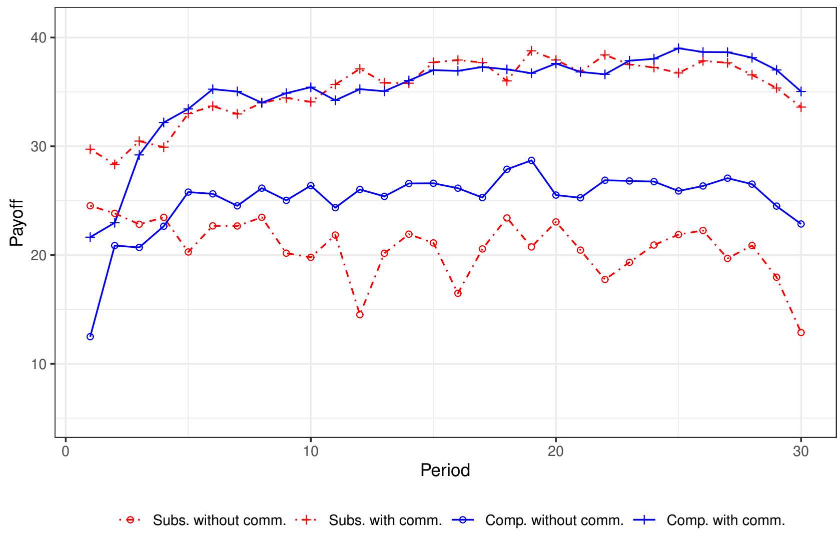


Figure 14. Average payoffs per period for complementarity and substitutability treatments with and without chat.

C.2 Communication or extra time?

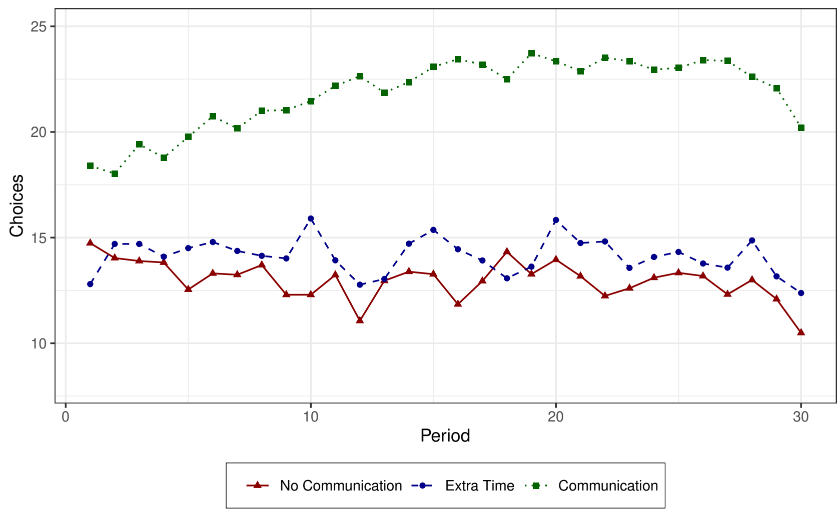


Figure 15. Average choices within each substitutability treatment, including extra sessions with extra time without communication.

Here, we provide comparisons with the extra sessions we have run to check if the observed

	No Communication	*Extra Time*	*Communication*
Ave. Choice (s.d.)	12.99 (7.71)	14.13 (7.47)	21.82 (7.93)
# Subjects	112	48	104

Table 6. Average choices within each substitutability treatment, including extra sessions with extra time without communication. The WMW test for any pair yields a $p-$value of 0.000. Tests are run over all periods, and thus, cover $30 \times n$ observations.

effect of communication is due to the extra time in the communication treatments. Figure 15 illustrates the average choices for each of the substitutability treatments, including extra sessions where subjects were given the same amount of time as in the communication treatments but were not able to communicate. As shown in the figure, the choices are very close to the case without extra time and much lower than the treatment with communication. Table 6 details the average choices for each treatment.

D Choices in treatments without communication

In the graphs below, pair IDs are printed on top of each plot next to the description (non-JPM, early JPM, or eventual JPM according to the definitions in Section 4.3.1). The plots are confined to the strategy space, *i.e.,* the interval $[0, 28]$. The Nash equilibrium is 14 and the JPM is 25.5 (dotted line) for both strategic environments. The optimal defection choice is 18 for complementarity and 10 for substitutability.

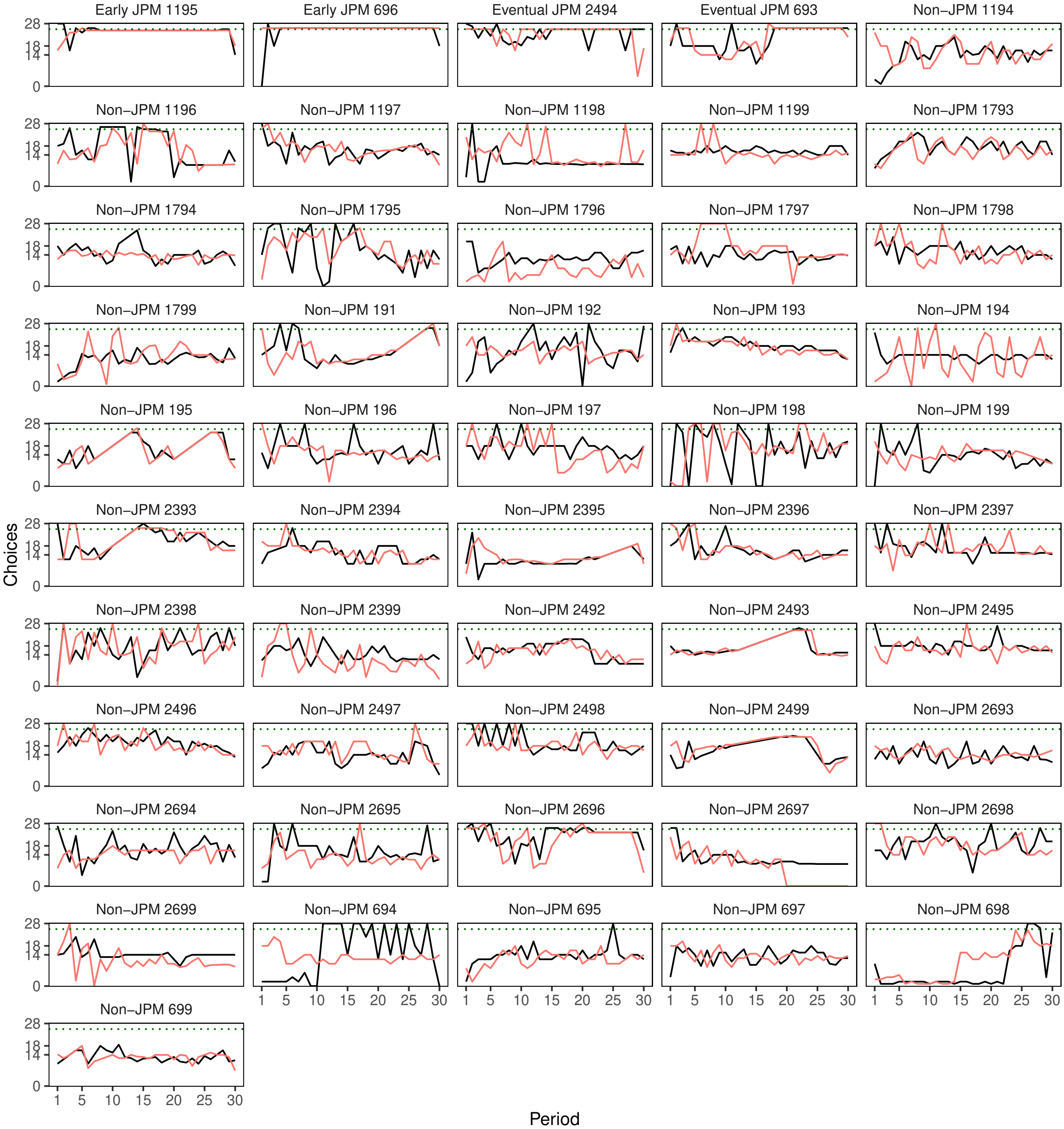


Figure 16. Complementarity without communication.

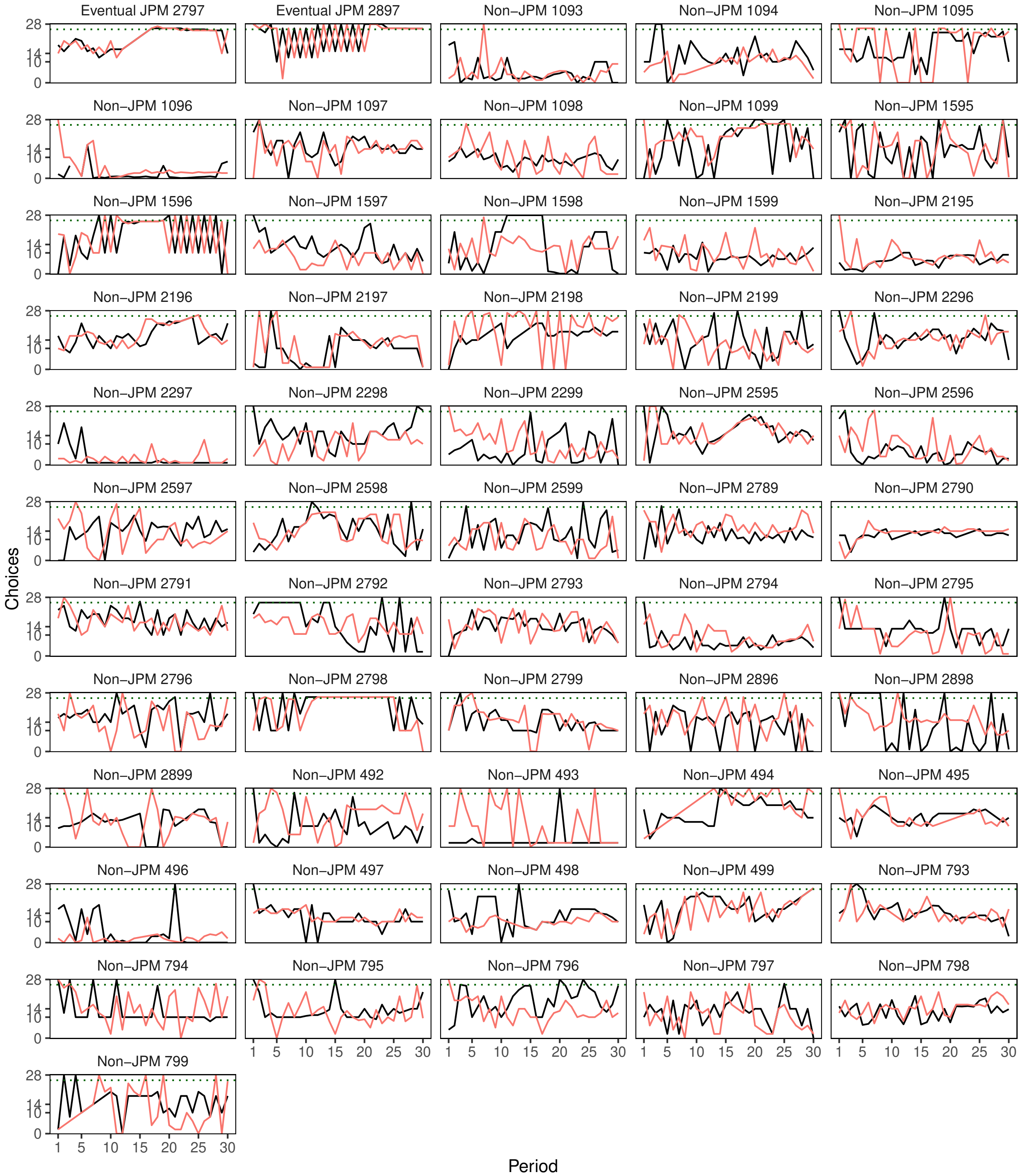


Figure 17. Substitutability without communication.

E Choices in treatments with communication

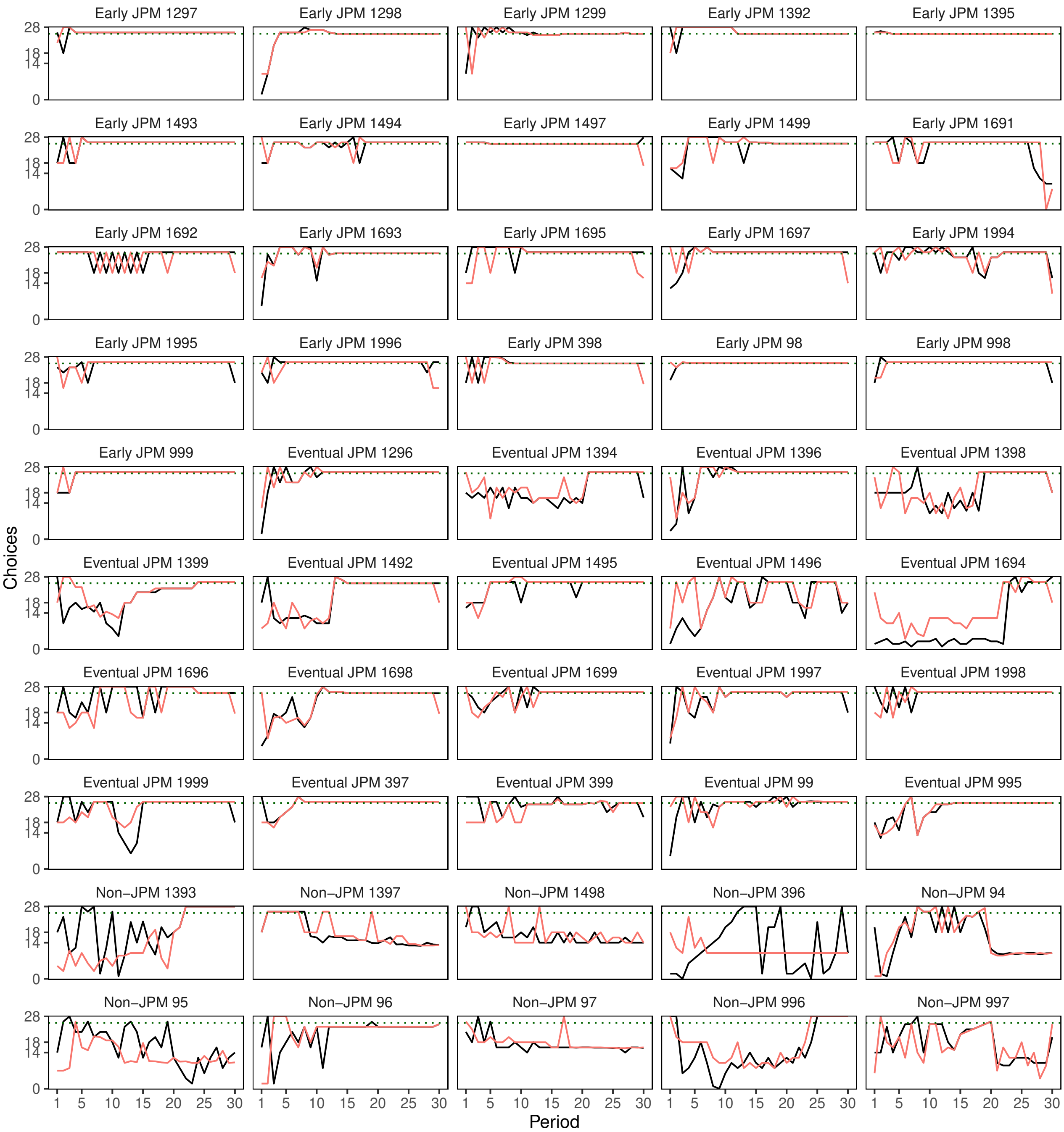


Figure 18. Complementarity with communication.

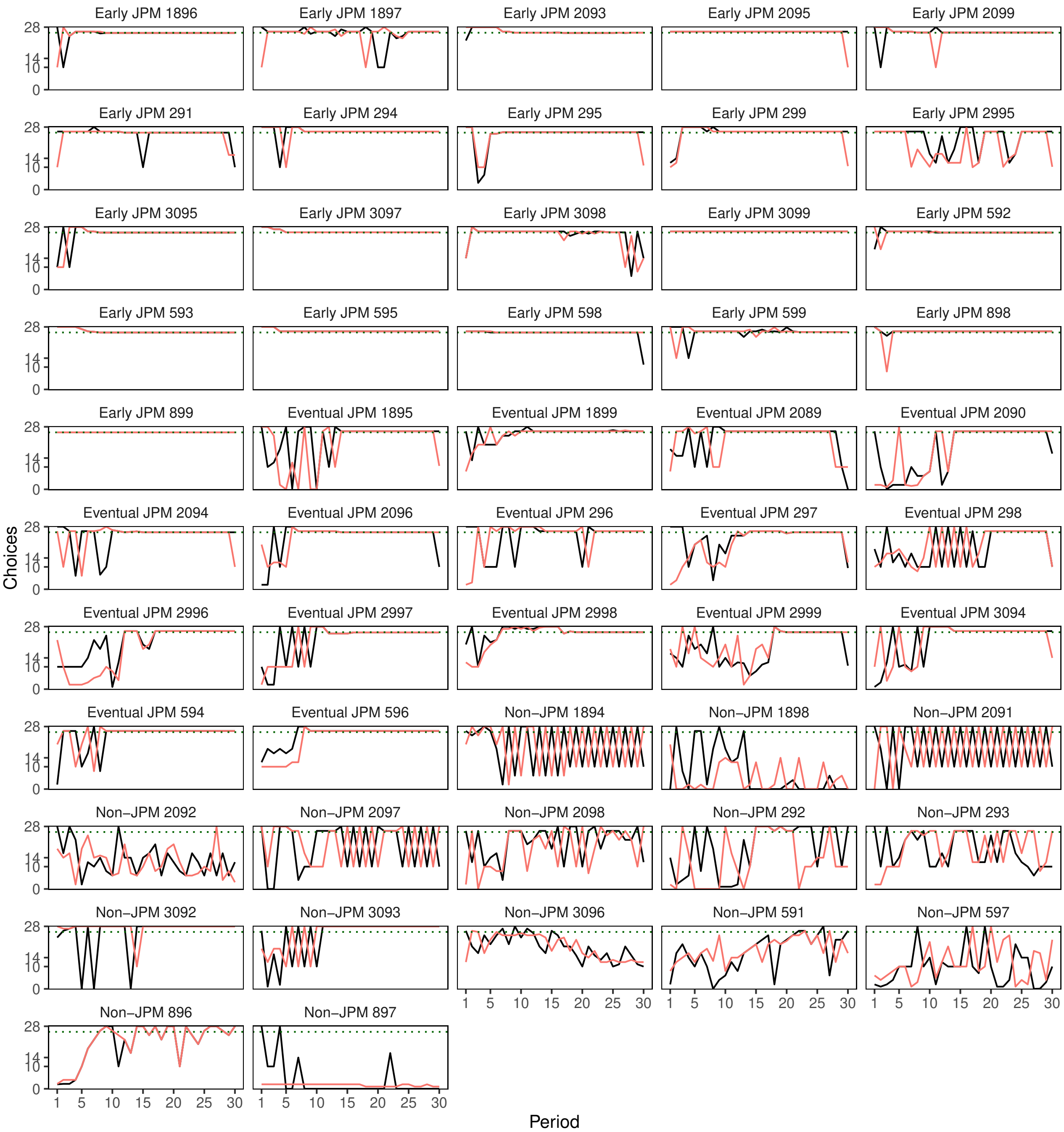


Figure 19. Substitutability with communication.

F Translations

Term (FR)	*Term (EN)*	*Subs Rank*	*Comp Rank*	*Term (FR)*	*Term (EN)*	*Subs Rank*	*Comp Rank*
met	put	2	3	continu	continue	30	38
plus	more	4	4	rien	nothing	31	40
mdr	lol	5	8	encor	again	32	36
gagn	win	6	5	sai	know	33	52
bon	good	8	14	croi	believe	35	51
deux	two	9	9	trop	too much	36	49
foi	time	10	13	moin	less	37	30
comm	like	11	12	gain	earn	38	26
même	better	12	7	temp	time	39	39
mieux	same	13	10	fin	end	40	34
pens	think	15	25	grave	serious	41	119
mettr	to put	16	24	peu	little	42	35
bien	good	17	19	chaqu	each	43	33
mainten	now	18	42	l'autr	the other	44	50
tour	turn	19	28	dernier	last	45	55
faut	must	20	16	compri	understood	46	48
pareil	same	21	18	invers	inverse	48	37
point	point	22	31	parc	because	49	73
aussi	too	24	27	toujour	always	50	45
d'accord	agreed	26	20	meilleur	best	64	41
veux	want	27	32	chiffr	number	135	45
rest	rest	29	29	tableau	table	185	44

Table 7. Most frequent (stemmed) terms depicted in Figure 8 with English translations and ranks in both treatments. Numbers and the term "haha" are removed. Last two terms are not shown in Figure 8.

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 necessary for any mixed-membership topic model, STM entails multimodal estimation that may depend on the 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 is 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 is *semantic coherence* as developed by Mimno et al. (2011), which is maximized when the most probable words in each 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, which we denote by ϕ, is a weighted harmonic mean of a word's 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.[39] 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 is 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 one. Hence, if the computed sample dispersion is greater than this, the number of topics might be too low, because the latent topics are unable to account for the variation. We also computed the document-completion held-out likelihood, being the estimation of the probability of words being used by a subject when those words have been removed in the estimation.[40] Figure 20 plots the relationship between these measures and the number of topics.

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

[39] We take $\omega = 0.7$, following Roberts et al. (2019).
[40] 50% of the content of 10% of documents are held out.

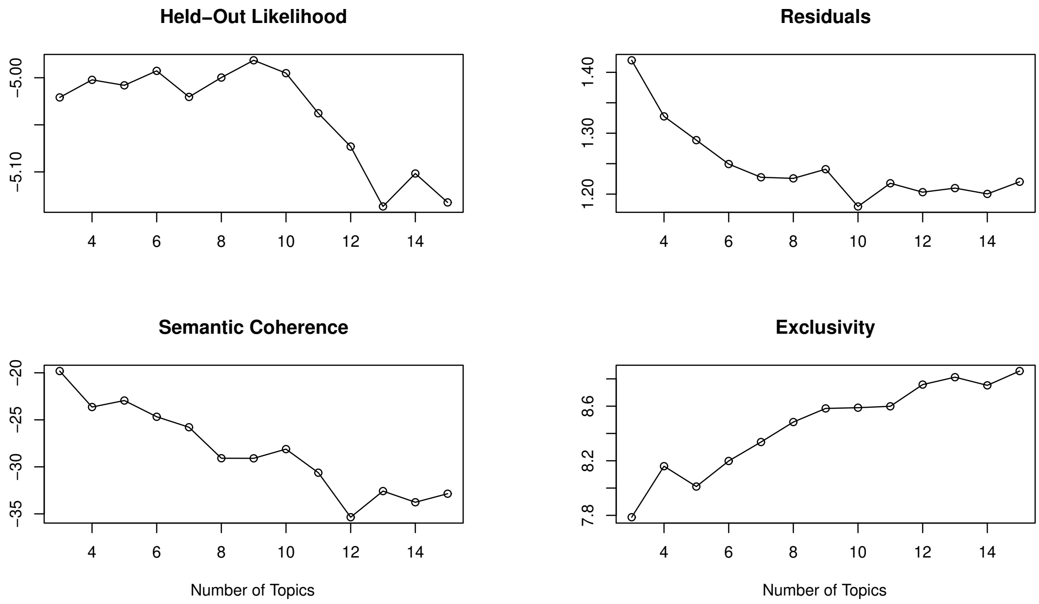


Figure 20. Diagnostics.

loss in terms of held-out likelihood. Both the residual analysis and exclusivity naturally point to a 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 overly concerned about the low performance of the three-topic model based on these measures. We believe including more topics in the estimation would not add to our analysis.

G.3 Estimated topic proportions within pairs

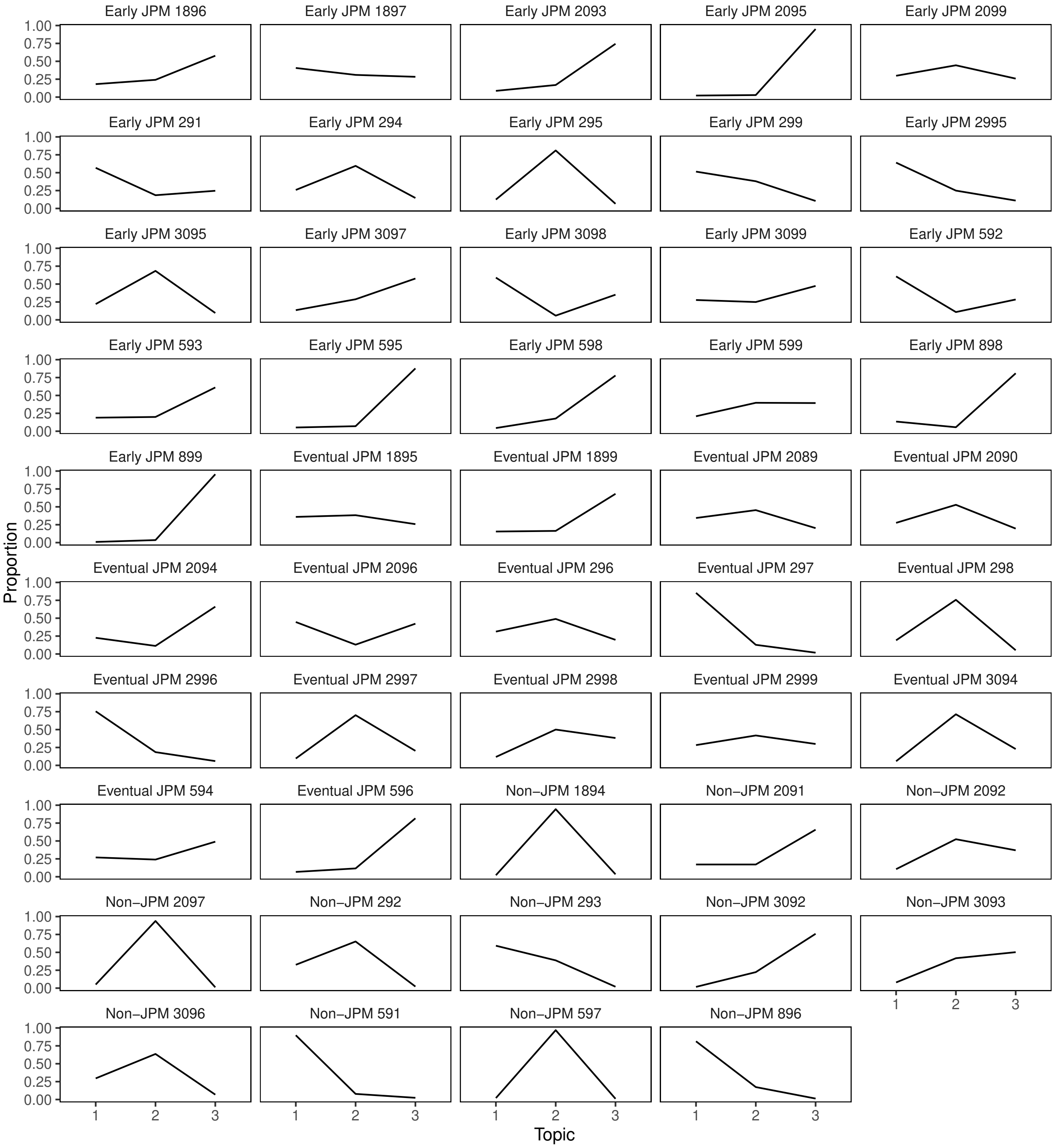


Figure 21. Estimated topic proportions within pairs in substitutability treatment.

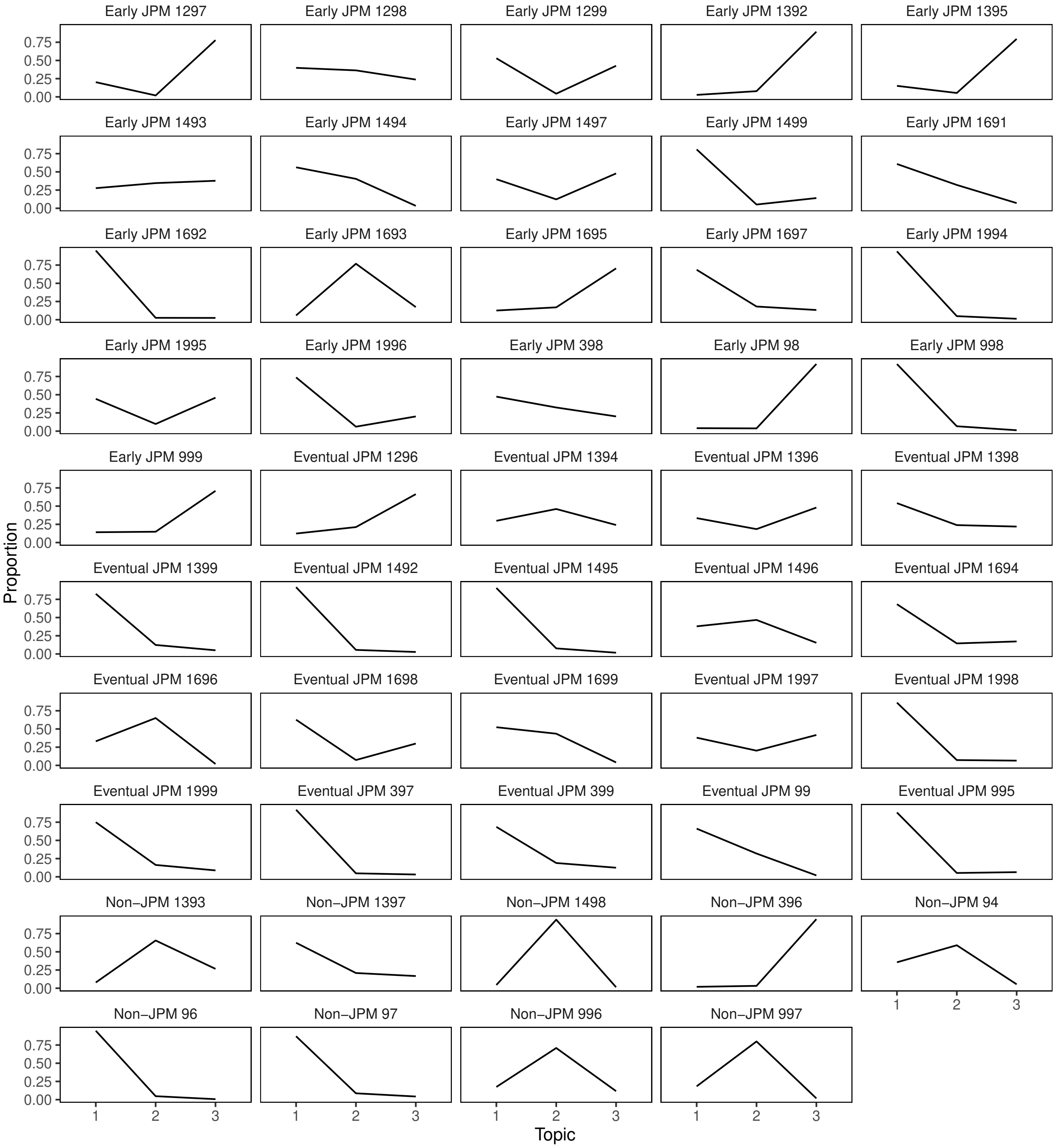


Figure 22. Estimated topic proportions within pairs in complementarity treatment.

G.4 Chat record examples

1	*2*	*3*
0.92	0.05	0.03

Table 8. 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 choosing 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 supposed 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 having a little look at 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 the 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 going like this
9	2	si tu vx on reste sur le 26	We'll 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 9. Chat record of Pair 397 in time order within periods.

1	*2*	*3*
0.08	0.66	0.27

Table 10. 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?	Does one of us have to put 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?	You have to rely on the table, to have the biggest gain, isn'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 to 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 11. 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 for 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	Where I'm at, I'm trying to hit the jackpot
9	2	tableauuuuuuu	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 don't 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	CONGRATULATIONS
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 12. 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 answers I 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 13. 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 check 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 rigged 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 for 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 14. 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	ouiiiiiii	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 15. 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 in 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	enfinnnnnn fini	finally finished
30	2	mdr c'est l'objectif	lol it's 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 16. Chat record of Pair 1393 in time order within periods.

1	*2*	*3*
0.05	0.07	0.88

Table 17. 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 both win 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 both have 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 both put 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 trooooooooooop 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 lose money
13	1	oui en effet	yes exactly
14			
15	2	−_	

Table 18. 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 19. Chat record of Pair 595 in time order within periods.