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An experimental study of e-mail games with strategic information transmission and communication cost

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Abstract

We experimentally examined several versions of Rubinstein (1989)'s e-mail game in the laboratory. He shows that, in the unique equilibrium of this game, players behave as if no information is exchanged, no matter how many messages are successfully sent. This has been regarded as a "paradox of almost common knowledge." Binmore and Samuelson (2001) later extended Rubinstein's model by replacing automatic information transmission with the strategic one, or by introducing communication costs. We test these theories in the laboratory experiment. In general, our experimental results fail to provide support for Binmore and Samuelson's prediction. While they predict that those changes will induce players to take heed of the exchanged messages, our experimental results show little evidences to support their predictions and contradictory results in some cases.

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1. Introduction

We experimentally examined several versions of Rubinstein (1989)'s E-mail game in the laboratory. The fundamental coordination problem for two players is as follows. Each player chooses between A and B. However, the coordination problems differ according to two possible states of the world, and only Player 1 is informed of the true state. Rubinstein introduces E-mail exchange to this game and allows the informed Player 1 to send a message about the true state via an E-mail system. However, messages may be lost with some probability in this system. Upon receiving the message from Player 1, the uninformed Player 2 responds for confirmation. Exchanges of messages continue until a message is lost. In Rubinstein's original formulation, the information transmission between players is assumed to be automatic. He showed that, in the unique equilibrium of this game, players behave as if no information were exchanged, no matter how many messages had been actually sent. This result has been regarded as a "paradox of almost common knowledge."

Binmore and Samuelson (2001) later extended Rubinstein's model. In the first version of their models, they introduced attention costs to the Rubinstein's model. In the second version, they substituted voluntary information transmission for the automatic one. In the third version, they consider the E-mail game with voluntary information transmission with sending and attention costs. They show that, in all these cases, there exist efficient equilibria in which players take heed of the communication.

We test these theories in the laboratory experiment. As for the experimental study of E-mail games, Camerer (2003) is the only study we are aware of[1]. In general, our experimental results fail to provide support for Binmore and Samuelson's prediction. While they predict that those changes will induce players to take heed of the exchanged messages, our experimental results show little evidences to support their predictions and contradictory results in some cases.

The organization of the paper is as follows. The next section introduces Rubinstein's E-mail game and its variants. In Section 3, we describe our experimental procedures and hypotheses. Experimental results are presented and analyzed in Section 4. The final section concludes.

[1] In his model, unlike in ours, automatic message exchange starts when the state with higher probability occurs. Furthermore, he only examined Rubinstein's original version of the game. Given these experimental settings, he confirmed that it was eventually the case that subjects always chose strategy A; i.e., the risk-dominant equilibrium obtains as the theory predicts.

2. The Model

The fundamental coordination situation is shown in Figure 1, where L > M > 1. Game X is chosen with probability *1-p* and Game Y with probability *p*, where *p* is strictly less than a half. That is, Game X is more likely. In Game X, A is the dominant strategy for both players. In Game Y, both (A,A) and (B, B) are pure-strategy Nash equilibria, of which (A, A) is the risk dominant equilibrium and (B, B) is Pareto superior.

Game X with probability *1-p*

1 \ 2	A	B
A	M, M	1, -L
B	-L, 1	0, 0

Game Y with probability *p*

1 \ 2	A	B
A	0, 0	1, -L
B	-L, 1	M, M

Figure 1. Fundamental coordination problem (L > M > 1 and p < 1/2).

If only Player 1 is informed of the true state of the world and there is no communication channel, then AA for Player 1 (i.e., choosing A in both states X and Y) and A for Player 2 constitutes the unique Bayesian Nash equilibrium. If there is complete information, the most efficient outcome is achieved by both players' choosing AB. What about the case where the informed Player 1 is allowed to communicate her knowledge to Player 2?

Rubinstein considered the following E-mail game: Only if less likely Game Y is chosen, Player 1's computer *automatically* sends a message via an e-mail system, in which the message may be lost with probability *q*. Upon receiving the message, the uninformed Player 2 responds by sending back *automatically* a confirmation message from his computer through the same email system. Exchanges of the messages between two players will continue until a message will have been lost. In this situation, the player who received *m* messages cannot know whether the message she/he sent successfully reached the opponent, or the opponent player has received it, but her/his confirmation message was lost. Player 1's strategy specifies what to choose in state X, and her choice in state Y that can depend on the number of messages she received. Player 2's strategy is choosing A or B according to the number of messages he received. In most of what follows, we restrict attention to some class of strategies. Let $(S_x, S_Y(m))$ denote Player 1's strategy that designates $S_x \in \{A, B\}$ in state X and $S_Y \in \{A, B\}$ if the number of messages she received is less than or equal to *m* messages in state Y. For Player 2, $S_Y(m)$ denotes his strategy such that he chooses $S_Y \in \{A, B\}$ if the number of messages she received is less than or equal to *m* messages.

Choosing A in both state of the world is obviously a Nash equilibrium, which is called "tacit," because, in this equilibrium, players behave as if no information were shared no matter how many messages had been successfully exchanged[2]. This equilibrium obviously yields a less efficient outcome when Game Y is chosen and sufficiently many messages have been exchanged.

To alleviate this pessimistic result, Binmore and Samuelson (2001) extended Rubinstein's model in several directions. By doing so, they show that *vocal equilibria* in which the messages are heeded exist. For one thing, they introduced costs for reading and sending messages to the original model. As Rubinstein has already mentioned in his paper, if the upper bound for the number of exchanged messages is predetermined, more efficient equilibrium, where both players play B in Game Y, exists. Thus, introduction of reading or sending costs may impose a cap on the number of messages to be exchanged and thus simulate the case where the number of the message is limited. For another, they replaced automatic message exchanges by voluntary ones. In this way, the intention of Player 1, that is, playing B in Game Y, can be communicated. This also induces vocal equilibria.

Binmore and Samuelson (2001) analyzed the following three cases: 1) Voluntary communication where both players can voluntarily choose whether or not to send a costless message, that is, how many messages they are willing to exchange. In this case, there are no sending or reading costs; 2) Automatic message exchange with attention (reading) costs. In this case, players are asked how many messages they are willing to read and they incur *ex ante* costs depending on the number of message to be read; 3) Voluntary communication with attention and sending costs. In this case, both players pay costs for sending a message in addition to the attention costs. The sending costs are incurred *ex post*.

In all these cases, in addition to tacit equilibria which always exist, vocal equilibria exist under certain conditions on the parameters. Note however, in the equilibria that exist, players have to succeed in coordinating precisely on the minimum number of received messages for playing B. This is not what we can hope to observe in our experiment, which does not allow players to learn over time. All we can hope to observe is whether players *try* to take heed of the number of messages. So, based on the predictions of Binmore and Samuelson (2001), we put the following hypotheses:

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2 We refer the readers for the proof, for example, in Osborne and Rubinstein (1994).

Hypothesis 1. *With no attention or sending costs, changing the message exchange from automatic to voluntary increases the frequency of AA (m) on the side of Player 1 and A(m) on the side of Player 2.*

Hypothesis 2. *In the case of automatic exchange of messages, introduction of attention costs increases the frequency of AA (m) (Player 1) and A(m)(Player 2).*

Hypothesis 3. *In the case of voluntary communication, introduction of attention costs increases the frequency of AA (m) (Player 1) and A(m) (Player 2).*

Hypothesis 4. *In the case of voluntary communication, introduction of sending costs increases the frequency of AA (m) (Player 1) and A(m) (Player 2).*

3. Experiment

Experiments were conducted in January and November 2011. Subjects were undergraduates at Chuo University in Japan, who were recruited via E-mail list in the university and most of whom were not from economics department. Only a few of them knew game theory and had no experience to participate in any experiment. For each session, 42-48 subjects participated, so 21-24 pairs were created. Each subject participated in only one session.

In the experiments, we compare the following five variants of the E-mail games based on the past research. In Session 1, Rubinstein's original model is tested. That is, messages are exchanged automatically and there is no cost for communication. In Session 2, attention costs are introduced to the original model. In Session 3, the case of voluntary communication with no cost is examined. In Session 4, attention costs are introduced to the game in Session 3. In the final Session 5, sending costs are introduced to the game in Session 3. In each session, the game was played only once.

In each session, before subjects played the E-mail game to be examined, two practice rounds had been run. In the first round, the incomplete-information game without communication was played. In the second round, subjects played the game with complete information, where both players were informed of the true state. Then, in the third round, the targeted E-mail game under its specific condition was played. This is to make sure that our subjects are familiar with the basic payoff structure and the difference in the informational conditions. However, the outcomes in the practice rounds were revealed after the all the rounds had ended.

The experiment was run under *strategy method*, that is, each player was asked to write down their contingent strategy before the game begins. More concretely, Player 1 chose her strategy for Game X as well as her strategy for Game Y contingent on the number of messages received, and Player 2 chose his strategy contingent on the number of messages received. In fact, subjects were asked to choose from the following four types of strategy: 1) to choose A regardless of the number of messages; 2) to choose B regardless of the number of messages; 3) If the number of messages received is less than or equal to *m* (subjects have to specify it), choose A, otherwise choose B; 4) If the number of messages received is less than or equal to *m* (subjects have to specify it), choose A, otherwise choose B. Although the set of strategies are restricted, we believe that these strategies cover plausible set of strategies in the E-mail games we examined. In addition, Player 1 of course chose her strategy for Game X. Subjects also pay attention or sending cost in Sessions 2, 4, and 5. Attention costs are 0.1 times the number of messages to be read. Sending costs are 0.1 times the number of messages actually sent. In the case of attention costs, players have to *ex ante* specify the number of messages to be read. In sending cost, player 1 pays according to the number of messages that are actually sent[3].

After both players had written down their strategies in the recording sheets, experimenters collected them. Then a computer program randomly determined the state of nature (the game to be played) and, in the case of state Y, how many messages could be exchanged between players without being lost. The probability of Game Y, *p*, is set equal to 0.8, and the probability of the message being lost, *q*, is 0.1. The game to be played and the number of messages that could be exchanged in the case of state Y were common among subjects. That is, for example, if Game Y is chosen, then every subject played that game. Then, each player was separately informed of how many messages had been received, which may depend on their sending/reading decisions as well as the random event. Finally, the outcome of the game is determined and subjects were paid in cash. For one hour experiment, average reward was JPY 2,234 (approximately $28 at that time).

4. Results

First consider the frequency of strategies chosen by each player in the first round (incomplete-information game without any communication). As already mentioned, the strategy profile (AA, A), where AA for Player 1 (that is, to choose A in both games) and A for Player 2 is the only pure strategy Bayesian Nash equilibrium in this game. Majority of both players behaved according to this equilibrium (62.8% of Player 1

[3] To help subjects calculate the conditional probability that their messages has reached their opponent, we also provided event tree and the probability table as shown in the instructions.

chose AA and 90.3% of Player 2 chose A) but non-negligible number of player 1 chose strategy AB (that is, to choose A in Game X and B in Game Y regardless of the number of received messages).

Next, consider the frequency of strategy for each player in the second round (complete-information game). In this game, there are two pure-strategy Nash equilibria, (AA, AA) and (AB, AB). Majority of both players chose either strategy AA (38.1% and 50.4% for Player 1 and 2 respectively) or AB (56.6% and 46.0% for Player 1 and 2 respectively). This also confirms the equilibrium prediction.

Player 1

	Session 1	**Session 2**	**Session 3**	**Session 4**	**Session 5**
AA	36.4%	52.2%	47.6%	47.8%	37.5%
AB	22.7%	26.1%	19.0%	17.4%	25.0%
AA(m)	31.8%	17.4%	28.6%	26.1%	25.0%
AB(m)	9.1%	4.3	0.0%	4.3%	4.2%
BA	0.0%	0.0%	0.0%	0.0%	0.0%
BB	0.0%	0.0%	4.8%	4.3%	8.3%
BA(m)	0.0%	0.0%	0.0%	0.0%	0.0%
BB(m)	0.0%	0.0%	0.0%	0.0%	0.0%

Player 2

	Session 1	**Session 2**	**Session 3**	**Session 4**	**Session 5**
A	54.5%	91.3%	47.6%	60.9%	58.3%
B	9.1%	0.0%	0.0%	0.0%	4.2%
A(m)	31.8%	8.7%	47.6%	26.1%	29.2%
B(m)	4.5%	0.0%	4.8%	13.0%	8.3%

Table 1. The frequencies of strategies for each player in the third round.

The frequencies of strategies in the E-mail games for all the sessions are presented in Table 1. As already stated, since the experiment was one-shot, all we can hope to observe is players' willingness to take heed of the communication result in state Y. Note that almost all the Player 1 subjects chose A in state X, as the theory predicts. So, we mostly focus on the choice in state Y.

First let us compare the results in Session 1 with those in Session 3. This concerns the effect of changing from automatic to voluntary communication. For Player 1, this shift seems to discourage communication efforts; The frequency of AA(m) decreased from 31.8% to 28.6%. In contrast, for Player 2, this shift encouraged her to take heed of the number of received messages. In fact, the frequency of A(m) increased from 31.8% to 47.6%. However, for both players, there is no significant difference between sessions 1 and 3 (The chi-square test, p-values are 0.817 and 0.289 for Players 1 and 2 respectively). So Hypothesis 1 is not confirmed.

Next, examining the results in Sessions 1 and 2, let us compare the effect of attention costs in the automatic communication environments. Unlike the suggestion by Binmore and Samuelson (2001), the introduction of attention costs is detrimental to the communication between both players. For Player 1, AA(m) decreased from 31.8% to 17.4%. For Player 2, A(m) decreased from 31.8% to 8.7%. The chi-square test rejects Hypothesis 2 at 10% level for Player 2 (p-value = 0.053), but does not for Player 1 (p-value = 0.260).

Let us turn to the effect of shifting from no cost condition to attention cost condition in the strategic communication conditions, that is, let us compare results in Session 3 with those in Session 4. For Player 1, the frequency of AA(m) slightly decreased from 28.6% to 26.1%. For player 2, A(m) decreased substantially from 47.6% to 26.1%. This result is also contrary to Binmore and Samuelson (2001)'s expectation. But the chi-square tests didn't reject our Hypothesis 3 for both players (p-values are 0.853 and 0.138 for Players 1 and 2 respectively).

Finally, if we compare the effect of shifting from no cost condition to sending cost condition in the strategic communication conditions, that is, Sessions 3 vs. 5, For Player 1, AA(m) decreased from 28.6% to 25.0%. Instead, Player 1 tended to change to AB. For Player 2, A(m) decreased from 47.6% to 29.2%. This result is also contrary to Binmore and Samuelson (2001)'s expectation. However, the chi-square tests showed no significant difference (p-values are 0.787 and 0.203 for Players 1 and 2 respectively).

5. Conclusion

In this paper, we experimentally examined various versions of the E-mail game proposed by Rubinstein (1989). It is of great interest to see whether changing modes of communication reverses Rubinstein's negative results. As suggested by Binmore and Samuelson (2001), we examined the effects of changing from automatic communication to voluntary one as well as that of introducing communication costs. While Binmore and Samuelson (2001) predict that those changes will induce players to take heed of the exchanged messages, our experimental results show little evidences to support their predictions and contradictory results in some cases.

References

Binmore, K. and L. Samuelson (2001) “Coordinated action in the electronic mail game,” *Games and Economic Behavior*, 35, 6-30.

Camerer, C. F. (2003) *Behavioral Game Theory Experiments in Strategic Interaction*, Princeton University Press.

Osborne, M. and A. Rubinstein (1994) *A Course in Game Theor*y, MIT Press, Cambridge MA.

Rubinstein, A. (1989) “The electronic mail game: Strategic behavior under ‘almost common knowledge’ ,” *American Economic Review*, 79, 385-391.