Title	The successful strategy for mutual cooperation in the experimental multi-game contact
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Citation	京都大学大学院経済学研究科Working Paper (2007), 91
Issue Date	2007-10-26
URL	http://hdl.handle.net/2433/65730
Right	
Type	Research Paper
Textversion	author

Working Paper No.91

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October, 2007

※ This research was supported by the Open Research Centre, "Experimental Economics: A new method of teaching economics and the research on its impact on society, " the Graduate School of Economics, Kyoto Sangyo University and the Japan Society for the Promotion of Science, the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for JSPS Fellows, 2006-2008, JSPS Grant-in-Aid for Scientific Research, Encouragement of Young Scientists (B), 19730146, Hiroshima City University Grant for Special Academic Research(General Studies), and Grant for the Murata Science Foundation.

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The successful strategy for mutual cooperation in the experimental multi-game contact[*]

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October 26, 2007

Key Words: Hard-TFT, Soft-TFT, multi-game contact, human behavior, cooperation and experimental economics

JEL Code: C72, C73, and C91

Abstract

Playing multiple games simultaneously is popular, but we hardly know how people act in this situation to reach mutual cooperation in the long run. To answer the question, we conduct a series of experiments on multi-game contact. The results indicate that the number of information sets in the stage game and the payoff structure are important. We find that for making mutual cooperation subjects employ two types of TFT strategies, which simplify the complicated contact. In these strategies, they avoid separating behavior such as cooparating in one game but deviating in the other. This makes it easy for the opponents to understand thier cooperative intention.

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[*] This research was supported by the Open Research Centre " Experimental Economics: A new method of teaching economics and the research on its impact on society, " the Graduate School of Economics, Kyoto Sangyo University and the Japan Society for the Promotion of Science, the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for JSPS Fellows, 2006-2008, JSPS Grant-in-Aid for Scientific Research, Encouragement of Young Scientists (B), 19730146, Hiroshima City University Grant for Special Academic Research(General Studies) , and Grant for the Murata Science Foundation.

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1 Introduction

It is not enough to examine the strategies of the firms in a single game because a lot of large firms compete or collude with each other in multiple markets. Toyota has been a multimarket rival of GM in the American and the Euro markets. Sony has been in competition with Nintendo in the portable game market (PSP vs. NDS) as well as in the home video-game console market (PS3 vs. Wii).

Multimarket contact has been investigated empirically since 1950's [8, 19] to answer the belief that the increase in the number of market contacts facilitates collusion. However, empirical support for this belief is not widely observed, because a lot of market conditions affect empirical data.

We can see multimarket contact generally in a society.[1] A wife and her husband face with cooking and cleaning. A person chooses whether she hangs around with her colleagues in her private time. The relationship between political and economic issues is discussed simultaneously in the diplomatic negotiation. When agents keep on making contact in multiple situations (markets, jobs, and places), we call this phenomenon 'multi-game contact', since the multi-game contact has a broader meaning than the multimarket contact.

Bernheim and Whinston [3] theorized firms' multi-game behavior. The basic theory assumes that two risk neutral agents face with each other in two infinitely repeated Prisoner's Dilemma (PD) games. The payoff structure may be the same or different between two games. They proved that the combination of different games brought cooperation easily because the lowest discount factor of multiple games to make mutual cooperation an equilibrium was lower than that of the single game which is more difficult to cooperate.

Spagnolo [25] proved that if a player had a strictly concave utility, playing two identical PD games strictly facilitated mutual cooperation more than playing the same games separately. Aoki [1] utilized this theory to consider the situation that irrigation in an agricultural village was linked to social exchange. Iwanari et al. [14] applied this into a trade issue.

Once a theory is established, it must be validated. Since the multi-game contact theory is a variation of repeated game theory, conducting experiment is one of the suitable tests. However, few studies have validated basic multi-game theory up to now. [2]

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[1] We assume that multimarket contact is a synchronic phenomenon. A study [24] in social psychology assumes that multimarket contact is a diachronic phenomenon where agents interact with each other in a PD game first and then in a public goods game.

[2] There are numerous studies on the experimental single markets. See [7] and [15]

On the other hand, the examination of the decision making under multi-game contact is so important that the analysis result is useful to expect what happens in the real multi-game contact and to build an economic policy in the contact. However, the analysis for the multi-game behavior is few. Under this situation, players can choose more complicated strategies than under a single-game contact. Detailed analysis of the decision making may find a new strategy generally used in the real multi-game contact. However, experimental studies on multi-game contact ignore the behavioral analysis.

Our purpose is to clarify the human behavior under the multi-game contact with simple PD games; first, we examine the percent cooperation difference between under the multi-game contact and the single game contact and within under the multi-game contact to validate the effect of the multi-game contact in the long run. Second, we dig into the property of the human behavior under this contact and the strategy for mutual cooperation.

We have three experimental results. First, when in the long run multi-game contact the percent cooperation is affected by the payoff structure difference and the number of information sets in the stage game. This is not found in the prior experimental studies on the multi-game contact but differs from the theoretical prediction. Second, some of the subjects employ three types of Tit For Tat strategies. Two of these strategies regard the opponent's alternatives in the last round as simply cooperation or deviation and return cooperation or deviation in all the games in the present round. Third, they combine one of two strategies and another strategy and send a message to their opponent for mutual cooperation.

This paper is organized in the following way. Section 2 introduces prior theories and experiments on the multi-game contact. Section 3 explains our experimental design with reference to the prior theories and experiments. Section 3.2 introduces some new concepts required for investigating our experimental results and defines various possible strategies used by the subjects. In Section 5, we interpret the reason why participants utilize TFT strategies. In Section 6, we discuss that the strategies from various viewpoints. Finally we conclude this paper and refer to our further study.

2 Literature survey

2.1 Theory

Let us introduce prior theoretical studies on multi-game contact. For example, Ohta and Kobayashi [16] examines the value of information under multi-game contact. Matsushima [17] investigates imperfect monitoring under multi-game contact. Hashimoto [13] utilizes evolutionary game theory and examine multi-game contact and finds chaotic phenomenon. However, the aims of these studies are different from our aim.

Price formation and the possibility of collusion in multi-game contact was first theorized by Bernheim and Whinston ([3], hereafter B&W) Although, price formation, quantity choice, Research and Development activity and entry and exit under multi-game contact have been examined empirically since 1950's [8, 4], B&W regarded the situation as infinitely repeated PD games and assumed that agents had an identical risk neutral utility function. Then they compared a situation where players played a game T (Table 2) with a situation where they played game S (Table 1) and T simultaneously. They showed that playing multiple games simultaneously decreased the minimum value of discount factor for cooperation with respect to the one when playing a single game and that playing two identical games did not promote or prevent cooperation.

Spagnolo ([25]) assumed that agents had strictly concave function $U(\sum x_i)$, where x_i is payoff from game i and $U'() > 0, U''() < 0$, and following two trigger strategies. First, players deviate only in the game where their opponent deviated. We call the situation in which this is utilized, "separate multi-game contact", because players ignore the connection between games and act as if they play a single game. Second, players offer "D" in all the games even if their opponent deviated only in one of the games. We call the situation in which this is utilized, "pooling multi-game contact", because players consider the decision results in all the games.

Then Spagnolo compared the separate multi-game contact with the pooling multi-game contact and showed that the former discount factor was larger than the latter one.

Spagnolo asserted that two identical games in the separate multi-game contact was more difficult for mutual cooperation than two identical games in the pooling multi-game contact, although his result seemingly indicated that playing two identical games facilitated mutual cooperation more than playing a single game.

Furthermore, although Spagnolo did not refer apparently, additionally assuming that $u()$ is a homogeneous function of degree k, we can easily show that the minimum discount factor in the pooling multi-game when playing two identical games is as large as the one when playing the same game.

Spagnolo [26] defined three relations;'not pooling relation', 'pooling relation' and 'strictly pooling relation'. First is satisfied when agents face a different agent in each relation. Second is satisfied when the same two agents face with each other in two games. Third is satisfied when they face each other in two games, and when in equilibrium agents choose the same actions in the two relations. First, second, and third relations are single market contact, separate multi-game contact, and pooling multi-game contact, respectively.

The point of view that the pooling multi-game contact is different from the separate multi-game contact condition is important but not found in B&W.[3] This view indicates that if agents face with each other in multiple situations and want to reach mutual cooperation, they have to adopt the strategy that connects a game and the other game. As section 4 indicates, the decision whether a player links a game and the other game is very important when we examine the cooperative behavior under the multi-game contact. Spagnolo suggested the importance of the behavioral analysis in the multi-game contact.

2.2 Prior Experiments

Feinberg and Sherman [9] utilized 4×4 payoff matrices as price competition and conducted multi-game contact experiments. The same payoff structure was used in all of their experiments. The subjects were not informed of the number of rounds (actually sixteen). They conducted two treatments. First is multi-game contact; a player played three identical games simultaneously with her opponent. Second is a single market contact; a player plays three identical games simultaneously with different three subjects. Through experiments, They found that the average price was higher in the treatment one than in the treatment two (nine percent significance).

According to view, this study compared treatment T with treatment TTT. However, it lacks the treatment where players play the two identical games simultaneously. The number of strategies in the stage game is sixty four (substantially twenty eight) in the first treatment. The effect of such numerous alternatives is ambiguous.

Phillips and Mason [20] utilized Cournot duopoly model (two different 22×22 payoff matrices) and conducted a single market and a multi-game treatment. The subjects were not told the number of rounds in the experiment. The treatment consisted of twenty-nine to forty-three rounds. Experimental results showed that the number of quantities was smaller in multi-game contact than in the single market contact. They asserted that experimental results were consistent with B&W's theory.

However, considering that the number of the rounds may increase the

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[3] In B&W, such a separation is meaningless because of the shape of utility function.

subjective discount factor, the authors' conclusion may be different from the theoretical prediction. It is unclear that the subjective discount factor is in the theoretically satisfied range. In addition, this study does not examine the treatment where players play the identical two games. Therefore, it is unclear that the percent cooperation change is due to the effect of adding one more game or the effect of the payoff structure of the added one.

Phillips and Mason [21] conducted a version of their past experiment [20]. Since all subjects knew that the game would last at least thirty five rounds and thereafter it would end with the probability of twenty percent, the authors controlled the subjective discount factor. They first attained the same result as their past experiment. Then the effect of the decision makings in the previous two rounds on the present decision making was analyzed econometrically. However, the analysis was applied into the pairs' decision makings. We can not grasp the individual decision making.

3 Experimental Design and Preparation of Analysis

3.1 Experimental Design

Tables 1 to 3 show the payoff matrices. From the viewpoint of the discount factor, game S is the most cooperative. Game T is almost as cooperative as game T'. As mentioned later, game T' is related to an information set.

In the experiments, the subjects offer alternatives simultaneously and independently through a computer console made by z-Tree [12]. In the single game contact treatment, they offer an alternative from a game. In multi-game contact treatment, they offer an alternative from each game, totally two or three alternatives in each round.

Following scheme is used to reduce the difference of monetary reward among treatments; $x \times \sum_{i=1}^{10} \pi_i + 800$, where π_i is a payoff randomly drawn from all the rounds. We draw ten round payoffs in total. The round number drawn for the reward is common to all the subjects in the same day . In multi-game contact treatment, the sum of payoffs from all the games are used for calculation. Finally x means 0.4, 0.2, and 0.13 in the single market contact, in multi-game contact treatment of two games and of three games, respectively.

Table 5 indicates the brief summary of the treatments. We conducted six treatments; S, T, TT, TTT, TT', and ST. Last four treatments are multi-game contact. Experiments were conducted at KEEL (Kyoto Sangyo

University Experimental Economics Laboratory) from June, 2005 to November, 2006. The subjects knew that their opponent was the identical but anonymous. In the multi-game contact, the subjects chose an alternative per game. They were not told the number of rounds in advance. We did not control the subjective discount factor of the subjects. However, in some treatments, after the experiment was over, we asked them about their expected number of rounds when they had come to mind at the beginning of the experiment.

We conduct treatments to investigate the effect of the change in the number of the information sets in the stage game and the effect of the the payoff structure change (Fig 1). Since the latter effect is easy to see, we explain the first effect. In the experiments for sequential decision making, a subject utilizes a few past choices and results of her opponent and herself. Especially, the last decision making and result will affect the present decision of the subject. Thus, it is reasonable that a player makes the present decision based on the information set that consists of the last round decision makings by the opponent. Such an information set has many types of the last round decision makings. One major type is the information set that bundles the substantially same strategies in the stage game by one strategy.

In treatment TT, because the payoff structures of all the games are identical, cooperation in one game and deviation in another game is indifferent. Therefore, in this treatment, there are three information sets; cooperation in all the games, deviation in all the games, and cooperation in one game and deviation in another game. On the other hand, in treatment ST (TT'), the information set in which a player cooperates in game S (T') and deviates in game T is different from the set in which she cooperates in game T and deviates in game S (T'). This treatment has four information sets; cooperation in all the games, deviation in all the games, cooperation in S (T') and deviation in B, and cooperation in T and deviation in S (T'). Similarly, the number of the information sets is four in treatment TTT. There are three patterns for offering C in a game and D in another two games. This pattern is one information set. Similarly, there are three patterns for offering D in a game and C in another two games. This pattern is one information set.

In the experiments, first, we compare the percent cooperation in treatment S with T, in treatment ST with TT' and in treatment ST (TT') with TTT to confirm the payoff structure change in identical information sets case. Second, comparing the percent cooperation in T with in TT and the percent cooperation in TT and TTT, we confirm the information set number change when the payoff structure in each game is identical.

Our experiment is based on B&W and Spagnolo. B&W investigated the multi-game contact from the repeated game theory and showed that the contact weakly facilitated mutual cooperation. We build the experimental setting according to the iterated game theory and to their theoretical model. Spagnolo classified the strategies in multi-game contact into two cases [4]; the strategy that a player chose the same alternatives in all the games (pooling strategy) and the strategy that she chose different alternatives in each game (separate strategy). Then he showed that the former strategy facilitates mutual cooperation. We examine whether our subjects utilize some pooling strategies or separate strategies from their adaptive behavior and if they utilize pooling ones, we want to know what kind of pooling strategies they employ.

Furthermore, our experiment considers the problems of prior experiments. First, the prior experiments have the problem of the discount factor control. Most of them do not control it seriously. [5] However, the reason why they did not control it is unexplained. To verify the theory, they have to control the subjective discount factor severely.

In our view, the severe control brings a new problem; we can not examine the long run behavior of a game. Since we want to investigate the subjects' sequential and long run behavior, it is better that we do not control the discount factor severely. In the discount factor controlled experiments, we might not conduct the large number of rounds.

Moreover, prior experiments examine only the validity of the theory. They only compare a game from the multi-game contact with the same game from the single market contact. It is an open question how people behave in the multi-game contact. To answer this, prior experimental design is complicated and the subjects' behavior in multi-game contact is ambiguous.

Finally, prior experimental studies do not explain why the multiple games are played instead of a large game; following B&W, playing two 2×2 games is identical with playing a 4×4 game. Spagnolo [26] introduced the notion of 'linking relation' and tried to explain the difference between playing two 2×2 games simultaneously and playing a 4×4 game.

Simultaneous play of multiple games is different from playing the large single game which integrate these games.[6] Suppose that a player faces with game B and another PD game M (Table 4) which consists of very small

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[4] Following B&W, the multi-game contact simply means that agents play games simultaneously and always choose the same alternatives in all the games. Therefore, they did not introduce them. Even if they found them, the risk neutral utility function would make them ignore the essential difference.

[5] Related to multi-game contact experiments, [6] controls the discount factor severely.

[6] This paragraph is based on discussion with Dr. Masumoto.

payoff. Integrating B and M into one large game and playing the large game is very different from playing B and M separately and simultaneously. Play with this large game vanishes the effect of the game M. Since the value of the payoff structure in the game M is much smaller than game B, integration weakens the effect of the game M. On the other hand, multi-game play keeps the effect. Players may utilize the game M to send some message to their opponent. They may deviate in the game M to punish her previous deviation. The game M is important in the multi-game cooperation and this role can not be observed in the large single game.

Integrating two games into a large game brings a new problem that we can not deal with the emergence of the linkage between games. Analyzing the linkage of the games is actually very important, when a firm builds a strategy, when a government deals with foreign affairs, and when people live with their family. In such situations, first, agents decide whether they associate a game with the other game or not. Then, they decide whether they offer the same alternative in each game.

Our advantage is to investigate whether the subjects connect a game and the other game. This investigation does not need one large game but multiple small games. With multiple games that consist of 2×2 strategies, we can examine whether and how the subjects reach mutual cooperation and what kind of strategy will bring mutual cooperation.

Therefore, we utilize simple payoff matrices and does not control the discount factor severely. With this setting, we conduct an experiment where multi-game contact lasts more than seventy rounds and investigate the decision making pattern of the subjects and its consequence.[7] Especially we can elucidate whether the subjects connect a game and the other game. To investigate the total effect of multi-game contact, we do not compare a game from multi-game contact treatment with the same game from the single game contact treatment. Our study is not enough for verification of multi-game contact theory because the strict control of the discount factor is not done. As stated in the section 7, we are conducting the experiments with the strict control of the discount factor.

3.2 Preparation for the analysis

The human behavior in the multi-game contact has not been examined, although such examination will provide an interesting and new insight into the behavior in the complicated situation. There seems to be two reasons why

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[7] Another method to figure out the decision making process is found in [23].

researchers did not consider the multi-game behavior. First reason is that they thought that players play multiple games separately. Prior experimental studies only compares the game B from the single market contact with the game T from multi-game contact. This analysis does not capture the whole characteristics of the multi-game contact. Moreover, existing theories do not recognize that the linkage of games affects a subject's mind.

Second, as the strategy in the multi-game contact is rarely defined, researchers do not have the tool for behavioral analysis. So far, only two trigger strategies has been proposed by B&W and Spagnolo. Since the multi-game contact is a complicated situation, human players can adopt a lot of strategies. Understanding of the human behavior in the multi-game contact requires the introduction of strategies instead of the trigger strategies, which are not adaptive at all.

We do not consider Hard-Trigger, Soft-Trigger, and Sep-Trigger when investigating the subjects' adaptive behavior because the human subjects is not strongly rational nor programmed player assumed by the game theory but an adaptive player who can change his or her strategy according to the opponent's strategy. It is obvious that TFT strategy is not the sub-game perfect Nash equilibrium but at most one of the Nash equilibria. Notwithstanding, TFT is important for expression of the adaptive human behavior.

In this paper, we introduce three strategies and four responses in total.Strategies are based on TFT strategy [2]in the single-game contact. Let us define Hard-TFT, Soft-TFT, and Sept-TFT. See Tables 6 and 7. Following is Soft-TFT. If an opponent of a player deviated in all the games in the last round, the player do the same in the present round. Otherwise, the player cooperate in all the games in the present round. Those who utilize it classify the opponent's last alternatives as only cooperation or deviation but they do not subtilize them. And then, they return cooperation or deviation in all the games. In this sense, it reduces the subject's cost for understanding the opponent's thought.

Let us explain Hard-TFT. If an opponent of a player deviated at least one game in the last round, the player offers deviation in all the games in the present round. Only if the opponent cooperates in all the games in the last round, the player offers cooperation in all the games in the present round. Obviously, when the opponent knows that the player is using Hard-TFT, it is more robust against her exploitation than Soft-TFT. In this situation, as she understands that her exploitation brings deviation in all the games by the player, she has little choice to cooperate in all the games. Therefore, Hard-TFT is theoretically easy to facilitate cooperation. However, like Soft-TFT, those who utilize it classify the opponent's last alternatives as only cooperation or deviation but they do not subtilize them. All they have to choose is all cooperation or all deviation. In this sense, it also reduces the subject's cost for understanding the opponent's thought.

Let us explain Sept-TFT. When players play multiple identical games, it is defined by the number of the games in which their opponent deviated in the last round and that where they do so in the present round. Since all the games are identical, the player do not care which game she should deviate against her opponent's last deviation but care that she equalizes the number of her deviations with the number of the opponent's last deviations. When playing two different games, the player chooses the same alternative in each game as his or her opponent offered in the last round. This simply mimics the opponent's last choices. Thus, those who utilize it do not classify the opponent's last alternatives. In this sense, it also reduces the subject's cost for understanding the opponent's thought.

When the opponent offered cooperation (deviation) in all the games in the last round and the player offers the same alternatives according to TFT strategies, we can not identify decision makings with one of three TFT strategies. In such a case, first, we go back to the most recent round in which the player offered a distinguishable TFT strategy. Then we apply this TFT to the present and indistinctive TFT strategy. When there is not a distinguishable TFT strategy in the past, we apply three strategies to the indistinctive offer. Strategies except for TFT strategies that exist between the indistinctive TFT round and the most recent distinguishable TFT round are ignored. See Table 8.[8]

Indeed, this classification is easily applicable for more than three games. That is, only we have to do is to modify Hard-TFT and Soft-TFT slightly. Suppose that multimarket contact consists of n games. k-Soft-TFT strategy is to offer cooperative alternatives in all the games when an opponent of a player offered cooperative alternatives in k $(k < n)$ games in the previous round. Similarly, k-Hard-TFT strategy is to offer deviations in all the games when an opponent of a player offered cooperative alternatives in k $(k < n)$ games in the previous round. Thus, definition of a strategy in this manner formulates human behavior with TFT strategies.

Let us explain four responses. When a player offers cooperation in all the games although his or her opponent deviated in all the games in the last round, the player's response is called Unilateral Cooperation (UC). When a player offer deviation in all the games although her opponent offer cooperation in all the games in the last round, the player's response is called

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[8]

Unilateral Deviation (UD). When a player offers cooperation in more games than the opponent did so in the last round, the player's response is called Partial Cooperation (PC). A part of PC is included in Soft-TFT. When, a player deviates in more (not less) games than the opponent did so in the last round, the player's response is Partial Deviation (PD).

4 Analysis

4.1 Overall result

We apply the two way analysis of variance with only one observation in each cell into rounds and treatments. We mainly use first seventy eight rounds to compare percent cooperation among all the treatments (Table 9). The statistical result shows that the percentage of cooperation is different among treatments at one percent significance (Table 10).

First, according to B&W, we briefly examine the percent cooperation difference. In the first seventy eight rounds, the percent cooperation in treatment T is significantly higher than that in treatment ST. In the end of the treatment, the percent cooperation in ST is almost the same as that in T. The percent cooperation in treatment T is significantly higher than that in treatment TT.

The questionnaire result indicates that at the beginning of the experiment, the subjects assumed that the experiments consisted of at least fifty rounds on average. This indicates that the predicted percentage of cooperation among games is unchanged if the discount factor is more than 0.3. Therefore, if we take players' subjective discount factor into account, the theoretical prediction is that the difference of percent cooperation among all the treatments is not significant.

However, our experimental result is different from the theoretical prediction. Unlike the prediction, the number of information sets and/or in the payoff structure affects mutual cooperation practically.

Second, we examine the percentage of cooperation difference among treatments in detail. When the number of information sets increases (from T to TT and from TT to TTT), there is the significant difference ($F = 18.8$ and $F = 177.6$). In two information sets case, it is significantly higher in treatment S than T ($F = 35.2$). In four information sets case, it is the highest in treatment ST, then TTT, and TT' ($F = 84.0$ in ST vs. TT', $F = 46.4$ in ST vs. TTT and $F = 7.84$ in TT' vs. TTT.) Especially, the percent cooperation in the first thirty nine rounds is significantly higher in

TTT than in TT' and that in the last thirty nine rounds is significantly higher in ST than in TTT. That in ST finally reaches that in TT.

This indicates that the increase in the number of information sets decreases the percentage of cooperation. This result differs from the theoretical prediction. Therefore it suggests that players face with complicated choices when the number increases.

Here, we make a remark for the difference between the number of games and the number of information sets. A reader may expect that the percent cooperation difference is affected by the former not by the latter. Comparison result between TT' and TTT indicates that in the latter rounds, the difference in the number of games does not affect the percent cooperation. In this case, the payoff structure in each game is almost the same. The number of games is different. The number of information sets is the same. On the other hand, the percent cooperation in TT is higher than that in TTT. In this case, the payoff structure in each game is the same. The number of games is different. The number of information sets is different. Integrating the first comparison and the second comparison, we find that the number of information sets is important for the percent cooperation.

At the same time, this result indicates that given the number of information sets, the percentage depends on the relatively cooperative game. Especially, when the number of information sets is four and the multi-game contact contains a game S, the percentage of cooperation increases. Therefore, when the increase in the percentage of cooperation is required in the four information sets case, the payoff structure is more important than the number of information sets. The percentage of cooperation difference between TT' and TTT is not significant in the last thirty nine rounds. This indicates that when the number of information sets increase from two to four, adding the same two games as the original game and adding a slightly different game is almost indifferent for cooperation.

The percentage of cooperation change is divided into the change in the number of information sets and in the payoff structure. Changing TT to TT' and TT to TTT, the percentage of cooperation change is negative. It is affected by the negative effect of the information set number change and the ineffective effect of the payoff structure change. Changing ST to TTT, the percentage of cooperation change is almost zero. It is affected neither by the negative effect of the change in the number of information sets or by the ineffective effect of the payoff structure change. Changing TT' to ST, the percentage of cooperation change is positive. It is affected only by the positive effect of the payoff structure change. Changing TT to ST, the percentage of cooperation change is almost zero in the long run. It is affected by the negative effect of the information set number change and the positive effect of the payoff structure change.

4.2 Behavioral analysis in multi-game contact

To identify the general strategy which helps to reach mutual cooperation in the multi-game contact, first, we consider the relationship between percent cooperation and the information sets used in the experiments. Then we explain how to classify the subjects' decision makings. Finally, we make it clear what kind of strategy can reach mutual cooperation.

In this section, a 'cooperator' is the subject whose percent cooperation is more than seventy five percent. The subject whose percent cooperation is in the range seventy five percent to twenty five percent is a 'medium player'. Otherwise, a subject is a 'deviator'. In most cases, if a player is a cooperator, her opponent is a cooperator, too.

Let us investigate the evolution of the subjects' behavior. Table 11 indicates the distribution of asymmetric alternatives (the mixture of cooperation in one game and deviation in another game). Asymmetric choices mean neither strictly cooperation or strictly deviation. In the upper part of the Table, the frequency of such alternatives is significantly smaller in the latter than in the former rounds except for treatment TT. The lower part of the Table indicates cooperators' choices. They tend to avoid asymmetric choices even in the former rounds. In the latter rounds, this tendency becomes more salient. Therefore, this Table indicates that even if the subjects can utilize asymmetric choices, they only use the symmetrical ones.

Then we examine the subjects' behavior with cluster analysis. The result[9] is shown in Table 12. It indicates that in any treatment, two strategies are utilized by cooperators; the strategy which consists of mainly Soft-TFT, and the one which consists of indistinctive TFT strategy (because both subjects agree on mutual cooperation in the initial rounds). The strategy which consists of mainly Hard-TFT is utilized by a few cooperators. On the other hand, there is few cooperators who utilize Sept-TFT mainly.[10]

Most of the subjects who used the indistinctive TFT strategy offer cooperation throughout the treatment. They successfully reached mutual cooperation in the initial rounds.

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[9] With JMP, we normalize the subjects' decision making distribution by standard deviation and conduct $K-$means cluster analysis that changes the distance with sampling rate. We classify the subjects' behavior into five clusters.

[10] In treatment BC, all the Sept-TFT subjects are cooperators, because all of their opponents utilize Soft-TFT or Hard-TFT.

Although Soft-TFT is weak against the opponent's partial exploitation, it is important that the percent cooperation in the Soft-TFT based cluster is very high. It is significantly more cooperative than that of single game treatment T (Table 13).Only exception is treatment TT', although the percent cooperation in that treatment is higher than that of treatment T.

The reason is that the players in this cluster utilize Hard-TFT. They counter with the opponent's exploitation; if a player adopts Soft-TFT but is exploited by her opponent for some rounds, she can offer Hard-TFT and stop her opponent's exploitation. After unilateral exploitation vanishes, deviation in all the games with each other or partial cooperation may last in some rounds. In such a case, she utilizes Soft-TFT again and/or UC and try to reach mutual cooperation. In the experiments, most players in this cluster utilize such strategies and response and reach mutual cooperation successfully.

On the other hand, although Hard-TFT is robust against the opponent's exploitation, the percentage of cooperation in the Hard-TFT based cluster is not so high. The reason is that most players in this cluster can utilize all cooperation or all deviation by Hard-TFT, but fail to choose the strategies and/or resposes that induce cooperation. Players using it may be misunderstood by their opponent. For example, even if their opponent wishes cooperation and offers PC, a Hard-TFT player returns deviation in all the games. In this case, their opponent may think that she does not want to cooperate or offer cooperative responses or strategies such as UC never again.

For mutual cooperation a Hard-TFT player needs to choose additional responses and/or strategies such as UC and Soft-TFT. However, most of the human players who use the strategy fail to choose them. Tables **??** to **??** suggest that deviators and medium players use PC and Sept-TFT in order to reach mutual cooperation. These are only a halfway solution to mutual cooperation.[11] In this experiments, most of the players in Hard-TFT cluster fail to reach mutual cooperation. This comes from the inappropriate combination of a strategy and a response.

However, Hard-TFT cluster can still bring mutual cooperation. Those who reach mutual cooperation successfully in this cluster utilize Hard-TFT mainly and other cooperative strategies and responses such as Soft-TFT and UC. Although the percentage of such subjects is not large, the fact that cooperators exist in this cluster indicates that this cluster can bring mutual

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[11] If her opponent utilizes Hard-TFT, the opponent does not understand her intention to cooperate.

cooperation.

These analysis indicates that cooperators utilize Soft-TFT (Hard-TFT) and other strict (tolerant) strategies and/or responses to prevent the opponent from exploiting and to reach and to keep mutual cooperation.

Thus, an effective strategy to reach and keep mutual cooperation reduces the number of alternatives in the stage game and utilizes the strategies that give the opponent the incentive to cooperate. We call this strategy *Cooperation Facilitation Strategy in the Multi-Game Contact (CFSMGC).*

In this experiment, Soft-TFT and a part of Hard-TFT cluster satisfy the condition of CFSMGC. The former has the major strategy, that is, Soft-TFT, and the minor and strict strategies and responses such as Hard-TFT and PD. The latter has the major strategy, that is, Hard-TFT, and the minor and tolerant strategies such and responses as UC and/or Soft-TFT. These clusters reduce the number of subjective information sets. Soft-TFT cluster facilitates mutual cooperation obviously. Although those who utilize Hard-TFT cluster often fail to reach mutual cooperation, some players adopt the strategies that induce mutual cooperation. Therefore, they belongs to the players who use CFSMGC.

5 Interpretation

Since TFT focuses on information sets in only the last round, it decreases the cognitive cost of a player, which is considered when a player try to understand the meaning of opponent's decision. On the other hand, a strategy in the repeated game is a list of alternatives in all the past and future information sets. The content of the list increases exponentially as the number of rounds increases since the increase in the number of the information sets that the player care is exponential. Soft-TFT and Hard-TFT returns only all cooperation or deviation in the present round. For the players, cooperation in one game and deviation in the other game has the same meaning as cooperation (Soft-TFT) or deviation (Hard-TFT) in all the games. Therefore, these are simple.[12]

Moreover, they reduce the opponent's cognitive cost since they have only

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[12] A reader may assume another TFT, which returns cooperation in all the games when the opponent's last choice of a particular game, say game S, was cooperation but does deviation in all the games when the last choice of the game was deviation. This strategy only focuses on a game and ignores the other game. It is not Soft-TFT or Hard-TFT.

However, as a consequence of reconsidering our subjects' behavior, we did not find that they employed such a strategy. That is, they did not attatch a high value to a particular game.

two alternatives to respond. They are very useful tool for sending a player's cooperative message to the opponent. On the other hand, since Sept-TFT mimics only the opponent's choices, the subjects need not deliberate the opponent's decision. However, they use all the alternatives. In this sense, it does not reduce the opponent's cognitive cost. It is not useful when sending a player's message to the opponent.

Using Soft-TFT and Hard-TFT suggests the existence of "subjective information set". It is an information set that a subject actually considers when she choose the present alternatives.[13] Subjective information set is more strategic than an information set. A player thinks that some information sets are indifferent for her present decision making. She can decide the number of subjective information sets strategically in her favor. It does not decrease the number of information sets in the stage game. Subjective ones give information sets some interpretation (figure **??**). In the left table in this figure, a subject interprets that three of four information sets have the same meaning for her decision making (Soft-TFT). Therefore, a Soft-TFT player plays the multi-game contact with two subjective information sets. In the right table, she interprets that all the information sets differ from each other for her decision making (Sept-TFT). A Sept-TFT player plays the multi-game contact with four subjective information sets.

Assuming that a player uses subjective information sets, the number of the sets will affect the cognitive cost. When the number increases, the cost will also increase. The cognitive cost reduction is required for players.

In every round, Soft-TFT or Hard-TFT players can reduce such costs since they classify the opponent's asymmetrical alternatives into cooperation or deviation. This is a simple classification. In reality, since asymmetric alternatives is not cooperation or deviation, they are ambiguous. However, they classify such ones into two categories arbitrarily. Based on this classification, they cooperate (deviate) in all the games for the opponent's cooperation (deviation). In the point that they do not examine their opponent's strategy carefully, they are lazy.

However, their laziness makes two TFT strategies an useful tool for mutual cooperation. Whatever alternatives the opponent chooses, the players return clear response. This makes it easy to inform the opponent of their attitude; when they employ Soft-TFT (Hard-TFT), their attitude is tolerant (severe).[14] At the same time, these strategies change the number of the

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[13] A information set explained in the textbook of game theory is given objectively and players in the game cannot change it arbitrarily.

[14] Since Hard-TFT deviates against the opponent's ambiguous alternatives, the opponent may regard it as exploitation. This is one of the reasons why Hard-based cluster

opponent's subjective information sets into two. This change enables the opponent to play the games with two TFT strategies.

Thus, there are two ways of cognitive cost reduction.;first, adoption of TFT dramatically decreases the number of infomation sets that players take into account. Second, adoption of Soft-TFT or Hard-TFT bring together the opponent's ambiguous alternatives into cooperation or deviation as a subjective information set. Soft-TFT or Hard-TFT players reduce the cost by reducing the number of subjective ones.

Moreover, experimental analysis indicates that Soft-TFT players also utilize Hard-TFT and that Hard-TFT players who successfully reach mutual cooperation also utilize UC or Soft-TFT. These clusters have cooperation facilitation and exploitation prevention with simple combination of strategies. Such CFSMGC is generated unintentionally by the players who want to cut cognitive cost.

6 Discussion

Let us discuss CFSMGC from various viewpoints. Prior experimental studies basically found that multimarket contact facilitated cooperation. This is different from our result. However, the result is natural if most of the subjects in the prior studies offer alternatives on the lines of 'CFSMGC'. We investigate the human behavior on which the prior experiments did not focus and find a valuable strategy to facilitate mutual cooperation in reality. This point distinguishes our study from the prior experimental studies.

Experimental result indicates that TFT strategies with another strategies will induce mutual cooperation. However, we can look for another CFSMGC if the subjects utilize all-C or Trigger strategy. Thus, there will be another CFSMGC. However, all-C is weak against exploitation and Trigger is not adaptively helpful for mutual cooperation.

The limitation of CFSMGC is clear when we consider that players repeatedly play multiple ultimatum games, trust games, and snatch games. In these games, the second mover takes advantage against the first mover. Therefore, the first mover can not utilize CFSMGC as the punishment scheme in these games. That is, CFSMGC does not facilitate mutual cooperation in some repeated play extensive form games, although CFSMGC facilitates mutual cooperation in the normal form games. Another strategy is required for mutual cooperation in the repeated extensive form games.

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subjects often fail to reach mutual cooperation.

Let us discuss the relationship between Fehr-Schmidt utility function [11] and CFSMGC from the viewpoint of cooperation facilitation device. Since Fehr-Schmidt utility function contains inequality aversion, the player who has this function prefers to be in the same situation as her opponent. On the other hand, CFSMGC does not have such an aversion. It does not avoid the asymmetric situation. Rather, for long-term mutual cooperation, it admits short-term inequality.[15] Moreover, although Fehr-Schmidt utility function focuses on the one-round decision making such as Ultimatum game, CFSMGC focuses on the long-run decision making in repeatedly played multiple games. We think that Fehr-Schmidt utility function is suitable for the explanation of cooperation in the one-shot game and that CFSMGC is suitable for the reason why people cooperate in the long run.

Social psychology has the goal/expectation theory [22], which contrives the conditions for reaching mutual cooperation in a repeated PD game. In our experiments, most of the opponents of the subjects with high percent cooperation have also high percent cooperation. This makes it clear that the subjects in the multi-game contact aim to reach mutual cooperation by trial and error. However, mutual cooperation is more difficult in the multi-game contact than in a repeated PD game. If they act following to the theory in former situation, CFSMGC will be one of possible strategies.

Moreover, CFSMGC has relation with GRIT (Graduated Reciprocation in Tension Reduction) strategy [18] proposed by Osgood in the middle of the cold war era. It is a gradual de-escalation process in which one side makes a unilateral compromise with the hope that the opponent will do the same.[16] It takes in an effective reaction against a unilateral exploitation by the opponent. He thought that it was useful for mutual cooperation. Since it was propounded before game theory was not developed, he did not mention the relationship between game theory and GRIT. CFSMGC is one of the suitable strategies to set up GRIT, because there are a lot of multi-game contacts even in the bilateral political relation such as economic and military issues. For mutual cooperation, the parties hereto are required to use CFSMGC.

Lastly, our study lacks the severe control of discount factor. As noted earlier, the severe control make it practically impossible to observe the long-run behavior in the experiment. We might not find the strategy which facilitates mutual cooperation. Decision making in the real world scarcely

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[15] If mutual cooperation in all the games is attained by Sept-TFT (which responds to the opponent's last choices), the result can be explained by Fehr-Schmidt utility function.

[16] http://www.colorado.edu/conflict/peace/glossary.htm

considers the possibility of the termination of a game. When people form relationships with their colleagues at the office and in private, they do not always take account of the future termination possibility of the relationships; they are not aware of the discount factor, or even if they are aware, their discount factor will be high enough. Since our study focuses on such a long run behavior in the multi-game contact, the severe control of discount factor is far from our present interest. However, in order to validate the multimarket contact theory, we need control the discount factor as [5] did.

7 Concluding remarks

This paper experimentally investigates the percentage of cooperation difference among treatments in the long run multi (single)-game contact. Comparison results show that the number of information sets and the payoff structure affect the percentage of cooperation contrary to the theoretical prediction. Then we define seven strategies including three TFT strategies for cluster analysis. The result indicates that the subjects adopt 'CFSMGC' that consists of Soft-TFT or Hard-TFT for mutual cooperation. CFSMGC is a reasonable strategy that brings mutual cooperation in the multi-game contact. Utilizing it, the number of alternatives decreases and helps subjects to avoid to offer complicated ones, and then, prevention against the opponent's exploitation enables them to reach mutual cooperation.

We remain the multimarket contact experiments with discount factor control and the experiments in which the payoff of a game is much larger than that of the other game. They enable us to validate the multimarket contact theory and to clarify the behavioral property in this situation.

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	C	D
C	800, 800	0, 1000
D	1000, 0	210, 210

Table 1: Game S

	C	D
C	800, 800	0, 1000
D	1000, 0	350, 350

Table 2: Game T

	C	D
C	780, 780	0, 1000
D	1000, 0	260, 260

Table 3: Game T’

	C	D
C	3,3	0,5
D	5,0	2,2

Table 4: Game M

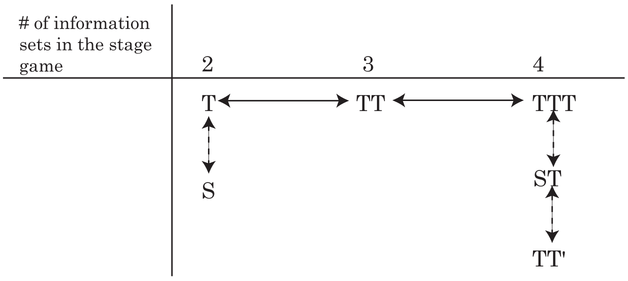
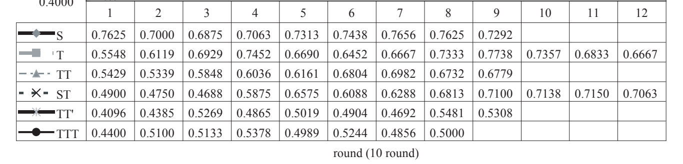


Figure 1: Experimental Design

date	treatment	# of subjects	# of rounds	reward (ave., JPY)
2005.6.1	T	26	123	3,552
2005.6.4	ST	22	123	3,211
2005.7.6	T	16	116	3,836
2005.7.9	ST	18	116	3,712
2005.10.12	TT	18	96	3,972
2005.10.15	TTT	18	78	3,959
2006.3.3	S	14	83	3,936
2006.3.4	TT	16	84	3,565
2006.6.7	S	18	88	3,385
2006.6.10	ST'	26	92	3,066
2006.11.22	TT	22	91	3,532
2006.11.25	TTT	12	83	3,037

Table 5: Treatment Profile



	1	2	3	4	5	6	7	8	9	10	11	12
S	0.7625	0.7000	0.6875	0.7063	0.7313	0.7438	0.7656	0.7625	0.7292			
T	0.5548	0.6119	0.6929	0.7452	0.6690	0.6452	0.6667	0.7333	0.7738	0.7357	0.6833	0.6667
TT	0.5429	0.5339	0.5848	0.6036	0.6161	0.6804	0.6982	0.6732	0.6779			
ST	0.4900	0.4750	0.4688	0.5875	0.6575	0.6088	0.6288	0.6813	0.7100	0.7138	0.7150	0.7063
TT'	0.4096	0.4385	0.5269	0.4865	0.5019	0.4904	0.4692	0.5481	0.5308			
TTT	0.4400	0.5100	0.5133	0.5378	0.4989	0.5244	0.4856	0.5000				

Figure 2: The evolution of the percent cooperation (per ten rounds)

Opponent's last choice	Player's present choice	Strategy
DD	DD	TFT
DD	CD	PC
DD	DC	PC
DD	CC	UC
CD	DD	Hard-TFT
CD	CD	Sept-TFT
CD	DC	Sept-TFT (TT)/ PD
CD	CC	Soft-TFT
DC	DD	Hard-TFT
DC	CD	Sept-TFT (TT)/ PD
DC	DC	Sept-TFT
DC	CC	Soft-TFT
CC	DD	UD
CC	CD	PD
CC	DC	PD
CC	CC	TFT

Table 6: Strategy and response in 2 games; TFT depends on what kind of TFT strategies a subject employed in the most recent round.

Opponent's last choice	Player's present choice	Strategy
DDD	DDD	TFT
DDD	CDD	PC
DDD	CCD	PC
DDD	CCC	UC
CDD	DDD	Hard-TFT
CDD	CDD	Sept-TFT
CDD	CCD	CC
CDD	CCC	Soft-TFT
CCD	DDD	Hard-TFT
CCD	CDD	PD
CCD	CCD	Sept-TFT
CCD	CCC	Soft-TFT
CCC	DDD	UD
CCC	CDD	PD
CCC	CCD	PD
CCC	CCC	TFT

Table 7: Strategy and response in 3 games; TFT depends on what kind of TFT strategies a subject employed in the most recent round.

		t	t+1	t+2	t+3	t+4
Player 1	Game T-1	D	C	C	C	C
	Game T-2	D	D	D	C	C
Player 2	Game T-1	C	C	C	C	C
	Game T-2	D	C	C	C	C
Player 1's Strategy		-	Sept-TFT	PD	Sept-TFT	Sept-TFT
Player 2's Strategy		-	UC	Soft-TFT	Soft-TFT	Soft-TFT

Table 8: Classification example: Treatment TT, Subject No.12, 12.10.2005

Game	all rounds	first half	second half	78	first 39 rounds	second 39 rounds
S (83)	0.7323	0.7150	0.7500	0.7316	0.7147	0.7484
T (116)	0.6821	0.6531	0.7110	0.6630	0.6484	0.6777
TT (84)	0.6194	0.5699	0.6688	0.6161	0.5646	0.6676
ST (116)	0.6172	0.5450	0.6894	0.5726	0.5010	0.6442
TT' (92)	0.4887	0.4707	0.5067	0.4820	0.4655	0.4985
TTT (78)	0.5013	0.5000	0.5026	0.5013	0.5000	0.5026

Table 9: The percentage of cooperation : in multi-game contact treatments, it is the average among all the games.

variable	C.V.	D.F	variance	F-value	Pr (>F)
round $(1-78)$	0.807	77	0.010	3.278	1.52E-14
treatment	3.570	5	0.714	223.451	2E-111
round $(1-39)$	0.306	38	0.008	2.419	4.88E-05
treatment	1.856	5	0.371	111.489	1.43E-54
round $(40-78)$	0.114	38	0.003	1.800	0.006
treatment	1.995	5	0.399	239.435	5.44E-80

Table 10: ANOVA result

	CD (CCD)		DC (DCC)		CD or DC	
All Players	First	Second	First	Second	First	Second
TT	0.1021	0.0801	0.0655	0.0664	0.0838	0.0733
TTT	0.0812	0.0291 ***	0.1485	0.0573 ***	0.2297	0.0863 ***
TT’	0.0779	0.0414**	0.1036	0.0404***		
ST	0.1192	0.0801 ***	0.0583	0.0340 ***		
Cooperators	First	Second	First	Second	First	Second
TT	0.0301	0.0167	0.0067	0.0089	0.0188	0.0131
TTT	0.0284	0.0303	0.0380	0.0186*	0.0286	0.0245
TT’	0.0103	0.0000	0.0385	0.0026**		
ST	0.0723	0.0000***	0.0186	0.0000***		

Table 11: Elinimation of asymmetric information sets in 78 rounds:$*$, $**$ and $***$ indicate the significant difference in 10% level, 5% level, and 1% level, respectively.

TT	SOFT	HARD	SEPT	UC	UD	PC	PD	# SUBJECTS	# COOPERATORS
TFT	0.921	0.920	0.918	0.037	0.026	0.009	0.005	14	11
SOFT-TFT	0.846	0.128	0.153	0.014	0.019	0.022	0.020	8	7
HARD-TFT	0.091	0.823	0.102	0.016	0.052	0.036	0.013	9	2
SEPT-TFT	0.039	0.229	0.532	0.017	0.030	0.140	0.036	12	1
OTHERS	0.274	0.252	0.239	0.060	0.052	0.092	0.055	12	2
TTT	SOFT	HARD	SEPT	UC	UD	PC	PD	# SUBJECTS	# COOPERATORS
TFT	0.929	0.905	0.920	0.007	0.015	0.007	0.011	7	6
SOFT-TFT	0.742	0.097	0.100	0.019	0.019	0.065	0.022	6	4
HARD-TFT	0.038	0.753	0.086	0.022	0.035	0.055	0.033	11	1
SEPT-TFT	0.060	0.145	0.621	0.008	0.000	0.117	0.075	5	0
OTHERS	0.519	0.519	0.519	0.156	0.000	0.325	0.000	1	0
TT’	SOFT	HARD	SEPT	UC	UD	PC	PD	# SUBJECTS	# COOPERATORS
SOFT-TFT	0.968	0.055	0.068	0.006	0.000	0.010	0.003	4	4
HARD-TFT	0.079	0.749	0.091	0.014	0.016	0.051	0.023	10	1
SEPT-TFT	0.552	0.634	0.855	0.011	0.013	0.035	0.004	6	5
OTHERS1	0.199	0.351	0.316	0.039	0.013	0.108	0.087	3	0
OTHERS2	0.143	0.268	0.087	0.091	0.130	0.139	0.143	3	0
ST	SOFT	HARD	SEPT	UC	UD	PC	PD	# SUBJECTS	# COOPERATORS
TFT	0.994	0.994	0.994	0.002	0.004	0.000	0.000	7	5
SOFT-TFT	0.840	0.074	0.030	0.043	0.004	0.013	0.017	6	5
HARD-TFT	0.106	0.827	0.139	0.029	0.017	0.030	0.021	12	5
SEPT-TFT	0.169	0.193	0.657	0.009	0.054	0.067	0.056	7	0
OTHERS	0.157	0.302	0.179	0.024	0.029	0.175	0.156	8	0

Table 12: Cluster analysis result

Treatment	# of Soft type players	percent cooperation	Significance (one tailed test)
TT	9	0.886	1 %
TTT	6	0.773	5 %
TT'	4	0.928	1 %
ST	6	0.890	5 %

Table 13: The statistical difference of the cooparation rate between in the multi -game contact (with Soft-TFT players) and in the single game T

	Subjective information set		
Information set in the last round	Soft type	Hard type	Separate type
CC	SIS 1	SIS 1	SIS 1
CD		SIS 2	SIS 2
DC			SIS 3
DD	SIS 2		SIS 4

Table 14: Subjective redcution of an information set

Table 15: Decision distribution and the percentage of cooperation in TT

Date	Game	No	T-TFT	R-TFT	S-TFT	UC	UD	PC	PD	% of coop.	CULSTER
304	TT	1	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
304	TT	2	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
304	TT	3	0.818	0.143	0.104	0.013	0.026	0.013	0.013	0.814	SOFT-TFT
304	TT	4	0.857	0.065	0.117	0.000	0.013	0.078	0.000	0.846	SOFT-TFT
304	TT	5	0.143	0.597	0.247	0.000	0.000	0.091	0.000	0.244	HARD-TFT
304	TT	6	0.013	0.247	0.377	0.000	0.013	0.273	0.104	0.288	SEPT-TFT
304	TT	7	0.039	0.234	0.649	0.065	0.000	0.013	0.000	0.122	SEPT-TFT
304	TT	8	0.195	0.831	0.208	0.000	0.065	0.052	0.039	0.051	HARD-TFT
304	TT	9	0.896	0.896	0.896	0.052	0.052	0.000	0.000	0.936	TFT
304	TT	10	0.974	0.974	0.974	0.026	0.000	0.000	0.000	0.949	TFT
304	TT	11	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
304	TT	12	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
304	TT	13	0.961	0.948	0.935	0.013	0.000	0.000	0.013	0.981	TFT
304	TT	14	0.935	0.922	0.922	0.013	0.013	0.000	0.039	0.968	TFT
304	TT	15	0.429	0.000	0.519	0.052	0.000	0.000	0.000	0.859	OTHERS
304	TT	16	0.455	0.325	0.026	0.000	0.104	0.065	0.078	0.744	OTHERS
1012	TT	1	0.182	0.182	0.312	0.013	0.039	0.104	0.221	0.391	OTHERS
1012	TT	2	0.299	0.195	0.299	0.052	0.026	0.091	0.065	0.468	OTHERS
1012	TT	3	0.091	0.792	0.117	0.013	0.013	0.026	0.000	0.115	HARD-TFT
1012	TT	4	0.000	0.429	0.260	0.013	0.026	0.234	0.039	0.179	SEPT-TFT
1012	TT	5	0.026	0.091	0.662	0.000	0.013	0.104	0.104	0.391	SEPT-TFT
1012	TT	6	0.104	0.286	0.390	0.039	0.026	0.130	0.026	0.423	SEPT-TFT
1012	TT	7	0.078	0.221	0.351	0.026	0.000	0.325	0.000	0.333	SEPT-TFT
1012	TT	8	0.013	0.429	0.429	0.000	0.052	0.091	0.013	0.186	SEPT-TFT
1012	TT	9	0.195	0.260	0.065	0.091	0.104	0.182	0.104	0.410	OTHERS
1012	TT	10	0.273	0.390	0.130	0.026	0.078	0.065	0.039	0.372	OTHERS
1012	TT	11	0.026	0.026	0.805	0.013	0.013	0.091	0.026	0.571	SEPT-TFT
1012	TT	12	0.481	0.156	0.247	0.026	0.039	0.052	0.000	0.545	OTHERS
1012	TT	13	0.987	0.987	0.987	0.013	0.000	0.000	0.000	0.994	TFT
1012	TT	14	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.987	SOFT-TFT
1012	TT	15	0.909	0.221	0.169	0.013	0.000	0.013	0.013	0.949	SOFT-TFT
1012	TT	16	0.169	0.948	0.169	0.000	0.013	0.026	0.013	0.929	HARD-TFT
1012	TT	17	0.169	0.338	0.247	0.143	0.026	0.078	0.026	0.436	OTHERS
1012	TT	18	0.052	0.390	0.169	0.039	0.143	0.169	0.091	0.327	OTHERS
1122	TT	1	0.675	0.675	0.675	0.143	0.052	0.130	0.000	0.205	TFT
1122	TT	2	0.026	0.818	0.026	0.039	0.143	0.000	0.000	0.051	HARD-TFT
1122	TT	3	0.013	0.013	0.909	0.026	0.000	0.052	0.013	0.955	SEPT-TFT
1122	TT	4	0.896	0.039	0.013	0.000	0.039	0.000	0.013	0.910	SOFT-TFT
1122	TT	5	0.000	0.948	0.000	0.026	0.013	0.000	0.013	0.968	HARD-TFT
1122	TT	6	0.974	0.156	0.156	0.013	0.013	0.000	0.000	0.968	SOFT-TFT
1122	TT	7	0.779	0.442	0.468	0.013	0.052	0.000	0.130	0.840	SOFT-TFT
1122	TT	8	0.636	0.000	0.247	0.078	0.026	0.000	0.013	0.917	SOFT-TFT
1122	TT	9	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
1122	TT	10	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
1122	TT	11	0.701	0.714	0.701	0.195	0.091	0.000	0.000	0.410	TFT
1122	TT	12	0.766	0.766	0.766	0.065	0.156	0.000	0.013	0.314	TFT
1122	TT	13	0.065	0.338	0.455	0.000	0.065	0.169	0.039	0.314	SEPT-TFT
1122	TT	14	0.221	0.234	0.403	0.065	0.026	0.065	0.013	0.378	OTHERS
1122	TT	15	0.013	0.182	0.766	0.000	0.026	0.013	0.000	0.692	SEPT-TFT
1122	TT	16	0.740	0.091	0.104	0.000	0.000	0.091	0.000	0.744	SOFT-TFT
1122	TT	17	0.117	0.870	0.065	0.026	0.039	0.013	0.000	0.699	HARD-TFT
1122	TT	18	0.052	0.935	0.052	0.026	0.013	0.026	0.000	0.718	HARD-TFT
1122	TT	19	0.182	0.234	0.273	0.052	0.026	0.208	0.026	0.417	OTHERS

1122	TT	20	0.078	0.260	0.338	0.026	0.130	0.182	0.065	0.321	SEPT-TFT
1122	TT	21	0.351	0.325	0.182	0.156	0.013	0.026	0.000	0.513	OTHERS
1122	TT	22	0.026	0.662	0.039	0.013	0.169	0.091	0.052	0.359	HARD-TFT

Table 16: Decision distribution and the percentage of cooperation in TT’

Date	Game	No	T-TFT	R-TFT	S-TFT	UC	UD	PC	PD	% of coop.	cluster
1022	TT’	1	0.117	0.117	0.987	0.000	0.013	0.000	0.000	0.833	SEP-TFT
1022	TT’	2	0.961	0.130	0.143	0.013	0.000	0.013	0.000	0.859	SOFT-TFT
1022	TT’	3	0.026	0.831	0.065	0.000	0.026	0.091	0.013	0.071	HARD-TFT
1022	TT’	4	0.052	0.714	0.156	0.013	0.000	0.052	0.013	0.096	HARD-TFT
1022	TT’	5	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	SOFT-TFT
1022	TT’	6	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.994	SEP-TFT
1022	TT’	7	0.935	0.052	0.091	0.000	0.000	0.026	0.000	0.910	SOFT-TFT
1022	TT’	8	0.052	0.052	1.000	0.000	0.000	0.000	0.000	0.897	SEP-TFT
1022	TT’	9	0.013	0.662	0.286	0.000	0.026	0.039	0.000	0.026	HARD-TFT
1022	TT’	10	0.455	0.506	0.026	0.000	0.000	0.000	0.013	0.038	HARD-TFT
1022	TT’	11	0.091	0.494	0.065	0.039	0.039	0.182	0.091	0.282	HARD-TFT
1022	TT’	12	0.156	0.221	0.312	0.026	0.000	0.156	0.130	0.314	OTHERS1
1022	TT’	13	0.429	0.416	0.247	0.091	0.026	0.039	0.065	0.692	OTHERS1
1022	TT’	14	0.130	0.351	0.039	0.078	0.182	0.104	0.117	0.603	OTHERS2
1022	TT’	15	0.870	0.870	0.870	0.039	0.065	0.026	0.000	0.788	SEP-TFT
1022	TT’	16	0.039	0.909	0.000	0.052	0.000	0.000	0.000	0.808	HARD-TFT
1022	TT’	17	0.039	0.649	0.169	0.013	0.000	0.039	0.091	0.167	HARD-TFT
1022	TT’	18	0.013	0.416	0.390	0.000	0.013	0.130	0.065	0.192	OTHERS1
1022	TT’	19	0.468	0.961	0.468	0.000	0.000	0.026	0.013	0.929	SEP-TFT
1022	TT’	20	0.974	0.039	0.039	0.013	0.000	0.000	0.013	0.942	SOFT-TFT
1022	TT’	21	0.000	0.883	0.039	0.000	0.026	0.039	0.013	0.045	HARD-TFT
1022	TT’	22	0.052	0.896	0.078	0.013	0.000	0.065	0.000	0.071	HARD-TFT
1022	TT’	23	0.195	0.247	0.117	0.052	0.143	0.104	0.143	0.378	OTHERS2
1022	TT’	24	0.104	0.208	0.104	0.143	0.065	0.208	0.169	0.462	OTHERS2
1022	TT’	25	0.026	0.948	0.026	0.013	0.039	0.000	0.000	0.013	HARD-TFT
1022	TT’	26	0.805	0.805	0.805	0.026	0.000	0.156	0.013	0.122	SEP-TFT

Table 17: Decision distribution and the percentage of cooperation in TTT

Date	Game	No	T-TFT	R-TFT	S-TFT	UC	UD	PC	PD	% of coop.	cluster
1015	TTT	1	0.000	0.883	0.013	0.000	0.078	0.013	0.013	0.034	HARD-TFT
1015	TTT	2	0.026	0.805	0.065	0.039	0.000	0.091	0.000	0.124	HARD-TFT
1015	TTT	3	0.636	0.169	0.247	0.013	0.039	0.117	0.013	0.641	SOFT-TFT
1015	TTT	4	0.091	0.182	0.675	0.026	0.000	0.013	0.039	0.641	SEPT-TFT
1015	TTT	5	0.000	0.857	0.117	0.013	0.000	0.000	0.013	0.380	HARD-TFT
1015	TTT	6	0.013	0.026	0.935	0.000	0.000	0.039	0.013	0.402	SEPT-TFT
1015	TTT	7	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
1015	TTT	8	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
1015	TTT	9	0.013	0.714	0.156	0.000	0.013	0.078	0.052	0.124	HARD-TFT
1015	TTT	10	0.078	0.026	0.831	0.000	0.000	0.026	0.039	0.145	SEPT-TFT
1015	TTT	11	0.026	0.273	0.325	0.000	0.000	0.260	0.143	0.329	SEPT-TFT
1015	TTT	12	0.091	0.221	0.338	0.013	0.000	0.247	0.143	0.355	SEPT-TFT
1015	TTT	13	0.818	0.104	0.052	0.000	0.000	0.026	0.026	0.731	SOFT-TFT
1015	TTT	14	0.701	0.078	0.130	0.013	0.000	0.078	0.000	0.761	SOFT-TFT
1015	TTT	15	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
1015	TTT	16	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
1015	TTT	17	0.857	0.688	0.636	0.052	0.026	0.013	0.000	0.915	TFT

1015	TTT	18	0.727	0.727	0.883	0.000	0.039	0.026	0.052	0.872	TFT
1125	TTT	1	0.701	0.026	0.000	0.039	0.026	0.143	0.065	0.821	SOFT-TFT
1125	TTT	2	0.675	0.143	0.104	0.013	0.026	0.013	0.026	0.769	SOFT-TFT
1125	TTT	3	0.039	0.494	0.286	0.026	0.000	0.091	0.065	0.175	HARD-TFT
1125	TTT	4	0.013	0.675	0.078	0.026	0.052	0.130	0.026	0.145	HARD-TFT
1125	TTT	5	0.922	0.065	0.065	0.039	0.026	0.013	0.000	0.915	SOFT-TFT
1125	TTT	6	0.078	0.909	0.078	0.013	0.026	0.013	0.039	0.868	HARD-TFT
1125	TTT	7	0.195	0.597	0.091	0.013	0.000	0.039	0.065	0.222	HARD-TFT
1125	TTT	8	0.026	0.623	0.052	0.052	0.065	0.117	0.091	0.201	HARD-TFT
1125	TTT	9	0.922	0.922	0.922	0.000	0.039	0.013	0.026	0.043	TFT
1125	TTT	10	0.013	0.909	0.000	0.065	0.013	0.000	0.000	0.090	HARD-TFT
1125	TTT	11	0.519	0.519	0.519	0.156	0.000	0.325	0.000	0.325	OTHERS
1125	TTT	12	0.013	0.818	0.013	0.000	0.143	0.039	0.000	0.013	HARD-TFT

Table 18: Decision distribution and the percentage of cooperation in ST

Date	Game	No	Soft-TFT	Hard-TFT	Sep-TFT	UC	UD	PC	PD	% of coop.	cluster
604	ST	1	0.117	0.013	0.688	0.013	0.065	0.013	0.091	0.609	SEP-TFT
604	ST	2	0.584	0.221	0.117	0.104	0.013	0.026	0.013	0.686	SOFT-TFT
604	ST	3	0.338	0.870	0.260	0.026	0.013	0.000	0.013	0.955	HARD-TFT
604	ST	4	0.234	0.922	0.234	0.026	0.013	0.000	0.039	0.942	HARD-TFT
604	ST	5	0.026	0.312	0.532	0.013	0.026	0.130	0.013	0.135	SEP-TFT
604	ST	6	0.013	0.701	0.130	0.039	0.039	0.052	0.026	0.103	HARD-TFT
604	ST	7	0.273	0.286	0.208	0.013	0.013	0.104	0.104	0.429	OTHERS
604	ST	8	0.234	0.299	0.104	0.026	0.052	0.234	0.078	0.455	OTHERS
604	ST	9	0.130	0.649	0.208	0.052	0.026	0.026	0.013	0.724	HARD-TFT
604	ST	10	0.221	0.104	0.636	0.000	0.039	0.078	0.052	0.705	SEP-TFT
604	ST	11	0.000	0.987	0.000	0.013	0.000	0.000	0.000	0.974	HARD-TFT
604	ST	12	0.987	0.987	0.987	0.013	0.000	0.000	0.000	0.981	TFT
604	ST	13	0.390	0.571	0.688	0.013	0.039	0.052	0.026	0.103	SEP-TFT
604	ST	14	0.442	0.818	0.558	0.013	0.000	0.052	0.000	0.122	HARD-TFT
604	ST	15	0.000	0.935	0.000	0.013	0.026	0.026	0.000	0.026	HARD-TFT
604	ST	16	0.065	0.078	0.883	0.026	0.013	0.065	0.000	0.071	SEP-TFT
604	ST	17	0.143	0.195	0.208	0.052	0.039	0.091	0.273	0.429	OTHERS
604	ST	18	0.091	0.195	0.182	0.000	0.026	0.221	0.286	0.429	OTHERS
604	ST	19	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.994	TFT
604	ST	20	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	SOFT-TFT
604	ST	21	0.221	0.468	0.208	0.052	0.052	0.117	0.013	0.314	OTHERS
604	ST	22	0.273	0.182	0.416	0.000	0.065	0.104	0.117	0.263	SEP-TFT
709	ST	1	0.844	0.052	0.052	0.013	0.013	0.026	0.026	0.891	SOFT-TFT
709	ST	2	0.883	0.052	0.013	0.013	0.000	0.013	0.052	0.891	SOFT-TFT
709	ST	3	0.013	0.429	0.130	0.013	0.039	0.156	0.221	0.269	OTHERS
709	ST	4	0.078	0.208	0.169	0.039	0.000	0.338	0.169	0.436	OTHERS
709	ST	5	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
709	ST	6	1.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	TFT
709	ST	7	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.026	TFT
709	ST	8	0.974	0.974	0.974	0.000	0.026	0.000	0.000	0.013	TFT
709	ST	9	0.026	0.974	0.026	0.000	0.013	0.013	0.000	0.596	HARD-TFT
709	ST	10	0.000	0.909	0.000	0.039	0.013	0.039	0.000	0.622	HARD-TFT
709	ST	11	0.078	0.779	0.065	0.026	0.000	0.026	0.026	0.782	HARD-TFT
709	ST	12	0.013	0.753	0.026	0.052	0.065	0.052	0.039	0.750	HARD-TFT
709	ST	13	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.994	TFT
709	ST	14	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	SOFT-TFT
709	ST	15	0.000	0.623	0.156	0.052	0.000	0.078	0.091	0.308	HARD-TFT
709	ST	16	0.208	0.338	0.221	0.000	0.013	0.143	0.104	0.295	OTHERS

709	ST	17	0.727	0.117	0.000	0.130	0.000	0.013	0.013	0.872	SOFT-TFT
709	ST	18	0.091	0.091	0.753	0.000	0.130	0.026	0.091	0.712	SEP-TFT