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COMMUNICATION AND COORDINATION IN SIGNALLING GAMES: AN EXPERIMENTAL STUDY

BY

Barry Sopher
and
Inigo Zapater

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C. V. STARR CENTER FOR APPLIED ECONOMICS

NEW YORK UNIVERSITY
FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF ECONOMICS
WASHINGTON SQUARE
NEW YORK, N.Y. 10003

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Send correspondence to:

Barry Sopher
Department of Economics
Rutgers University
New Jersey Hall
New Brunswick, NJ 08903

Abstract

This paper reports on an experiment testing *Credible Message Rationalizability* (CMR) in one-shot and repeated signalling games with costless communication. CMR is a non-equilibrium theory combining rationalizability with the idea of honesty as a focal policy. Two conventions of behavior arise in the games, *Partial* and *Full Truth-telling*. In one-shot games, subjects manage to refine honesty roughly as predicted by CMR. In repeated games, Full truth-telling is more prevalent. The repeated game gives the receiver power to impose a preferred convention. Full truth-telling is especially prevalent when there is a conflict between conventions.

1. Introduction

In recent years the study of costless communication, or "cheap talk", in games has attracted a lot of interest. Game theorists are interested in knowing the effect, if any, of cheap talk on the outcome of a game. That is, does allowing non-binding, non-verifiable statements lead to different outcomes than not allowing such statements. Indeed, one of the justifications sometimes given for the use of Nash equilibrium as a solution concept is that the players get together and engage in some form of non-binding communication that results in the play of strategies that form a Nash equilibrium. Thus, it is natural that the study of cheap talk has been conducted largely in an equilibrium framework.

The multiplicity of Nash equilibria in many games has spawned a large literature on refinements, but the implausibility of the computational requirements of Nash refinements leads to questions about the practical usefulness of such an approach. Banks, Camerer and Porter (1992) found some empirical support for refinements, but they concluded that those refinements that "worked best" in experiments were those that led to outcomes consistent with other possible stories: e.g., simple rules-of-thumb.

A natural theoretical response to such findings is to formally embed behavioral rules in the description of the game, and see what results. This is the basic idea of Rabin's (1990) *Credible Message Rationalizability* (CMR), which we test in the experiments reported on in this paper. CMR employs the notion of rationalizability, augmented by the assumption of "honesty" as a focal policy. The notion of honesty intended here will require more explanation below, but for the present, we note that it is not meant in the conventional sense of "telling the whole truth." Honesty is intended to include "not lying," but may include the possibility of not telling the whole truth, or partial truth-telling.

This paper reports on an experiment that tests CMR, and a generalization of this theory by Zapater (1991), *Generalized CMR* (GCMR). We restricted analysis to simple *signalling* games, in which there is a *sender* with a privately known random *type* and a *receiver* with a prior probability distribution for the sender's type. A sender sends a message containing a statement about his type, and the receiver then takes one of several available *actions*, with payoffs determined only by the sender's type and the receiver's action. A *credible* message is one that would, if believed, give the sender his highest possible payoff. GCMR relaxes the credibility requirements somewhat.

In the experiment, subjects were given a menu consisting of one message for each possible subset of the set of types. We considered one-shot and repeated versions of 4 different games. For some games, CMR predicts that each sender type will separate, truthfully revealing his private information, and that the receiver will believe this and respond appropriately. For other games, CMR predicts that at least some types will pool, not revealing their types. This latter type of behavior, although not consistent with full truth-telling, is consistent with the CMR notion of honesty. GMCR provides sharper predictions for some situations than CMR.

Although CMR is not an equilibrium theory, it does have common knowledge requirements: rationality and "honesty". Honesty is a focal policy, but there are other possible focal policies that players could follow. For example, "full truth-telling" is a very simple focal policy. If CMR is to work, then, players have to learn (jointly) that CMR's version of honesty is, in some sense, the best policy to follow. Further, even if a player believes in the spirit of CMR, it may take some time to figure out all the implications of CMR, especially for a complicated game. Therefore, two types of learning may be required for CMR to work: the coordination problem of settling on a focal policy, and the computational problem of deducing the implications of a policy.

We allowed subjects to play (and learn) in two environments. Some subjects played a finitely repeated game against a series of randomly selected opponents, while other subjects played a finitely repeated game against the same opponent. The results of the experiment, briefly, indicate generally strong support for CMR, but the degree of support depends on the environment. The subjects seem to understand that full truth-telling needs to be refined, and in the aggregate they manage to establish some, but not all, of the implications of CMR.

We briefly summarize the results is as follows: There are two basic conventions of behavior that arise in the games, which we call *Partial* and *Full Truth-telling*. The Partial truth-telling convention allows a sender to withhold some information, by, e.g., pooling some of his types through the messages he sends. The Full truth-telling convention requires a sender to completely reveal his type (separate) with the message he sends. In the one-shot games, the subjects seem to realize that Full truth-telling is not a consistent policy to follow, because in some situations (i.e., for some types of sender) the receiver could take advantage of the sender. On the other hand, they also seem to realize that lying about one's type is not generally useful either, since *some* communication of information leads to improvements for both players. We suspect that with a lot more experience with the game they might eventually learn to refine the idea of honesty in a way that is consistent with CMR.

These conclusions must be qualified somewhat for some of the repeated games, where behavior sometimes deviated markedly from the one-shot games. Specifically, we find that, even with its inconsistencies, the Full truth-telling convention is much more prevalent in the repeated games. We think that the repeated game gives the receiver some power to impose his preferred convention that is not available to him in the one-shot games. The Full truth-telling convention is especially prevalent when there is a conflict between conventions (i.e., when the sender and receiver would like different conventions).

The rest of the paper is organized as follows. In Section 2, equilibrium and non-equilibrium theories of communication in signalling games are outlined and illustrated using as examples the games we study in the experiments. Section 3 contains details of the experimental design and the procedures followed in the experiments. Section 4 contains a more detailed account of the experimental results. Section 5 contains a discussion of related theoretical and empirical work on communication and coordination in games. An appendix containing the instructions given to subjects in the experiments is available upon request.

2. Credible Message Rationalizability and Other Theories of Communication

In this paper we present the results of an experiment in which subjects played Games 0, 1, 2 and 3, illustrated in Figure 1. Our main purpose is to test the predictions of the different solution concepts existing in the literature for simple communication games. In this section we discuss both equilibrium and non-equilibrium theories of communication, using the games we analyze in the experiments to illustrate concepts. Detailed predictions for each game are presented in Section 4. This section is only for illustration of some of the main concepts, and is not intended as a thorough statement of predictions.

Figure 1 about here

A simple communication game consists of two players. An informed player called the sender, who is an element of a finite set of types $T = \{t_1, \ldots, t_N\}$, and an uninformed player, the receiver. The players have prior beliefs represented by the probability distribution *p* over *T*. So for example, in game 0, illustrated in Figure 1, the set of types is T = {1, 2}, the prior belief for type 1 is p(1) = 1/2, and the set of actions is {A, B, C}. We have restricted the set of possible messages in Game 0 (and all other games) to a minimal set of messages that allow the sender to communicate any partition of the set of possible types, or to remain silent. Thus, in Game 0, the messages are:

Message 1: "I am type 1"

Message 2: "I am type 2"

Message 3: "I am type 1 or type 2"

Message 4: "No message"

Notice that the receiver always wants as much information as possible. On the other hand, it is not always in the sender's interest to reveal his identity. The analysis of these games focuses on what and how much truthful information will be transmitted.

We can divide the solutions proposed for these kind of games into two groups: equilibrium and non-equilibrium solutions. The former look at the set of Nash equilibria of the communication game and use some intuitive arguments to refine away some implausible equilibria. The latter use rationalizability combined with some focal policy to determine the outcome of the game.

The simplest equilibrium selection criterium is Pareto dominance. This has been mentioned in Crawford and Sobel (1982). See also Van Huyck, Battalio and Beil (1989, 1990). If one equilibrium is better than any other equilibria for all types of sender (and the receiver), then it is likely that that equilibrium will result. For instance, in Game 0 there exist pooling equilibria where R responds to any message with action C, and separating equilibria, where each type of sender and the receiver get their highest possible payoffs. In this case the equilibria can be Pareto-ranked, and all types of sender and the receiver prefer separation.

Neologism-proofness (Farrell (1985)) and a generalization of that concept, Announcement-proofness (A-P) (Matthews, Okuno-Fujiwara, and Postelwaite (1991)) considers each equilibrium of the game and asks what happens if the sender tries to introduce a new word into the vocabulary of the game, in an attempt to convince the receiver to play in a different way from the one prescribed by the equilibrium. That is, how should the receiver interpret such a message? The theory of neologism-proofness proposes that the receiver should reason in the following way: "The unexpected message must come from a type, or set of types, that expect to get a better payoff that in equilibrium." The idea, then, is that the receiver considers what each subset of the possible types, K, have to gain from sending such a message. If the receiver updates his beliefs, conditioning on K, and his resulting best response generates payoffs for all types in the set K that are greater than or equal to their payoffs in the original equilibrium, then the original equilibrium is not neologism-proof. For example, in Game 0, the pooling equilibrium is not neologism-proof. In the pooling equilibrium, type 1 gets a payoff of 2, but he can announce that he is in fact type 1. If the receiver believes him, she will respond with action A, and that will give type 1 a payoff of 8. Notice that type 2 will not send that message because he will get a lower payoff than in equilibrium, hence, the receiver has the correct beliefs. Announcement-proofness allows for more than one message to be sent at the same time. For example, in Game 0, S could announce that if he is type 1 he will send message m, and that if he is type 2 he will send message m'. This is an announcement and it will also break the pooling equilibrium.

Rabin (1990) has criticized the above approach as follows. The reason for analyzing cheap-talk in games is to understand the power of costless communication in coordinating the actions of different players. If we begin by looking at the Nash equilibria of a game, we are already assuming a lot of coordination. For this reason, he uses rationalizability as his basic solution concept. Rationalizability is a weaker solution concept than Nash equilibrium, and on its own it does not have any predictive power in these kind of a games. It only assumes that the rationality of the players is common knowledge, but it does not say anything about what a message should mean. To enrich the environment he assumes that all players share a common trait, honesty. Honesty, understood as full revelation of information, would be an extreme assumption. For example, although a player may be inherently honest, it need not be in his own interest to reveal his identity. Rabin's assumption is that players will reveal truthful information when it is in their interest to do so. Suppose that there is a message that says "I am type t" and that if the receiver believes such a message and responds accordingly, say with action A, then type t would get his highest possible payoff. If that is the case then the receiver is likely to believe the message "I am type t". For the receiver to be sure that, in fact, the message is true, he has to check that no other type would want to send the same message. For example, action A could offer some other type an attractive payoff. If that were the case, then the receiver's best response need not be action A, and then type t might not send the message "I am type t" after all. In Game 0 the messages "I am type 1" and "I am type 2" are credible because if the receiver believes those messages, then those messages will give types 1 and 2 their highest possible payoffs.

On the other hand, consider Game 3, also illustrated in Figure 1. The message "I am type 1 or type 2" is credible. The best response to that message, if true, is action A, and that gives type 1 and type 2 their highest possible payoffs. Action A is the worst action for type 3, so he will send some other message. Here we see that types 1 and 2 do not lie, but also that they do not tell the whole truth.

The requirement that a credible message should give its senders their highest possible payoff is a way of making sure that these types will not want to send some other message. This in turn could make the credibility of a message a fragile thing. Suppose that all types in some game are equally likely, and that the sender sends the message "I am type 1 or type 2". If the receiver believes this message, he will believe that he is dealing with type 1 or type 2 with probability 1/2 each. Suppose that his best action in this case is some action A, but that A does not give type 1 his highest payoff. Then it could be that type 1 will try some other message in hopes of getting his highest payoff. This observation changes the receiver's beliefs, and possibly he should not respond with action A.

Things are not always so delicate as this, however. Consider Game 2. In this game, type 3 could send the message "I am type 3", and he could expect to get a payoff of 6 if he is believed. On the other hand, there is no clear message for type 1 or type 2 to send, in the sense that no message sent by type 1, if believed, would give type 1 his highest payoff. Similarly for type 2. The question is, would either type 1 or type 2 possibly want to use the message "I am type 3". If so, this would ruin the meaning of that message for type 3. If we inspect the payoffs in more detail we see that type 1 would like the receiver to believe that he is type 2, and the other way around for type 2. Nevertheless, these types do agree on the fact that actions A and B are better that actions C and D, so they should be able to say that they are not type 3. If the receiver hears "I am type 1" he would not know if it is in fact type 1 or type 2, but he will know that he is not dealing with type 3, so he should respond with action A or B. Thus, type 3 can use the message "I am type 3" with confidence. The spirit of the preceding discussion, in which predictions are made on the basis of something other than a player's best possible payoffs, is formalized in a generalization of CMR, Generalized CMR (GCMR). See Zapater (1993) for a full discussion.[1]

In Game 2, full truth-telling is not in conflict with GCMR, in the sense that both separate types 1 and 2 from type 3. If the sender wants to induce the same kind of separation in Game 3, he must employ more sophisticated behavior. For example, a type 1 sender who naively reports his true type in a message may get stuck with his worst payoff of 3. Since type 3 would like the receiver to believe he is type 1, the receiver might conclude that the message "I am type 1" is coming from a type 3 sender, and thus choose action C. Game 1 is even simpler than Game 2, because there are only two possible types, but is nonetheless significantly more interesting than Game 0. We will discuss each of these games in more detail in Section 4.

3. Experimental Design and Procedures

Design

There are four different parameter sets, corresponding to the four games considered in Section 2. We were primarily interested in the performance of CMR and GCMR in each game. We were also interested in the relative performance between the one-shot and repeated games for a given parameter set. The main reason for introducing repeated games is to allow players to learn more sophisticated behavior than full-truth-telling or silence. CMR is really a theory of play in the one-shot game, and when the same game is repeated with the same players, some features unique to a repeated game may arise. The one-shot predictions are, nonetheless, one possible outcome for the repeated game, so it is of interest to see whether the one-shot predictions are robust to this extension of the game.

In five of six experimental groups, subjects were senders in some periods and receivers in other periods, for sets of 5 to 10 periods at a time. In one experimental group (#6), players were randomly assigned one role (sender or receiver) for the entire experiment, and played from 5 to 25 periods at a time.

Each experiment consisted of 2 sessions. In Session 1 of each experiment, Game 0 was played. Session 1 consisted of 10 periods of play, with each subject playing as a sender for 5 consecutive periods and a receiver for the other 5 periods. The details of pairings, etc., are contained in the appendix. Group 6 played this game for only 5 periods. We considered this game to be mainly a warm-up exercise for subjects.

Three parameter sets were used in Session 2, corresponding to Games 1, 2 and 3 above. Session 2 consisted of 20 periods of play, with each subject playing as a sender for 10 consecutive periods and as a receiver for the other 10 periods. Group 6 played a modified version of Game 1 (Game 1') in which the entry (10,4) in row 2, column C, was changed to (15,4). The game played by Group 6 also differs from the games played by other groups in that Session 2 consisted of 25 consecutive periods of play, instead of 10.

There were one-shot and repeated versions of Games 1 and 3, plus a longer repeated version using the modified Game 1'. There was a one-shot version of

Game 2, but not a repeated version. The predictions for each parameter set are summarized in Table 1. The schedule of experiments, including date conducted, parameter set, whether one-shot or repeated, etc. is contained in Table 2.

Tables 1 & 2 about here

Procedures

All of the experiments were conducted at New York University in April of 1992. The subjects were undergraduate students from economics classes. Each experimental group was recruited in classes within one week of the scheduled time of the experiment. At the time they were recruited, subjects were told that they would be participating in an experiment concerned with "the economics of decision-making," that the experiment was expected to last about 2 hours, and that average earnings would be about $25. Only one experiment lasted longer than 2 hours (by 15 minutes), and average earnings turned out to be slightly more than $26 per subject.

The experiments were conducted in a conference room equipped with cardboard dividers to give privacy to each subject. In each experiment there were 8, 10 or 12 subjects, with half seated on each side of the table. Instructions were passed out, read aloud to subjects, and then questions answered. The instruction period typically took about 20 minutes. After instructions were read and questions answered, Session 1 began. Occasionally some additional questions arose in the early periods of Session 1, that required some additional answering of individual questions. We do not believe there was any significant confusion as to what the procedures were and how earnings were determined after the first period or two of Session 1. Full details of the step-by-step conduct of the experiment are contained in an appendix, available on request from the authors.

4. Experimental Results

In this section, detailed discussion of the predictions of various theories for the games, and the results of our experiment, are discussed. We have not conducted formal statistical tests on the data, since our sample sizes are relatively small, and the structure of the games do not lend themselves to straightforward or enlightening hypothesis testing. Instead, we present aggregate cross-tabulations of two sorts for each game--sender type against message sent, and message sent against action taken--and base most of the discussion on these cross-tabulations. We also discuss some of the individual pair data.

4.1 Game 0 Results (Session 1)

We first consider the results of Session 1 (Game 0), shown in Figure 1. The purpose of Game 0 was mainly to train participants in the mechanics of the experiment (sending messages, taking actions, recording information). Because this game is so simple, many different theories predict the same thing, so we cannot say much about the performance of, say, CMR vs. Nash, without more complicated games. On the other hand, for this very reason, this warm-up game does not seem to bias subjects towards one or another theory.

There are two types of Nash equilibria in Game 0: pooling equilibria, in which both sender types send the same message, and separating equilibria, in which each type sends a distinct message. There are several equilibria of each type, many of which do not use the "natural meaning" of the language. For example, one separating equilibrium is for type 1 to send message 2 ("I am type

2"), for the receiver to respond with action A, and for type 2 to send message 1 ("I am type 1"), and for the receiver to respond with Action B. Restricting messages to their natural meanings, there is one separating equilibrium, and two pooling equilibria (only message 3 or 4 sent).

Action C is a safe strategy for the receiver, so if risk or regret looms large in the receiver's mind, one might expect to see action C chosen, which could be thought of as a pooling equilibrium in which all messages have the same meaning--i.e., nothing. On the other hand, many other theories--CMR and its generalization, announcement proofness, pareto efficiency and simple truth-telling---all predict separation.

Table 3a shows a cross-tabulation of sender type against the messages chosen by the senders. The table shows this cross-tabulation separately for those groups that played one-shot games (Groups 1-3) and those that played repeated games (Groups 4-6). In Game 0 there were 2 possible sender types and (thus) 4 possible messages (shown at the bottom of the table). In Game 0, each sender type has a credible message, which is to state its true type. For both one-shot and repeated games, this is what most of the senders do: about 75% in the one-shot, 79% in the repeated games state their true types. The remaining senders either lie (and state that they are the "other" type, or they do not identify themselves (say they are "type 1 or type 2", or say nothing). There appears to be no difference between the cross-tabulations in the one-shot vs. the repeated games.

Tables 3a & 3b about here

Table 3b shows a cross-tabulation of the message received and action taken by the receiver, again separately for the one-shot and repeated games. Of the set of messages that purport to identify a sender (i.e., Message 1 and Message 2) that were sent, about 80% (in one-shot games) and 77% (in repeated games) were responded to as if they were believed (assuming subjects were best-responding). Again, as with the senders' message-sending behavior, there appears to be no big differences between the one-shot and repeated games with respect to action-taking behavior by receivers. The one possible exception to this is that receivers show a slightly stronger tendency to take action 'C' in response to all messages in the repeated games. In the game against different opponents a message that is not full-truth telling could be due to the shortsightedness of one player and would not necessarily carry over to the next match, while in the repeated game with the same opponent, the same kind of message might make the receiver doubt the rationality of the sender. Action C could thus be either a punishment for not being fully truthful, or it could be a safe response to an irrational sender.

Although the aggregated results are consistent with separation and truth-telling, there are plenty of exceptions. For example, some senders say they are type 2 when in fact they are type 1[2]. This could be due to learning (i.e., just mistakes). On the other hand, these exceptions could be significant in that a subject may, besides learning the rules of the experiment, gather information about the rationality of the other subjects in the experiment. Further, one might learn that what one considers focal in the game is not necessarily focal for the other subjects. This is important because CMR assumes that, from the structure of the payoff matrix, players can infer everything they need in order to play the game. That is, by examining the payoff matrix, people can infer that certain types should play one way, and the behavior of other players in the game can then be deduced from rationality. Even if some people understand the reasoning of CMR, they may not play as predicted by CMR if they believe the players they will face are not rational with probability 1. A comparison to behavior in ultimatum bargaining games seems appropriate: Even if one understands that a rational person should prefer "something to nothing" and accept any offer greater than zero in an ultimatum bargaining game, it does not follow that making the smallest possible offer is the best policy, when you do not believe the other player is rational with probability 1.

4.2 Game 1 Results (Session 2)

We now consider Game 1, the first non-trivial game. In this game, truth-telling does not coincide with the CMR prediction. Thus, Game 1 requires a higher degree of sophistication in interpreting messages. The basic CMR prediction for this game is as follows: A type 1 sender sends message 1, while type 2 sends any message except message 1. The receiver responds to message 1 with action A, and responds to any other message with action B. Notice that this implies that the receiver must understand that although a sender may "hide" his identity, message 1 will only come from type 1. That is, any message other than message 1 comes from type 2. Truth-telling is like CMR, except that type 2 always sends message 2, rather than "anything but message 1". Since truth-telling requires type 2 to directly reveal his identity, a receiver who believes that truth-telling is focal and receives message 3 or 4 will need a new interpretation of the situation. This may include questioning whether type 1 is really behind message 1.

In the repeated version of Game 1, a sender could use "no message" (message 4), regardless of his type, in an attempt to induce action C, the one that maximizes his *ex ante* expected utility. Notice, though, that this strategy does not satisfy backwards induction, by a familiar argument.[3] Alternatively, the sender could stick to sending message 1 early in the game, even when he is not of type 1, in an attempt to establish that he does not intend to communicate any information about his type, and thus try to induce action C in this way. Notice that this will tend to ruin the meaning of message 1, so perhaps this would be more credible than sending message 4. On the other hand, the sender would have to be "lucky," and draw type 2 early in the game, if this method were to have any hope of working.

We now note the implications of some other theories for Game 1. In general, there are both separating and pooling Nash equilibria. As in Game 0, a severely risk-averse receiver might want to respond to every message with action C. It should be noted that any pooling equilibrium is not announcement-proof, since it will pay type 1 to deviate from it. Pareto efficiency implies the same thing: Though the sender will prefer the pooling equilibrium *ex ante* (before he knows his type), a type 1 sender will prefer the separating equilibrium. The receiver also prefers the separating equilibrium.

Table 4a shows cross-tabulations of sender type by message sent in the one-shot and repeated versions of Game 1. Note that there are two versions of the repeated game: Group 4 played the standard version, in which a given pair plays for 10 periods, while Group 6 played a longer version, in which a given pair plays for 25 consecutive periods. There appears to be strong support for CMR in both the one-shot and repeated versions of the game, for sender behavior. For example, between 86% and 92% of type 1 senders send message 1, "I am type 1", and manage to separate themselves from type 2 senders, as predicted by the theory. CMR predicts nothing specific for type 2 senders, except that they should not send message 1. In both the one-shot and repeated versions of the game, very few type 2 senders send message 1, consistent with CMR. But there is a slight difference between the one-shot and repeated games, as follows: type 2 senders appear slightly more inclined to send message 2, identifying themselves as type 2, in the repeated game than in the one-shot game.

The purpose of the long repeated game (Group 6) was to challenge the theory a bit more. Specifically, it seems that a sophisticated sender could "pool" his two types in the repeated game, always sending the same message, and maybe get the receiver to take action C, giving the sender a higher expected payoff. The first thing we did was to change the (10,4) entry to (15,4), as an additional allure to the sender. We also extended the game, from 10 to 25 periods, to give time for the pooling convention, if it is to arise, to be established. In fact, we were not able to upset the predicted CMR outcome: The frequencies of sender behavior in the long repeated game are virtually identical to the regular repeated game. Thus, comments on the repeated version of Game 1 below refer to both the regular and the extended version, unless otherwise noted.

Tables 4a & 4b about here

Table 4b shows cross-tabulations of message received by action taken for the one-shot and repeated versions of Game 1. In all versions of the game, message 1 is responded to as if it were true a majority of the time: 75% for the one-shot version and 87-88% of the time in the repeated versions. According to CMR, any other message than 1 ought to be taken to mean the sender is type 2. In all versions of the game, message 2 is interpreted in this way (76% in one-shot, 82-90% in repeated).

The most notable difference between the one-shot and repeated versions of Game 1 is that the receiver in the repeated game is much less likely to choose action C in response to a message other than 1 or 2. But responses to messages 3 and 4, which do not explicitly identify the sender, are very different across games. Only 36% of responses to message 3 or 4 in the one-shot game are action B, while from 76 to 84% in the repeated versions are action B. So, repeating the game seems to help the CMR predictions, in Game 1. One possible explanation is that it is easier for the receiver to tell that message 3 or 4 is sent by a type 2, presumably because he has noticed that message 1 is sent in those periods when (as he soon learns) the sender is type 1. Another possibility is that the receiver simply has more power in the repeated game, in the sense that he can impose the separating outcome. That is, the receiver may simply not choose action C, not allowing the sender to benefit from pooling his types. We do not observe any systematic evidence that receivers are "punishing" in this way, but this, of course, does not preclude the possibility that senders did not try to pool for fear of such punishment.

Overall, then, only one part of the CMR prediction really works. Type 1 sends message 1, and the receiver responds with action A, but the receiver fails to follow the CMR logic all the way through. In fact, analysis of the individual data reveals that almost all of the subjects, when playing the role of a receiver, choose both actions B and C in response to messages 3 and 4. This suggests that almost all of the receivers are not entirely sure of how to interpret such messages, mixing between the optimal CMR response of action B and the safe response of action C. Things do work a bit better in the repeated game, however. Both frameworks involve repetition, and hence the possibility of learning. The differences may be that with different opponents, it is not clear how much the experience with one subject should affect behavior with the next opponent. When one is playing against the same opponent this difficulty disappears. At the same time, new features appear, such as experimentation and possible attempts at enforcing different conventions. This is analyzed in the PAIR DATA subsection below.

Truth-telling does not fare well in the one-shot game, as 59% of the time type 2 senders hide their identity (i.e., send message 3 or 4). In the repeated game the comparable figure is 44%, which suggests that truth-telling is considered a better strategy in that context. This may just be a reflection of learning over time in the repeated game: if it is clear that any message other than message 1 is coming from type 2, then the sender might as well send message 2, and avoid any confusion. Truth-telling, in general, goes from 39% to 58% in the second half of the game, which is consistent with this dynamic learning story.

Pure risk considerations predict that receivers ought to choose action C. We note that C is used most frequently in the one-shot game as a response to message 3 or 4, suggesting that it is a response to uncertainty about the sender's type. In the repeated game, this use of action C is much less frequent. Our interpretation is that safety is a fall-back policy when a player discovers that his view of what is focal is not shared by other players. This is similar to the findings of Van Huyck, Battalio and Beil (1989,1990) that a safe strategy, in the absence of an external focal coordinating device to aid in selecting a payoff-dominant equilibrium, appears to be a fall-back strategy.

Pair Data

In the repeated game, since the same sender and receiver are paired for a number of periods, it makes sense to look at overall behavior, pair by pair, and see how the theories fair. In short version of Game 1 there were 10 subjects who formed two sets of five pairs, each playing together for 10 consecutive periods. Of these ten pairs, behavior is perfectly consistent with CMR for 5 pairs, reasonably consistent for another 3 pairs, and quite inconsistent for 2 pairs. Of these last two pairs, the same subject is present in both pairs, once as a sender and once as a receiver.[4] If the two pairs involving this subject are eliminated, CMR looks even better.

In the long repeated version of Game 1, there were 10 subjects forming one set of five pairs, each playing together for 25 consecutive periods. In four of these five pairs we observe what might be termed "experimentation" in early periods, followed by behavior more less as predicted by CMR. Experimentation lasted from 4 to 15 periods among these pairs. For example, there are cases of the sender lying about his type when he is type 1, which could be an attempt to enforce the pooling equilibrium. One interpretation is that if the strategy does not succeed early on (in the sense of forcing the receiver to take action C always), then one must revert to CMR behavior--it is too costly not to. In one other case, the receiver is the experimenter, choosing action C seven times in the first twelve periods in response to different messages, before adopting CMR-like behavior. This could be interpreted as an information gathering phase, in which the receiver implicitly asks the sender to establish a convention. In the fifth pair, behavior is closer to CMR from the outset, with a qualification. The sender in this pair is a truth-teller, and the receiver sometimes chooses C in response to the message 2. This could be interpreted as a reward from the receiver to the sender for telling the truth.

4.3 Game 2 Results (Session 2)

There are three kinds of Nash equilibria in Game 2: a pooling equilibrium, and two partially-separating equilibria, one in which sender types 1 and 2 send the same message, another in which sender types 1 and 2 mix over the same set of messages. In these partially-separating equilibria, the receiver responds to the type 1 and 2 messages with any action in the set {A, B}. The type 3 sender sends a different message from types 1 and 2, and the receiver responds with action C. A safe response, on the other hand, is for the receiver to choose action D all the time. Notice that, as in Game 1, the pooling equilibrium is not announcement-proof. CMR, in fact, has no prediction for this game, though the generalized CMR does make predictions. Specifically, sender types 1 and 2 could send messages 1, 2 or 4, and the receiver can respond with any message in {A, B}. Sender type 3 might want to send message 3, and the receiver would respond with action C. Finally, note that, by Pareto efficiency, all players prefer the partially separating equilibrium to the pooling equilibrium, but sender types 1 and 2 have conflicting interests (i.e., type 1 would like message 2 to be sent and believed by the receiver, while type 2 would like message 1 to be sent and believed by the receiver.

Table 5 shows cross-tabulations for both sender type against message, and for message received against action taken, for the one-shot version of Game 2. We have not conducted a repeated version of Game 2, partly because it seemed to work so well (vis-a-vis CMR), and we did not think that the repeated version would change the aggregate results.

Although type 1 and 2 senders do not use the explicit pooling message, #4, "I am type 1 or type 2", very often (16%), the set of messages they do send appear to be treated as having this meaning. Specifically, messages 1, 2 and 4 seem to identify the sender as type 1 or type 2, since 100% of the time, the response to these messages is either action A or action B. Also, 100% of the time the response to message 3 is action C.

Table 5 about here

It is interesting to consider what might happen in the repeated version of this game. Specifically, if Games 1 and 2 are any guide, we might expect to see more truth-telling. However, it seems unlikely that this would affect the aggregate results very much, since (unlike, as we shall see, Game 3) there is no conflict between the two conventions (Partial- and Full-truth-telling). Put differently, the receiver's response to either a pooling message for type 1 and 2, or a truth-telling message from either type 1 or type 2, is the same: choose A or B.

Overall, the subjects in Game 2 behave very closely to the GCMR predictions. Risk (or safety) seems to play only a minor role, since it is only when message 5 ("I am type 2 or 3") is sent that action D is taken, and this only happens twice. The striking thing here is the systematic nature of the results (which are not predicted by CMR). Consistent with GCMR, people do things to get a relatively high payoff, even though there is no consistent way for them to get their highest payoff. For example, although both type 1 and type 2 senders lie, they do so in a consistent way: messages 1, 2 and 4 have the same meaning, as evidenced by the systematic pattern of responses to these messages by the receivers. This is in contrast to Game 3, considered next, in which only message 4 will allow types 1 and 2 to pool.

4.4 Game 3 Results (Session 2)

Game 3 is a greater challenge to CMR than the other games. First, note that there are two Nash equilibria: pooling, and partially-separating, in which only types 1 and 2 pool. Unlike the other games, there is no safest action here, though action C is a best response with no communication. As usual, the pooling equilibrium is not announcement-proof. CMR predicts that types 1 and 2 send message 4, and that any message other than 4 should be interpreted as coming from type 3. Truth-telling is not optimal for any type of sender. By Pareto efficiency, the sender *ex ante* prefers the partially-separating equilibrium, but *ex post*, type 3 does not get his highest payoff with this equilibrium (since he can be identified).

Game 3 is a bigger challenge to CMR because now types 1 and 2 must pool by sending message 4. That is, they must hide some information. At the same time, type 3 need not directly reveal his identity--thus, the CMR prediction is very different from truth-telling in this game. If type 1 decides to be an honest guy, he can expect trouble, since type 3 would like to be mistaken for type 1, and thus it will be hard for type 1 to establish that as a convention.

Table 6a shows cross-tabulations of sender type by message sent for a one-shot and a repeated version of Game 3. CMR predicts that types 1 and 2 will send a joint message (such as message 4: "I am type 1 or type 2"), and that type 3 will do something different.

A striking result is that type 1 and 2 senders seem to have trouble using message 4. Analysis of individual data provides some insight. Of the 8 subjects in the one-shot version of Game 3, four of them always used message 4 when they were type 1 or 2, two of them never used message 4, and the other two used message 4 early in the game, but abandoned it later, possibly because they did not get action A in response. This suggests that though some subjects see the game as CMR predicts, others do not, and thus playing according to CMR may not be the best course of action. Receivers, for their part, seem to understand that message 4 comes from type 1 or type 2, but they are not certain, since 40% of the responses are different from action A. In fact, type 3 never sends message 4, so it must be either that the receiver is playing safe (choosing action C and ignoring messages), or the receiver is playing hunches (choosing actions B and C in the hopes of getting a higher payoff).

CMR performs reasonably well (though not overwhelmingly so) in the one-shot version, but something interesting happens in the repeated version. Specifically, type 1 and type 2 senders are much more likely to reveal their true type in a message in the repeated game. Overall, 58% of type 1 or 2 senders in the one-shot version, versus 16% in the repeated version, send the pooling message, "I am type 1 or 2". On the other hand, 25% of type 1 or 2 senders in the one-shot version, versus 54% in the repeated version, state their true type explicitly.

This "Full-truth-telling" behavior is hard to understand on its face: If a sender believes the receiver will choose a (myopic) best-response, then he can never expect to do better by telling the truth in Game 3. For example, if a sender says he is type 1 and is believed, then the receiver would respond with action B. Similarly, the best response to the message "I am type 2", if it is believed, is to choose action C. In both cases, the sender does worse than if he sent message 4: "I am type 1 or type 2", to which the receiver's best response is action A.

One possible explanation is that receivers in the repeated game punish "Partial-truth-telling" (saying "I am type 1 or type 2"), and reward Full-truth-telling, by allocating actions between the one that gives the sender a good payoff and the one that gives the receiver a good payoff. As in Game 1, we do not see any explicit evidence of punishment, though this is not necessary: it would only be necessary for a sender to believe that such punishment is possible. More generally, we suspect that the repeated version of the game gives the sender less commitment power (or less of a first-mover advantage) than the one-shot version does.

The behavior of type 3 senders is different in the two versions of Game 2 as well. Note that type 3 will do best if he can get the receiver to believe that he is a type 1, so that the receiver chooses action B. On the other hand, type 3 can identify himself as type 3, and, if believed, the receiver will choose action C, and the sender will receive his second best payoff. In the one-shot game, many type 3 senders (56%) choose message 1, presumably hoping to fool the receiver. No type 3 senders send message 3, "I am type 3", in the one-shot game. In the repeated version of Game 2, only 32% of type 3 senders send message 1, but 36% choose message 3.

Tables 6a & 6b about here

Table 6b shows cross-tabulations of message received by action taken in the one-shot and repeated version of Game 3. The main things to note in this table are as follows. First, the one-shot version: Message 4, apparently, is taken to be truthful 60% of the time (17/28 times the action A is chosen). Message 1, apparently, is taken to mean that the sender is type 3 in 64% of case (18/27 times the action C is chosen). Message 3 is sent only 2 times. In the repeated version, message 4 receives a response of action A 77% of the time (10/13 cases), while message 3 receives a response of action C 90% of the time (18/20 cases).

The biggest difference between the one-shot and repeated games seems to be in the responses to messages 1 and 2. In the one-shot game, message 1 is generally interpreted as a message sent by type 3, but in the repeated game, actions A, B and C all account for a significant proportion of responses. 50% of the responses to message 1 are action A, which suggests an attempt to establish trust, or to reward the sender for Full-truth-telling, since action B would, in fact, be the best response if message 1 were believed.

It appears that the prediction of CMR falls apart in the repeated game setting, but analysis of individual pair behavior mitigates this failure somewhat. Specifically, a reasonable interpretation of the individual pair data is that the only *stable* behavior observed was consistent with CMR. In the one-shot version, 4 of 8 senders could be classified as consistent with CMR, while in the repeated version, only 1 sender in 10 does exactly as CMR predicts in every period. Thus, CMR does not seem to perform well in the repeated games. But in the repeated game there are more opportunities to make mistakes, to try out alternative conventions, etc. So another way of evaluating the theory is to ask whether any alternative conventions, such as the Full-truth-telling convention, are stable for any pairs of players. The fact is that the two conventions-- Partial- and Full-truth-telling-- are in conflict. The Full-truth-telling convention requires a certain type of cooperation from the receiver, in the sense that he is supposed to allocate actions in such a way as to give each player a good payoff part of the time. Not surprisingly, this is a fragile convention, and it inevitably breaks down in later periods, for those pairs who try to follow it in earlier periods. No single pair followed the Full-truth-telling convention until the end of the game. Thus, we salvage one bit of support for CMR from the repeated games from the fact that those who followed the CMR convention were able to do so until the end.

Perhaps the best way to summarize the results of Game 3 is to compare it again with Games 1 and 2. In Games 1 and 2, the CMR predictions can be implemented by truth-telling, while in Game 3 this is not true. In fact, truth-telling can turn out to be a complex, confusing matter in Game 3. To the extent that truth-telling conventions arise, there is an incentive to cheat on the convention, so the convention turns out to be unstable. In general, the failure of CMR in Game 3 seems to be related to the subtlety of behavior required: one must, as a type 1 or 2 sender, use message 4, and nothing else. If types 1 and 2 do not all understand this, then everyone can get confused.

5. Related Work on Communication and Coordination

Theoretical work on communication and coordination can be divided into two main categories: *equilibrium* and *non-equilibrium* approaches, with the former constituting most of the research. Equilibrium approaches include the seminal papers of Crawford and Sobel (1982) and Green and Stokey (1980), who first showed that in a signalling game where the sender's and receiver's interests do not coincide, there exist equilibria in which some truthful information can be transmitted; that is, cheap talk can matter.

Farrell (1985), continuing with the equilibrium approach, developed the idea of a *Neologism-Proof* equilibrium. Multiplicity of equilibria is a problem with cheap-talk equilibria, since for any equilibrium in a simple cheap talk game, where some signal is sent with probability zero, we can construct an equivalent equilibrium where all the signals are sent with positive probability. Imagine that, perhaps through evolution, an equilibrium is reached where certain words of a language common to the players are used with their true meaning. Farrell's idea is that an equilibrium should prevail if no subset of sender types prefer to start using a "new word" than to use the equilibrium messages. This reduces the set of equilibria. Matthews, Okuno-Fujiwara and Postelwaite (1991) refined the idea of Neologism-Proofness by allowing deviations (called "announcements") that contain more than one message. Their concept of *announcement-proofness* is thus more restrictive than Farrell's.

Blume and Sobel (1991) suggest that if communication in a signalling game is costless, the sender should be able to continue to send messages once some information has been transmitted. For example if there is a message that means that the sender belongs to some subset of possible types, the sender could propose a new equilibrium, given that the sender must belong now to a smaller set. Roughly, an equilibrium would not prevail if once a message has been sent the types sending that message in equilibrium strictly prefer to keep on talking. An equilibrium where this kind of renegotiation is not possible is called *Communication-Proof*.

The approach of Rabin (1990), which we have focussed on in the experiments, is completely different from the above mentioned equilibrium approaches. He criticizes the equilibrium approach, as we have already noted in Section 2, on the grounds that truthful communication is basically a coordination problem, and that use of an equilibrium concept assumes coordination. Thus, this view suggests that the messages themselves are the primal objects. When sent and interpreted appropriately, the communication process leads one to an outcome, which need not be a full equilibrium. The equilibrium approach, on the other hand, suggests that the equilibria are the primal objects, and that, somehow, coordination is achieved by players managing to choose one of the possible equilibria.

There has been some recent work experimentally testing the role of communication in games. For example, Cooper, Dejong, Forsythe and Ross (1989, 1991) have examined the efficacy of one- and two-way communication in achieving coordination in simultaneous-move coordination games. Our experiment differs from the coordination games studied by Cooper, et al., most importantly, in that in the sender/receiver games only one player can make a binding decision (the receiver) that affects payoffs. Moreover, this decision is made after the sender has made his (non-binding) decision of which message to send. This makes it easier to sort out how one player is responding to the other than in simultaneous-move games. The result that one-way communication seemed to work better in the Cooper, et al., experiments would seem to be due to the commitment power implicit in the one-way structure of communication. The breakdown of CMR in the repeated version of one of our games might be viewed as a related phenomenon, with the repeated nature of the game diluting the commitment power of the sender's message, compared to the one-shot game.

Palfrey and Rosenthal (1991) have tested the effects of cheap talk in public goods games. Introduction of cheap talk in such games was found to affect play. Specifically, although the messages sent by subjects were not systematic (i.e., no single theory explained the message behavior), subjects responded to messages in a systematic way. We found similarly mixed results in the repeated version of Game 2, where the conflict between the conventions of Partial- and Full-truth-telling led to a different kinds of message-sending behavior.

6. Conclusions

Our overall assessment of the experiment is that CMR performs well, even if it does not explain all behavior observed. It performs reasonably well within each of the one-shot games. In Game 1, the repeated version of the game strengthens the case for CMR. Indeed, two different manipulations of the game do nothing to shake the explanatory power of CMR. Repeated play with the same opponent does not always work in favor of CMR. For example, in the repeated version of Game 3, there is an interesting breakdown of CMR. We posit that some sort of punish/reward responses to truth-telling or its lack are responsible for this result. On the other hand, analysis of the individual pair data suggests that CMR, though it does not explain the majority of play, nonetheless is a reasonable explanation since any other conventions of play that are attempted turn out to be unstable. The one-shot version of Game 2 adds additional support to GCMR, and we expect that a repeated version of Game 2 would not yield very different results because the conventions of CMR play and truth-telling are not in conflict, as they are in Game 3.

We have characterized the results in terms of full and partial truth-telling. It should be emphasized that the use of the full truth-telling convention does not appear to be driven by ethical considerations, since a majority of subjects did something other than "telling the whole truth" at some point. Rather, we think that the majority of subjects realized that some kind of refinement of full truth-telling would be the best policy. Establishment (not to mention discernment) of a focal policy is tricky, so full truth-telling tends to be used because it is easy. CMR assumes that a particular form of honesty is focal, and that players, with this in mind, can figure out the rest. Repetition in our games was intended to give subjects enough time to figure out what is focal (through interaction with other players), and what the full implications of the focal policy are. Our results show that full understanding and implementation of CMR-type play is a difficult and demanding task for subjects. Further, it matters what type of repetition subjects experience. For example, in the repeated games with the same opponent, new features not present in the one-shot games, such as the power of the receiver to attempt to impose a preferred convention, arise. When there is a conflict of preferred conventions, then the game may look more like bargaining or negotiation, and it is not clear if more experience would lead to play consistent with CMR.

We think that CMR and GCMR are still worthy candidates for further testing, but other ways of establishing a focal policy should be investigated. For example, players could be allowed to discuss in detail, prior to play, what the "right" way to play would be, or a menu of possible ways of playing the game could be suggested. Play by experienced subjects in repeated sessions would be worthwhile, since it would allow one to assess the predictive value of CMR for relatively sophisticated subjects, who presumably have more sophisticated notions of the implications of various possible policies.

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Figure 1

Session 1, Game 0

Action

Type		A	B	C
	t1	8, 7	4, 2	2, 5
	t2	1, 3	6, 6	3, 4

Session 2, Game 1

Action

Type		A	B	C
	t1	8, 7	1, 2	4, 5
	t2	1, 1	4, 6	10,4

Session 2, Game 2

Action

Type		A	B	C	D
	t1	8, 6	5, 7	1, 1	0, 5
	t2	6, 7	7, 6	2, 1	0, 5
	t3	1, 0	1, 1	6, 7	2, 5

Session 2, Game 3

Action

Type		A	B	C
	t1	7, 8	4,10	3, 2
	t2	7, 6	3, 2	5, 8
	t3	1, 1	6, 2	4, 7

Table 1: Predictions

Game	CMR	GCMR	No-communication baseline
0	separation	separation	pooling
1	1 separates	1 separates	pooling
	2 ?	2 might separate	
2	1 and 2 ?	1 and 2 might pool	pooling
	3 separates	3 separates	
3	1 and 2 pool	1 and 2 pool	pooling
	3 ?	3 might separate	

Table 2: Experiments Conducted

Group	Date	Session 1	Session 2	Description
Group 1	April 6, 1992	Game 0	Game 3	one-shot games
Group 2	April 6, 1992	Game 0	Game 1	one-shot games
Group 3	April 7, 1992	Game 0	Game 2	one-shot games
Group 4	April 8, 1992	Game 0	Game 1	repeated games
Group 5	April 13, 1992	Game 0	Game 3	repeated games
Group 6	April 14, 1992	Game 0	Game 1'	long repeated games

Table 4a: Session 2, Game 1
(One-shot vs. Repeated Games)
Types vs. Messages*

Group 2 (one-shot)

type	message 1	2	3	4	Total
1	38	0	2	4	44
2	2	21	23	10	56
Total	40	21	25	14	100

Group 4 (repeated)

type	message 1	2	3	4	Total
1	38	0	2	1	41
2	4	29	13	13	59
Total	42	29	15	14	100

Group 6 (long repeated**)

type	message 1	2	3	4	Total
1	55	1	4	1	61
2	5	33	13	13	64
Total	60	34	17	14	125

Table 4b: Session 2, Game 1
(One-shot vs. Repeated Games)
Messages* vs. Actions

Group 2 (one-shot)

message	action A	B	C	Total
1	30	3	7	40
2	3	16	2	21
3	7	9	9	25
4	0	5	9	14
Total	40	33	27	100

* Menu of Messages:
Message 1 – "I am type 1"
Message 2– "I am type 2"
Message 3– "I am type 1 or 2"
Message 4– "No message"

Group 4 (repeated)

message	action A	B	C	Total
1	37	2	3	42
2	1	26	2	29
3	1	11	3	15
4	2	11	1	14
Total	41	50	9	100

Group 6 (long repeated**)

message	action 1	2	3	Total
1	52	2	6	60
2	2	28	4	34
3	1	14	2	17
4	0	13	1	14
Total	55	57	13	125

** Entry for Row 2, Column C of Game 1 was changed from (10,4) to (15,4). Also, games were 25 periods long, instead of 10 periods.

Table 5: Session 2, Game 2
(One-shot Games Only)
Types vs. Messages*

Group 3 (one-shot)

type	message 1	2	3	4	5	Total
1	6	17	0	5	1	29
2	13	8	1	4	0	26
3	0	1	23	0	1	25
Total	19	26	24	9	2	80

Messages* vs. Actions

Group 3 (one-shot)

message	action A	B	C	D	Total
1	5	14	0	0	19
2	13	13	0	0	26
3	0	0	24	0	24
4	2	7	0	0	9
5	0	0	0	2	2
Total	20	34	24	2	80

* Menu of Messages:
Message 1 - "I am type 1"
Message 2 - "I am type 2"
Message 3 - "I am type 3"
Message 4 - "I am type 1 or 2"
Message 5 - "I am type 2 or 3"
Message 6 - "I am type 1 or 3"
Message 7 - "I am type 1, 2 or 3"
Message 8 - "No Message"

Table 6a: Session 2, Game 3
(One-shot vs. Repeated Games)
Types vs. Messages*

Group 1 (one-shot)

type \ message	1	2	3	4	5	6	7	8	Total
1	8	2	0	10	0	1	0	0	21
2	1	4	2	18	2	0	0	0	27
3	18	1	0	0	3	5	3	2	32
Total	27	7	2	28	5	6	3	2	80

Group 5 (repeated)

type \ message	1	2	3	4	5	6	7	8	Total
1	23	3	2	4	3	1	2	0	38
2	9	18	2	8	1	0	0	0	38
3	14	2	16	1	3	6	0	2	44
Total	46	23	20	13	7	6	3	2	120

Table 6b: Session 2, Game 3
(One-shot vs. Repeated Games)
Messages* vs. Actions

Group 1 (one-shot)

message \ action	A	B	C	Total
1	3	6	18	27
2	0	0	7	7
3	0	0	2	2
4	17	5	6	28
5	0	0	5	5
6	0	2	4	6
7	0	0	3	3
8	0	0	2	2
Total	20	13	47	80

Group 5 (repeated)

message \ action	A	B	C	Total
1	23	12	11	46
2	10	2	11	23
3	0	2	18	20
4	10	1	2	13
5	2	1	4	7
6	1	1	5	7
7	1	0	1	2
8	1	1	0	2
Total	48	20	52	120

* Menu of Messages:
Message 1 - "I am type 1"
Message 2 - "I am type 2"
Message 3 - "I am type 3"
Message 4 - "I am type 1 or 2"
Message 5 - "I am type 2 or 3"
Message 6 - "I am type 1 or 3"
Message 7 - "I am type 1, 2 or 3"
Message 8 - "No Message"

1.The paper is available on request from the author.

2.In fact, individual data shows that less than 50% of players used a truth-telling strategy throughout the one-shot games, so it is not just that there are a few outliers in the data.

3.This is the familiar chain-store paradox. If a sender is type 1 in the last period, he will want to send message 1 then, and thus a reputation for always "fighting entry" by sending "no message" will not be credible.

4.The subject is number 10. As a receiver, this subject responds to messages (2, 4, 2, 1, 2, 2, 1, 1, 1, 3) with actions (B, A, A, C, B, B, B, A, B, B). As a sender, this subject, as types (1, 1, 2, 1, 2, 2, 1, 1, 2, 2), send messages (3, 1, 2, 4, 3, 2, 1, 1, 2, 1). We consider this a model of inconsistency.