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Effect of time on making decisions in an ultimatum game - Application to medical ICT field

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Abstract – **In clinical field, it is important for medical personnel, patients and their families to decide speedy and precisely, for the decisions affect efficiency of treatment and satisfaction for the treatment. And more importantly, sometimes, the decisions affect patient's life. Thus, development of decision support system should be a primary topic in medical engineering field. In this study, effect of time in decision making was investigated as a step for the development of the system. In concrete, as a test of economic decision making, we conducted an ultimatum game experiment with a controlled length of time for making the decision. An ultimatum game is a game in which a reward is divided between two people. Previous work has established that people make economically irrational choices due to the effect of emotion in ultimatum games. We focused on the effect of the length of time given to make a decision in the game. The control of time length is new for the use of ultimatum games. This study verified the result of previous work on the effect of emotion in decision making and newly demonstrated the fact that the length of time taken to make a decision affects its result - a longer time-length leads to a more economically reasonable decision. This feature is assumed to be correlated to brain activity in the insula, the amygdala and the prefrontal cortex. And applicable to the medical ICT field.**

Index Terms - decision making, ultimatum game, emotion, time

I. INTRODUCTION

In clinical field, it is important for medical personnel, patients and their families to decide speedy and precisely, for the decisions affect efficiency of treatment and satisfaction for the treatment. And more importantly, sometimes, the decisions affect patient's life. Thus, development of decision support system should be a primary topic in medical engineering field. In this study, effect of time in decision making was investigated as a step for the development of the system. In concrete, rationality of the decision was investigated under controlled time to decision in ultimatum game.

Decision making is not always economically reasonable due to the effect of emotion. Irrational decision making related to emotion has been investigated in the fields of psychology, behavioral economics and neuroeconomics. In psychology, it was shown that decisions are influenced by irrational cognitive biases such as hindsight bias[1~4] or the framing effect[5]. In the field of behavioral economics, irrational decision making was formularized in the Prisoner's Dilemma. In addition, it was shown that one aspect of these cognitive biases uses heuristics as an anchoring bias[6]. In neuroeconomics, the conflict between emotional and economic decisions was studied with the ultimatum game[7, 8]. Previous studies on the relationship between emotion and time show that emotion can affect subjective time length; negative emotions, such as fear, make subjective time longer[9~15]. Langer et al.[9] purported that the fear of death can lengthen subjective time, and several studies have supported this hypothesis. For example, Watts and Sharrock[10] showed that arachnophobic subjects experience longer subjective time than controls when in the presence of a spider, and Eagleman and Holcombe[12] showed that fear during bungee jumping lengthens subjective time. In addition, Noulhiane et al.[15] found that emotional music makes subjective time longer.

However, there are few studies on the relationship between decision making and time. We conducted this study to test the hypothesis that the time to make a decision affects the decision result. We used an ultimatum game to create an emotional context for the decision-making process, but we focused on the relationship between the decision and the time available to make the decision. The use of a controlled time length is a novel component to the ultimatum game.

II. METHODS

A. Ultimatum game

The ultimatum game is a traditional experimental task in neuroeconomics research. In the game, two players split a sum of money. One player is the "proposer" and the other is the "responder." The proposer suggests a ratio by which to split the money and the responder can either accept or reject this offer. If it is accepted, the money is split as proposed, but if the responder rejects the offer, then neither player receives anything. In either event, the game is over.

The economically reasonable decision for the responder is to always accept this offer, on the grounds that any monetary amount is preferable to none. However, considerable behavioral research in industrialized cultures indicates that low offers (approximately 20% of the total) have an approximately 50% chance of being rejected[16~19]. Based on participant reports, it appears that low offers are often

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rejected due to an angry reaction to an offer that is perceived as unfair. The negative emotions provoked by unfair treatment can lead people to sacrifice financial gain to punish their partner. Unfair offers in the ultimatum game induce conflict in the responder between economically reasonable (“accept”) and emotional (“reject”) motives. So far, there are variety of studies on ultimatum game such as effect of cultural difference[20] and comparison between ultimatum game and dictator game [21].

B. *Task*

Our experiment was conducted as a randomized two-level, three-factor design. The factors were the fairness of the distribution ratio, the length of time allotted to make each decision and the proposer of the game. The amount of money to be distributed was 1000 yen per trial. Two different distribution ratios were permitted: 500:500 yen for the “fair” condition, and 900:100 yen for the “unfair” condition. For the second factor, two lengths of time were allotted to make the decision: 6 seconds and 18 seconds. And as the third factor, two types of proposer were presented: a “person” and a “PC.” Two trials were conducted for each subject under each set of conditions, for all combinations of conditions, in random order. The acceptance rate of the responder was analyzed.

C. *Procedure*

The task was conducted in a university conference room. Before the task, the experimenter confirmed that each subjects was in the right condition to participate in the experiment: that the subject was in a calm mental state; that the subject did not need to attend to an urgent matter after the experiment; that the temperature of the room was comfortable for the subject. The subject was told the procedure and rules of the ultimatum game. After the experimenter asked if the subject had questions regarding the procedure or rules, the subject started the game. The experimenter made the subject believe that the proposer was in another room making each subsequent offer. The subject was also made to believe that when the proposer was unable to make an offer in a timely manner, the system would propose one automatically. During the task, the experimenter was in the same room but stayed quiet and made the subject think that the experimenter was not paying attention to the subject conducting the task. The trials were conducted on a PC screen, and the result of each trial was recorded automatically.

D. *Subjects*

The subjects were 60 people (26 female, 34 male) in their twenties and thirties, with an average age of 25.6 years old. Subjects were naïve to the ultimatum game.

E. *Flow in a trial*

In a trial, the following stages were shown to each subject in a continuous series: fixation-point (12 sec), identity of the proposer as a person or a PC (6 sec), ratio offered (6 sec or 18 sec), option to accept or reject (6 sec) and obtained amount of 0, 100 or 500 yen (6 sec). Fig. 1 illustrates the series of stages.

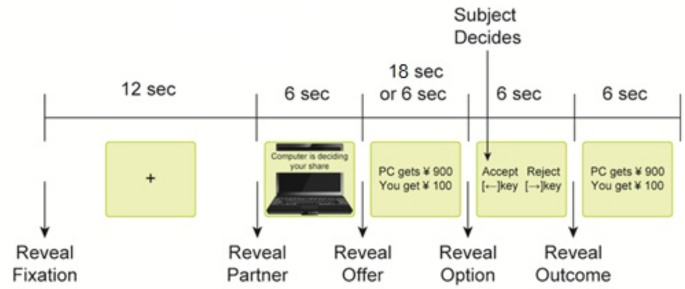

Fig. 1 One trial is composed of five stages.

III. RESULTS

Our experiment was conducted as a randomized two-level, three-factor design. The factors were fairness (fair or unfair), decision time length (6 sec or 18 sec), and types of proposer (person or PC). Each of the eight combinations was tried twice with all 60 subjects.

The results of the distribution analysis of the three factors are shown in Table 1. The main effects of the respective factors – fairness, time length, and types of proposer – were established. Interactions were also established in “proposer*time length,” “ proposer*fairness” and “time length*fairness.”

TABLE I
DISTRIBUTION ANALYSIS OF 3 FACTORS – PROPOSER, TIME AND FAIRNESS.

Factor	Degree of freedom	Sum of squared deviation	F-value	p-value
Proposer	1	1.75	25.47	<0.001
Time	1	2.7	39.25	<0.001
Fairness	1	12.35	179.57	<0.001
Proposer* Time	1	0.68	9.81	0.0018
Proposer* Fairness	1	2.27	32.98	<0.001
Time*Fairness	1	2.7	39.25	<0.001

In all fair conditions, irrespective of time length or proposer, the acceptance rates were more than 95%. The acceptance rates in the fair condition were 98.3% for the “person*6 sec” combination, 97.5% for the “person*18 sec” case (Fig. 2a), 95.8% for the “computer*6 sec” case and 96.7% for the “computer*18 sec” case (Fig. 2b). There were significant differences between the fair and unfair conditions with respect to both proposer and time length (person*6 sec, $p<0.01$; person*18 sec, $p<0.01$; PC*6 sec, $p<0.01$; PC*18 sec, $p<0.05$).

The first notable outcome was the difference in the decision result for different decision time lengths when the proposer was a person. In the “fair*person” scenario, there was no significant difference in the acceptance rate for different decision time lengths. However, in the “unfair*person” situation, the acceptance rate in the 18 sec condition (75.0% acceptance) was higher than that of the 6 sec condition (29.2% acceptance) [$t(118)=-6.94$, $p<0.01$] (Fig. 2a). This suggests that there is an effect of time length on the decision result.

The second notable outcome was the difference in the decision result for different time lengths when the proposer was a PC. In the case of the "fair*PC", there was no significant difference in the acceptance rate for different time lengths. In the case of the "unfair*PC," the acceptance rate in the 18 sec condition (85.0% acceptance) was higher than that of the 6 sec condition (70.8% acceptance) [t(118) = -2.26, p<0.05] (Fig. 2b). However, the difference was not as large as when the proposer was believed to be a person. This also suggests an effect of time length on the decision result.

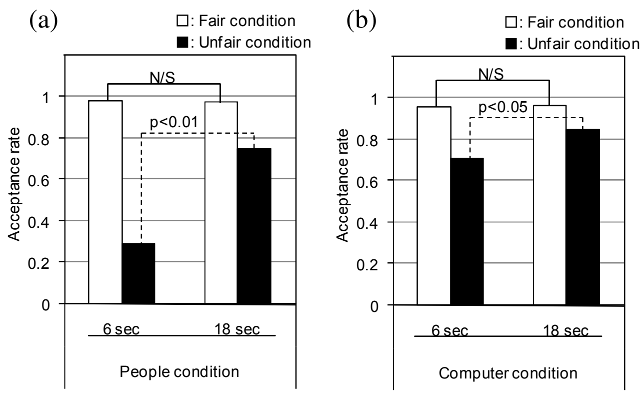

Fig. 2 Comparison of acceptance rates in (a) person proposer conditions and (b) computer proposer conditions. Longer decision time lengths result in significantly higher acceptance rates in the unfair condition in both proposer conditions.

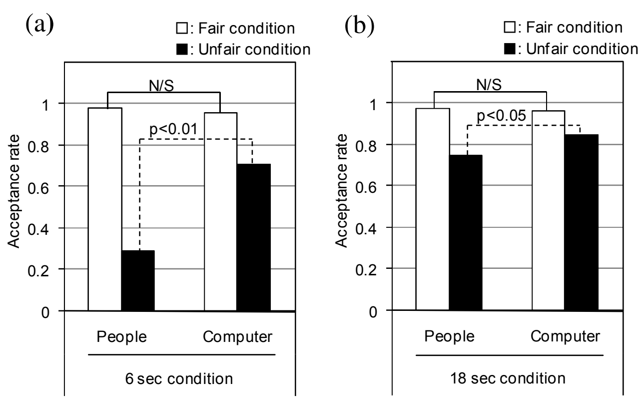

Fig. 3 Comparison of acceptance rates by proposer type. A computer proposer results in a significantly higher acceptance rate than a person in the unfair condition in both (a) 6 sec conditions and (b) 18 sec conditions.

The third notable outcome was the difference in the decision result for different proposers when the offer was unfair. In the "unfair*6 sec" condition, the acceptance rate for a PC proposer (70.8% acceptance) was significantly higher than for a person (29.2% acceptance) [t(118)=-6.67, p<0.01] (Fig. 3a). In the "unfair*18 sec" condition, the acceptance rate for a PC proposer (85.0% acceptance) was significantly higher than for a person (75.0% acceptance) [t(118)=2.52, p<0.05] (Fig. 3b), although the difference was not as large as for the 6 sec condition.

IV. DISCUSSION

Our experiment was conducted on 60 people as a completely randomized two-level, three-factor design. The 3 factors were fairness, time length and proposer. The eight combinations of factors were presented twice to every subject.

As mentioned in the Results section above, in the "unfair*6 sec" condition, the acceptance rate for a proposer believed to be a PC was significantly higher than for a person. This result suggests that the more emotionally a subject decides, the lower the acceptance rate. This result of a PC proposer facilitating a higher acceptance rate is consistent with the results of previous research by Sanfey et al.[8], and indicates that the experiment was sufficiently reproducible.

In the "unfair*person" scenario, the acceptance rate in the 18 sec condition was significantly higher than that in the 6 sec condition, indicating that subjects decided in a comparatively more economically reasonable manner despite knowing that the offer was unfair.

In the instances where the proposer was a PC, the difference in the acceptance rates between the fair and unfair offers in the 18 sec condition was smaller than that in the 6 sec condition. However, these differences in acceptance rates in the PC condition were smaller than those in the person condition. An interpretation of this is that the more emotionally the subject decides, the lower the acceptance rate of unfair offers.

We conducted this study to investigate the relationship between emotion-related decision making and the decision time length. We found that the shorter time length (6 sec) condition led to a more irrational decision compared to decisions made in the longer time length (18 sec) condition. This result suggests that the longer time period weakens the emotional factor of the decision-making process. Thus, we verified our hypothesis that the length of time taken to make a decision affects the result of that decision in an ultimatum game.

Sanfey et al.[8] investigated the brain activity of the responder in the ultimatum game with functional MRI. This study found that the insula of the recipient was activated in the unfair proposal condition; the insula is active in processing negative emotions such as anger or antipathy. In addition, the prefrontal cortex (PFC) and dorso-lateral prefrontal cortex (DLPFC) were also found to be activated at the same time. The PFC is active in commanding high dimensional level activity; the DLPFC is related to rational decision making for achieving a target and is assumed to be activated by the task of grasping the situation regarding the amount of money in the game. These researchers also investigated the conflict caused by the activation of these areas to determine whether anger (represented in the activity of insula) overcomes the orientation to an objective (represented in the activity of the PFC). When a subject rejects an unfair offer, insula activates more strongly than the PFC. On the other hand, when the subject accepts an unfair offer, the PFC activates more strongly than insula. And when there is conflict in the subject's mind, the anterior cingulate cortex (ACC) is activated; the ACC is active in the identification of conflict.

Based on these results, the researchers concluded that the subjects decide by weighing economic rationality against emotion.

In the study referenced above, both the insula and the PFC were activated in a 6 sec condition. They believed that both the emotional aspect and the rational aspect were at work in that condition. We believe that the same conflict also occurred in our experiment, but was caused by the difference in time given to make a decision. When the time for decision making increased from 6 sec to 18 sec, the acceptance rate also increased. It is likely that this economically reasonable decision reflects the fact that activation of the PFC surpassed that of the insula over time.

Some pharmacology studies have been also conducted in ultimatum game. Crockett et al.[22] had their eyes on serotonin that is related to impulsive self-control in social behavior. Subjects conducted the game twice. The second trial was conducted after more than 1 week of the first trial. Subjects were assigned to one of two groups – one was placebo group and another was acute tryptophan depletion (ATD) group. ATD made amount of serotonin less. Comparison between placebo treatment and ATD clarified that reject rate in ATD treatment was statistically larger than that in placebo, in the case of unfair condition. Gospic et al.[23] clarified that Benzodiazepine treatment decreased the rejection rate (from 37.6% to 19.0%) concomitantly with a diminished amygdala response to unfair proposals, and this in spite of an unchanged feeling of unfairness and unchanged insular response. In the control group, rejection was directly linked to an increase in amygdala activity. These results allow a functional anatomical detection of the early neural components of rejection associated with the initial reactive emotional response. Thus, the act of immediate rejection seems to be mediated by the limbic system and is not solely driven by cortical processes.

As mentioned earlier, clarification of the mechanism of activation change in the brain in the 18 sec scenario remains a problem. Further study is expected to clarify whether the change to an economically rational decision reflects an increase in the strength of the activation of the PFC or a weakening of the emotional effects of activity in the insula or amygdala. Perhaps, the shift is due to the release of the anchoring bias as attention travels between these areas. And there is room to study relationship between their activations and pharmacological treatments. We believe observing the brain activity during decision making will clarify the neuro-system that is related to the decision-making process. We also believe result in our study can be applicable for development of decision support system in medical ICT field, such as medical decision making systems[24~25] that currently exist, telemedicine system[26] and so on.

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