Additional information increases uncertainty in the securities market - using both laboratory and fMRI experiments

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ABSTRACT

The paper shows that in double auction markets with uneven information distribution that is common knowledge, returns are a J-shaped function of the information known by different investors. Huber proposed the trend reversal of future earnings flow as the reason of J-shaped function. But our paper asserts the psychological state of investor as the reason. Functional magnetic resonance imaging (fMRI) scans of subjects in a simple game which extracts the essence of double auction markets with uneven information distribution indicate that subjects with medium amounts of information use different brain areas engendering different psychological states. The paper argues that these patterns are consistent with medium-informed investors using a matching strategy rather than the maximizing strategy of the least and best informed investors. The paper motivates an accounting connection by remarking that financial statement disclosure is mandated in most developed stock markets.

Key Words: Efficient market hypothesis, Laboratory market, fMRI experiment, Psychology bias, Matching Law

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I. Introduction

Providing investors with a significant amount of securities investment-related information in the form of accounting data—which represent public information by nature —is a basic securities market policy tool employed in developed economies. Its aim is to make securities investment-related information common knowledge among investors in order to ensure transparency and fairness in the market. Needless to say, the macroeconomic objective of this measure is to lure investors' savings into the securities market to finance private sector investment in the form of direct finance. From a microeconomic perspective, it is aimed at supporting utility maximization behavior among investors in the securities market, because investors will use the information they acquire to make appropriate and timely estimates and engage in securities investment to earn a profit, thereby maximizing the utilities derived from current-period consumption and future consumption.

The Efficient Market Hypothesis (hereinafter referred to as the "EMH") is well known as a theory that supports government public policy for the securities market which aims to achieves above-mentioned micro- and macro- economic purposes. Especially the semi-strong form of EMH is important for government's financial reporting policy. First formulated by J.F. Muth [1961] and P. Samuelson [1965] during the 1960s, the EMH was applied to some economics topics by R.E. Lucas and T.J. Sargent [1981] and to finance research in the 1970s by Eugene F. Fama [1970][1]. Initial research findings showed

[1] The rational expectations hypothesis has been called as the " efficient markets hypothesis

favorable empirical corroboration of the EMH. In particular the semi-strong form of EMH was supported by many accounting researchers. Such initial research trend and result supported that EMH especially the semi-strong form of EMH became the foundation of government accounting policy. However, the late 1970s to the 1980s saw experimental studies being used to verify the EMH (see Plott and Sunder 1982,1988), and the results of empirical studies questioning the validity of the EMH were published[2], leading to widespread debate on the pros and cons of the theory. During the 1990s, more studies questioned the validity of the EMH in both the experimental and empirical fields[3]. Moreover, the results of psychology investigations negatively affected the process of verifying the EMH (see Hirshleife 2001). The existence of cognitive bias in securities markets was pointed out, and findings cast doubt on the EMH. In an experimental paper, it is pointed out that "the market pricing process could be strongly affected by information held by many participants, and such distortion will be even more significant if such information is favorable (good news). However, if the widely shared information is unfavorable (bad news), the adjustment speed is not as fast" (see Yamaji and Gotoh, 2010).[4]

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and used quite extensively in financial market research (see Sheffrin, p.112).

[2] On the information efficiency of securities markets, questions have also been raised due to the existence of anomalies using empirical analysis. See Ball 1978, Ou and Penman 1989, Fama and French 1993.

[3] Please refer to the following studies from the field of experimental accounting: Lundholm 1991, Bloomfield and Libby 1996.

[4] Assuming a market which does not incorporate the future expectations, etc., of market participants – which is less likely to be influenced by psychological bias – it is clear that the

Bringing together results on validation of the EMH obtained through studies conducted in the 1980s and the questions raised about the EMH by the results of psychology studies and our experiments, one possible interpretation is that pricing phenomena in the securities market that demonstrate the informational efficiency of the market according to the EMH should be considered specific cases that only appear in markets with a special information holding structure and rationally behaving market participants. In reality, investors are capable of making decisions with a wider range of characteristics, underlining the need to recognize this possibility through experimental and empirical studies. Some recent studies have referred to one such class of investment decision making with a wider range of characteristics as the psychological class. In the field of behavioral economics or behavioral finance, efforts have been made to explain investment activities and market pricing phenomena that appear irrational under the existing economics framework with the assistance of results from psychology research[5].

Research in this area has become more complex. Neuro-economics and neuroscience have also affected research on the decision-making processes of human beings. In particular, the technology of functional magnetic resonance imaging (later referred to as fMRI) can gradually clarify which parts of the brain are activated during economic decision making (see Glimcher et al. 2009).

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market pricing mechanism is significantly robust and is likely to see through misleading information in a timely manner (see also Yamaji and Gotoh 2010).

[5] Hirshleifer (2001) uses the term “irrational” is used from the viewpoint of constructivist rationality referred by Smith (2008).

Our paper aims to distinguish between specific cases that appear as informationally efficient only in markets with a special information holding structure and specific cases that appear as informationally inefficient in markets with a special information holding structure. Specifically the paper builds on past research and, using findings from laboratory and fMRI experiments, points out the possibility that depending on the level of information investors acquire in the securities market, they may not buy and sell securities based on a generally consistent and rational decision-making model, but may modify their decision-making rules in certain circumstances according to psychological factors and trade securities based on such rules.

II. Development of Hypotheses

As can be seen from the discussion so far, we pay much attention to a series of studies that aimed to clarify irrational investor behavior in securities markets, and subsequently start by questioning and localizing the efficient market hypothesis, the theoretical pivot of finance research until today. We also try to develop research aiming to clarify the psychological aspects of investor behavior. Through public policy including government's financial reporting policy, an increasing volume of information has been provided to investors. However, questions have consistently been asked as to whether such information has always been beneficial to investors (see Huber 2006, 2007, 2008a, 2008b). If we rely on the aforementioned EMH, the additional information provided to market participants is likely to lead to an incremental increase in the payoffs market participants receive from

trading. This view is also in line with conventional wisdom. Our laboratory experiment findings are used to re-examine this issue; that is, whether such phenomena can be verified, or whether different types of phenomena based on psychological irrationality in the decision-making processes of investors may be observed.

A naïve argument goes like this: any increase in information reduces uncertainty, thereby allowing for better prediction of investment opportunities, leading to increased gains. This explanation is not likely to conflict with the semi-strong form of the EMH. That is, the acquisition of new information does not allow the investor to achieve consistent excess returns. However, in the case where new information is continuously obtained without being disseminated to the market, the investor may realize a one-off excess return. Therefore, repetition of such behavior is likely to allow the investor to consistently earn high trading profits. Grossman and Stiglitz (1980) assert that under the strong form of the EMH, which presupposes that prices reflect all information, the investor cannot consistently earn a higher rate of return unless by sheer luck. We can therefore formulate two hypotheses regarding the level of information obtained and trading profit in the securities market. The first hypothesis assumes that there is no relationship between the level of information acquired and the return achieved, and relies on the strong form of the efficient market hypothesis (EMH1). The second hypothesis assumes that having more information means earning a higher return, and relies on the semi-strong form of the efficient market hypothesis (EMH2).

On the other hand, based on the time preference approach suggested by Arrow (1971), it may be considered possible to avert risk in a world without any information through

portfolio choice behavior. In other words, an investor who has no information in the securities market do investment randomly and can earn the average market gain. Coupling this with the fact that insiders are in an advantageous position due to having more information and thereby earn an excess return under the semi-strong form of EMH, the real issue becomes the source of the excess return earned by those with insider information. By classifying the information holding structure of market participants into three categories, i.e., the best informed investors (including insiders), the medium informed investors, and investors with hardly any information, our conclusion is that the source of excess return gained by the best informed investors is the medium informed investors. of course the issue becomes serious when trades in securities market are a kind of zero-sum game structure. As we shall see below, the issue keeps being important even in non zero-sum game structure of market trading.

The reasons securities investment trading occurs in such unequal information holding circumstances are a topic with a long research history. Those without information will not take part in the trading game, and will continue their portfolio/uninformed investment behavior. At the same time, if the best informed investors and the medium informed investors engage in a buy-sell game, the former beat the latter due to their informational advantage. That is, the reason the medium informed investors want to trade with the best informed investors under this structure is that the medium informed investors believe they can obtain a kind of insider information through their trading with the best informed investors and can use it to gain an extra return through their trading with the least informed investors. Kyle (1985), O'Hera (1995) and Spulber (1999) assume that the medium

informed investors try to play a role as financial mediators in the securities markets. It is possible that the medium informed investors cannot earn high returns because they must take many more factors surrounding securities markets into consideration than the least informed investors to dominate trading between the two classes of informed investors. Such an inference leads to the fact that the relationship between the level of information acquired and the return earned will be represented by a J-shaped curve, as shown in Figure 1. It is quite possible to conceive of such a hypothesis.

In addition, if we rely on Simon (1957)'s bounded rationality hypothesis, having too much information may result in failure to process such information, leading to the possibility of an investor with excess information incurring a loss. This forms the basis of the V-shaped hypothesis, which suggests that there is no significant difference between the returns of the least informed investors and those of the best informed investors, rather than the latter gaining the highest return.

As described above, there is no unified/dominant theory on the nexus between the level of information obtained by investors and their returns in the securities market. Specifically, as clarified and experimentally proved by the series of studies conducted by Huber (2007) (2008a), the J-curve possibility is considered to have upgraded the complexity and gravity of this issue in the securities market.

Figure 1: Rate of return per information level based on different hypotheses

This paper is aimed at experimentally verifying the possibility that the provision of information to the securities market, which is the categorical imperative for accounting, may sometimes yield both the expected results and unexpectedly variable results in other circumstances depending upon information holding structure, as well as at reexamining the possibility raised by Huber. Building on past research (experiments), there are two issues to be addressed.

1) In an environment where investors' information levels increase incrementally, it is not possible to verify which of the above hypotheses is dominant without conducting an experiment under more sophisticated conditions. In order to show this is true, we conducted an additional informational experiment. The results of the laboratory experiment would statistically verify (or otherwise) two null hypotheses:

Null hypothesis 1) There is no relationship between the level of information acquired and the return achieved (EMH1);

Null hypothesis 2) Having more information means earning a higher return (EMH2).

2) If the results of the laboratory experiment showed it was possible for each investor's return structure to be J-shaped, V-shaped, or at least different from that envisioned by the EMH, under circumstances where an investor's information increases incrementally, we would then conduct a neuro-scientific experiment on the brain using fMRI (functional magnetic resonance imaging) to supplement the earlier laboratory experiment results and interpret the findings from a different perspective.

Null hypothesis 3) There is no difference between activated parts of the brain under different information holding structures.

The rest of the paper is organized as follows. Section III presents the design of our laboratory experiment, in which we change some experimental conditions adopted in that of Huber (2007, 2008), together with the results. Section IV outlines the design of the fMRI experiment and examines the implications of the results. The fifth section offers a concluding synopsis.

III. Laboratory Experiment - Design and Results

This section is aimed at verifying the J-curve effect by analyzing a repeat of Huber's laboratory experiment under an environment featuring incremental increases in investors' information levels, but with some different conditions.

Laboratory investment experiment

Six subjects were each assigned a different level of information to be used as a basis for buying and selling stock in a fictitious computer LAN-based market via a double auction[6]. First, the setup of the market in which the experiment was conducted is explained in 1). The information provided to the subjects is then described in 2), and the real monetary remuneration the subjects received for their work is discussed in 3). Finally, the details of the subjects are shown in 4).

[6] The rationale behind choosing six subjects was to clarify that the objective of the experiment was to explore the relationship between the information level and the return achieved as a result of decisions made. It is desirable to have more than five participants, but the number of participants need not necessarily be limited to six.

The Market

Each of the six subjects individually bought and sold a single stock based on the level of information received. The market price was determined by the six subjects only through this information. The subjects were basically free to make an offer to the market at any price. That is, their trades were executed through limit orders, and neither stop orders nor market orders were allowed. Short selling was not allowed either.

The duration of each trading period was one minute. At the end of each period, new information was provided, and the next one minute round began. Each trade experiment consisting of 15 to 25 consecutive periods was called one experiment treatment. The subjects were not informed in advance of the number of trading periods within a single treatment, but the treatment was terminated after 15 to 25 rounds. Subjects were not told the duration of each trading period before the experiment. Sixteen treatments were conducted.

Information

The six subjects received information on current and future dividends. However, each subject was assigned a different level of information, that is, the number of future periods for which information was disclosed was different for each subject. One subject knew only the current dividend; the second subject knew the dividend for the current period and the next period, and so on. The best informed subject knew the current dividend and five future dividends. It should be noted that although all the subjects were informed that their information had been differentiated into six patterns (this was common knowledge), they

were not aware of the level of information held by the other participants, that is, who had information up to which period.

At the end of a round, the information provided to each subject was adjusted by one period. The subject who originally knew the current dividend and five future dividends now possessed dividend information for four future periods, and he/she received new dividend information for the fifth period in the future which was not yet known to the market. The same went for all participants, from the investor who only knew the dividend for the current period to the subject who knew the dividends for four periods. **Extra-Figure 1** depicts an example of the subject provided with information for three periods.

Basically, four trends were used for the dividend information: an increasing trend, a decreasing trend, a regularly cyclical trend, and a random trend. The most important difference between Huber's experiment and our experiment is the trend pattern of provided information. Huber pointed that the cause of lowest performance of the middle informed investors was the trend reversal of provided dividend information (Huber 2007, p.2550). So we did not include the intentional trend reversal pattern of dividend information in provided information patterns. Moreover the trend of the dividend information for each experiment treatment was randomly determined. Each subject randomly took turns as each of the four types of information holders during the four experiment treatments. Four kinds of dividend information trends were used four times, resulting in 16 experiment treatments being conducted.

Remuneration

Each subject was endowed with 1,600 Francs[7] and 40 shares of stock before the beginning of each period. At the end of each one minute period, interest was paid at the rate of 5% for cash holdings, and dividends were paid for stock held according to the dividend information provided. For example, if the dividend information provided for the current period was seven Francs per stock, the subject earned 360 Francs without participating in the market, that is, the sum of 280 Francs (40 shares of stock times seven Francs) in dividends and 80 Francs in interest (US$1600 × 0.05). Therefore, the subjects aimed to earn higher trading returns by participating in the market and intelligently trading stock. The interest rate over the course of each experiment treatment was set below the dividend rate.

The return to each subject for each experiment treatment was determined by the sum of the returns from trading, dividends paid and interest earned. As the value of stock trading was valued in Francs, the trading return was denominated in Francs. The remuneration paid to the subject at the end of the experiment was paid in Yen by applying an appropriate Franc to Yen exchange rate (γ) for each subject. In playing the game, each subject (investor) was assumed to maximize his/her remuneration for each experiment treatment as expressed in the following formula.

$$R_i = \gamma \ (\Sigma \ d \ x_i + \Sigma \ r \ C_i + \Sigma \ P_s - \Sigma \ P_p) \qquad (1)$$

R_i : remuneration of investor i;

γ : Franc to Yen exchange rate;

r : interest rate;

[7] We used "Francs" as the money unit for the game instead of "Yen," the use of which is so widespread that it would enable subjects to imagine the real world.

d : dividend rate;

x_i : number of shares of stock held by investor i at the end of each round;

P_s : revenue from selling stock;

P_p : expenditure for buying stock;

C_i : amount of cash held by investor i at the end of each round.

The subjects were undergraduate students from Ryukyu University, Doshisha University and Kyoto University which were located in Japan. The experiment was conducted at Ryukyu University in July 2009. The instructions given to the laboratory experiment subjects are set out in **Appendix 1**.

Laboratory experiment results

The results of the laboratory experiment are as follows.

Table 1 reports the results of the 16 experiment treatments, in which the subjects were rotated so they all experienced each information level at random. The six subjects' return distribution is clustered into three groups. The least informed group consisted of subjects with one or two pieces of dividend information. The medium informed group comprised those with three or four pieces of dividend information. Those with five or six pieces of dividend information were in the best informed group.

Table 1 The Relationship between the Quantity of Information and Profit Ranking

Because our experiment did not unify the expected return of each experiment treatment, we did not employ the real return data in Francs to avoid overestimating the income of subjects who achieved high returns by chance in experiment treatments with a higher dividend trend. We therefore used the normalized data to verify the first two null hypotheses listed at the end of Section II. In Table 2, we report the results of statistical tests conducted by adopting analysis of variance and t tests of three normalized averages of returns adjusted by the Bonferroni method.

Table 2 the Results of Statistical Tests

By relaxing the level of statistical significance, we can say that the return gained by the medium informed investors is lower than that gained by the other classes of investors. Moreover, there is no significant difference between the returns of the least informed investors and those of the best informed investors. The relationship between the level of information obtained and the return earned will therefore be represented not by a J-shaped curve, but by the V-shaped curve shown in Figure 1.

The results of our experiment indicate the following:

1) The relationship between the information level and profit is not reflected in the simple increasing function assumed by the efficient market hypothesis. Investors with a low level of information gain a relatively high return, medium level investors gain less, but beyond a certain point, the return becomes higher as the information level increases;

2) Note that this is not the case where there is no relationship between the level of information and the return. Statistically, the return of the medium informed investors is significantly lower than that of investors with different levels of information;

3) On the other hand, there is no statistically significant difference between the return of the least informed and that of the best informed.

Based on the results of 1), 2) and 3), we can reject null hypotheses 1) and 2) listed in Section II.

4) Furthermore, an interesting finding of our experiment relates to the number of transactions executed by subjects in the least informed, medium informed and best informed categories. As Figure 2 shows, the number of transactions executed by the medium informed group throughout the experiment treatments is significantly higher. This finding is not similar to that reached in previous studies (Huber (2007), p.2553, Huber (2008), p.101), and is an important outcome which requires careful interpretation.

Figure 2 Relative Frequency of Number of Trading According to Information Level

Interpretation of laboratory experiment results

Let us confirm the factual findings of our laboratory experiment.

1) On the one hand, the results exhibited a relationship whereby the return of the medium informed was significantly lower than that inferred by the relationship between the level of information and the return in the efficient market hypothesis;

2) On the other hand, there was no statistically significant difference between the return of the least informed and that of the best informed;
3) The return of the best informed was significantly lower than the return theoretically expected;
4) The medium informed engaged in a significantly higher number of trades compared to those in the other information levels.

The implications of these findings are as follows. When the level of information provided to investors continuously increases, it is normally assumed that the degree of risk or uncertainty gradually declines and that the return gained increases. However, the experimental results indicate that as an investor receives sufficient information to become a member of the medium informed group, he/she is suddenly thrust into an environment featuring a different kind of risk or uncertainty, and therefore needs to engage in securities transactions under a new decision-making principle. Therefore, in a V-shaped return-information level relationship, the behavior of the medium informed does not fit the decision-making pattern envisioned in current economic and finance theory whereby decisions are made based on a single decision-making (expected utility maximization) function, adding the probability of the state of nature for continuous decision making. On the contrary, it is possible that the medium informed make specific decisions in a specific psychological environment. We can say so because we omitted the trend reversal pattern of dividend information in our experiment, contrary to Huber's experiment.

In addition, the fact that the return of the best informed is significantly lower than expected is a sign that the best informed too often encounter difficulties raised by bounded

rationality to make rational decisions. The least informed diligently continue making rational decisions in securities markets so they can earn an average return.

In order to examine these conjectures concerning the effect of investor's psychological environment on the relationship between the level of information and the return, we conduct an fMRI experiment and report the results in the next section.

IV. fMRI Experiment

Significance of fMRI Experiment

Next, we conduct a simplified version of the abovementioned laboratory experiment using fMRI in order to provide corroborative evidence of our hypothesis that the major factors contributing to the V-shaped return-information level relationship are the specific psychological condition of the medium informed investors and the decision-making rule they follow. The essence of experiment depicted in the previous section is naturally followed by the fMRI experiment described in this section.

First, the procedure followed in the experiment is described in detail. The purpose of the fMRI experiment is to provide supplementary support for the results of the laboratory experiment, showing that because each investor with each level of information faces a particular psychological condition, he/she sometimes makes a rational decision, but makes an irrational one in other cases. We trace the parts of the investor's brain activated when he/she makes a decision with a particular level of information.

Section II describes null hypothesis 3) to be verified using the fMRI experiment. If this null hypothesis is rejected, the alternative hypotheses would be summarized as follows:

1) The best informed investors can make their own rational decisions without regard to the behavior of others;

2) The medium informed investors must pay attention to decision making among the best informed investors. This means that they must distinguish between the bids and asks of the best informed investors and those of the least informed investors in the auction market and utilize the investment behavior of the best informed;

3) Because the least informed investors can refer to all the information provided by other participants in the auction market, consisting of investors with a higher level of information than their own, they do not encounter the additional task the medium informed investors must have.

We should find brain data verifying three alternative hypotheses. In particular alternative hypothesis 2) should be best discussed in detail.

The concept underlying this experiment is that when a medium informed investor engages in a trade, the investor cannot distinguish whether the bid-ask information he/she is given has been provided by an investor who has a higher level of information (the best informed) or by an investor with a lower level of information (the least informed). This is why in the previous experiment we observed the phenomenon whereby the medium informed, when faced with such investment timing, experienced psychological confusion, engaged in investment behavior that differed from that expected by conventional economics, and suffered from a low level of return.

Specifically, the uncertainty relating to the bid-ask spread faced by the medium informed in the laboratory experiment described above is a specific type of uncertainty which is not explained in ordinary economic theory. Generally speaking, conventional economics and finance theory holds that an increase in the information level continually reduces the risk associated with the investment environment, and leads to the continuation of future securities trading. In such a case, the decision-making structure may be expressed by a single expected utility maximization function. Conversely, in our view, the medium informed possess a non-continuous risk assessment or recognize a new uncertainty, forcing them to adopt a non-continuous decision-making approach different from that employed by those in the least informed or best informed group. The specific decision-making model adopted by the medium informed will be tentatively presented in a later section.

We first analyze brain activity patterns in specific parts of the brain among investors with different levels of information in order to provide additional evidence that they are forced to resort to a specific decision-making approach. The following experiment is conducted by using fMRI in order to replicate the essence of the situation faced by the least informed, medium informed and best informed investors in securities market experiment.

Description of fMRI Experiment

We provide the visual stimulation depicted in Figure 3 to the fMRI subject[8].The subject who enters the fMRI scanner engages in a game of guessing whether or not the average of the values displayed on the screen is larger than five. (For more details, please see

[8] Please refer to Appendix 2 for details on the stimulation image.

Appendix 2.) Each value displayed on the screen is a single-digit number chosen from six values. One, three or five of these values are displayed on the screen at a time, and each participant assumes what the remaining values are to judge whether or not the average of the values displayed on the screen is larger than five. The game is played by three participants, so the fMRI subject is joined by two others. Each subject is assigned either one, three or five values, and these numbers are displayed. Based on the displayed numbers, the participants are asked to assess whether or not the average of the original set of six numbers is higher than five. The numbers in the set of six values are chosen so that the average is not exactly five. A return is paid according to the number of correct answers[9]. Each subject can see whether or not the assessment was correct through the screen display, with the cumulative number of correct answers shown in the bottom right-hand corner.

Figure 3: Concept of fMRI Experiment

In addition, the three participants can see the assessment results of the two other participants, that is, higher than five (H) or lower (L) than five, using a T account. If a dark square (■) appears on the left-hand (debit) side with the heading 'H', it means someone assumed the average was higher than five. If it appears on the right-hand (credit) side, it means someone assumed the average was lower than five. It should be noted that while

[9] In this section concerning the fMRI experiment, we do not discuss the returns of investors because the returns of differently informed subjects are not interlocked with each other in a market. Our fMRI experiment is exclusively aimed at reproducing the psychological conditions of differently informed investors in simulated laboratory markets.

each subject receives the assessment result by way of information, he/she cannot link the assessment with the participant. That is, the subject cannot tell which of the other two participants made the assessment.

Needless to say, the subject who receives five values represents the best informed investors, the subject receiving three values represents the medium informed investors, and the subject receiving one value represents the least informed investors. The subject who receives five values can make a judgment (make a decision) without any reference to the assessments of the other two subjects because he/she is the best informed investor. However, he/she is forced to calculate the average quickly and promptly respond to the guessing game.

We presume that the case reflecting the specific phenomenon experienced by the medium informed investor in the previous laboratory experiment is translated to the case where the subject who receives three values learns that the assessments of the two other participants are split between High and Low. Specifically, we envisage a situation where the subject receives the information depicted in the top left-hand corner of Figure 3. We expect that a subject encountering such a situation in the fMRI scanner results in specific parts of the brain being activated.

The subject receiving one value representing the least informed investors can keep making normal and rational decisions without any psychological dilemma.

The process for each game is as follows: the value information is displayed first (T = 0), then from two seconds (T = 2) later, the information on the other participants' assessments is shown until four seconds (T = 4), followed shortly afterwards by the fMRI subject

thinking before making the HL assessment. The fMRI subject makes a decision by pushing one of the two buttons with his/her finger. Immediately after the fMRI subject makes a decision (i.e. when he/she pushes the button), the next game starts[10].

We expect that specific areas of the brain are activated for subjects in which activities are not visible under other circumstances. If these areas can be found, and if past studies show that these areas are involved in making specific decisions, it will represent evidence corroborating the existence of the specific environment, and thus the specific decision-making circumstances, faced by different kinds of informed investors in the securities market.

We now continue describing the fMRI experiment. Earlier, we explained a game that takes only a few seconds per round in which participants guess the average of some values. In practice, 36 guessing games on average are played in one experiment treatment. This means that each subject experiences each of the following six situations six times.

S1) He/she is less informed, with the remaining two in agreement;

S2) He/she is less informed, with the remaining two split;

S3) He/she is medium informed, with the remaining two in agreement;

S4) He/she is medium informed, with the remaining two split;

S5) He/she is best informed, with the remaining two in agreement;

S6) He/she is best informed, with the remaining two split.

[10] The description uses the term “three subjects”. In the actual experiment, the two subjects other than the fMRI subject are not real people, but are substituted by subjects from a sample extracted from records of past games. Therefore, the fMRI subject actually plays games with virtual subjects on a PC.

We conduct six experiment treatments over approximately 45 minutes when the subject plays the fMRI game. Therefore, six types of games are played 36 times, for a total of 216 rounds. During the first three experiment treatments, the games based on the above six situations appear randomly during one experiment treatment to give the subjects six assessments each. In the last three experiment treatments, the six situations appear in the above order in six rotations.

Needless to say, the brain activation image of the subject playing the game is captured with fMRI to provide data for analysis.

Figure 4. The Elapsed Time, fMRI Imaging of fMRI, Pictures Watched by Subjects and Onset

We now describe the details of the fMRI brain imaging conditions using Figure 4. fMRI scans of the brain are taken every three seconds to produce the 3D image of the brain. In the case of our average-guessing game, it takes an average of around eight seconds to play one round. Therefore, it takes approximately five minutes to complete 36 games comprising one treatment. Since one set of brain images is produced every three seconds, approximately 100 sets of images will be created for every experiment treatment, and approximately 600 sets of images for six experiment treatments. Not all of them will be used, and only those taken at an appropriate time (onset time) will be utilized. Onset time is set at just after four seconds from the time the game starts.

In order to synchronize the images and numerical stimulations shown to the subject, we use the PC software "Presentation"[11] to display the values and visual stimulations on the reflective screen inside the fMRI scanner. First, the numerical information appears on the screen, and two seconds later, the HL assessment information of the other participants is displayed for two seconds. The assessment period for the subject starts from the fourth second (shown as α and β in Figure 4). The "onset", the starting point for the collection of images, is inserted at the point in time when the assessment information of the two other subjects appears on the screen in full. In other words, the onset is inserted at the point when the subject makes his/her own HL decision. This onset time is used as the starting point, and "Image created at the appropriate time" refers to the fMRI image generated at the point closest to a certain number of seconds after the information appears in full, and is recognized as the brain response of the decision made (H or L) at that point[12].

In addition, the selected images are fed into SPM 8[13], software for analyzing fMRI images, and following statistical processing, the areas which were active in a statistically significant manner are specified by the 3D coordinates in the assigned 3D brain map.

[11] Software from Neurobehavioral Systems, Inc.

[12] There is a tendency to consider the time the button is pushed as the time the decision is made. However, we recognize the time lag between the decision being made and the button being pushed, so our onset time setting enables us to collect fMRI data within a certain time span.

[13] Software developed by Statistical Parametric Mapping.

The same fMRI experiment is implemented for 21 subjects. The results for 16 of these are used for the analysis, as the data for five subjects show anomalies and are therefore discarded.

Results of fMRI Experiment

We examine the brain responses of the 16 subjects using the cases described above. Because the case "4) medium informed investor with the other two participants split" is, of course, the most important for our analysis, we first show the results of the S4 case. The S5 and S6 cases will be shown subsequently. We do not report the results of S1 and S2, but we mention these cases in the text. We employ the image results presented by SPM8. The statistically recognized parts activated with appropriate masking satisfy the 0.001 significance level for the brain voxel and the 0.05 significance level for clustering.

The analysis of case S4 is conducted as follows: the parts of the brain activated among the medium informed should be analyzed when they encounter the situation in which the decisions of the two other subjects are split. We therefore produce a manipulated image (S4-S3), because the uniqueness of the situation involving the medium informed with a split decision between the two other subjects is accentuated by deducting the parts activated in S3 from those activated in S4. As we have already explained, S3 is the image data on brain parts activated in a medium informed investor when he/she faces a unanimous decision by the two other subjects. Of course, the manipulated image (S4-S3) is masked with S3 at 0.05 because we must delete the effect of significantly unactivated parts of S3. The results of SPM8 over the case (S4-S3) are shown in Figure 5.

Figure 5: Active Areas of the Brain in Case (S4-S3)

The significantly activated areas of the brain in the above image can be described as follows: visual cortex (V1, V2, V3, V4), anterior cingulate cortex (ACC), middle frontal gyrus (MFG), inferior frontal gyrus (IFG), anterior insula (AI), temporo-parietal junction (TPJ), operculum (OP), intraparietal sulcus (IPS). Judging from the data, null hypothesis 3) described in Section II is rejected. We can therefore say that the uniqueness of the brain parts activated in a medium informed investor with a split decision between other investors can be recognized at a statistically significant level.

As the next step, we show the results of cases S5 and S6 in Figure 6. These cases are for the best informed subject. We produce a manipulated image (S5+S6) - (S1+S2) with masking (S1+S2) at 0.05 to depict the uniqueness of the activated brain parts of the best informed subject. This analysis also enables us to recognize which areas of the brain of the best informed subject are uniquely activated in comparison with the least informed subject.

Figure 6: Active Areas of the Brain in Case ((S5+S6) - (S1+S2))

Finally, we produce another manipulated image (S1+S2) - (S5+S6) with masking (S5+S6) at 0.05 to depict the uniqueness of the brain parts activated in the least informed subject, but we cannot find any unique area of the brain.

Figure 7 summarizes the analytical results produced to verify the psychological hypotheses listed in the top of this section.

Figure 7 Brain Mechanism of Investment Decision Making in Economic and Social Situations (T=4)

The left-hand side of Figure 7 indicates the interpretation of special psychological aspects of the medium informed investor's decision making with a split decision between the two other investors. First, the full information received by the medium informed investor stimulates his visual cortex (VC), and he/she watches the situation where he/she has three values and the two other investors made a split decision. This stimulation is conveyed to two areas of the brain. One area is used for social processing of information, and the other area is used for economic and rational processing of information. According to the previous research (see Yamazaki [2002], Herwig et al [2007]), the right and left inferior front gyrus (IFG) are activated to facilitate the emotional evaluation of his/her own information and induce anxiety over future possibilities. Further activation of the middle frontal gyrus (MFG) is a sign of a reaction to uncertainty accruing from this additional knowledge, and activation of the anterior insula (AI) raises the level of discomfort (such as anxiety and feelings of anxiousness) arising from this uncertainty (see Kirsten et al. [2005]). Based on activation of the intraparietal sulcus (IPS) and the temporo-parietal junction (TPJ), the subject socially recognizes the existence of surrounding others who are making different decisions (see Young et al. 2007, Camerer 2009,). Finally, the anterior cingulate

cortex (ACC) adjusts two kinds of results from two areas: one is the rational and emotional evaluation of the information the subject receives, and the other is recognition of the existence of others making different decisions. The subject can at last adjust his/her response to the dilemma between emotion and rationality, predict the future return and the others' decisions, and reach his/her own final decision (see Sanfey et al., 2003, Glimcher and Rustichini 2004,Brown and Braver, 2005).

On the other hand, the unique brain areas of the best informed could be identified without reference to the two other subjects. These are the visual cortex and the intraparietal sulcus (IPS). These areas can be recognized even after deducting all the brain areas activated in the least informed from all the brain areas activated in the best informed. There is no need to take the existence of the two other subjects into account, nor is there any anxiety over the best informed having five values. However, the best informed must feel pressured to take advantage of the large amount of information available to gain a higher return, though the least informed feels no such pressure. Excessive activation of the intraparietal sulcus (IPS) of the best informed therefore leads to his/her bounded rationality (see Kirsten et al. 2005).

The findings of the analysis of our fMRI experiment show that in a market with least informed and best informed investors, the medium informed investors develop an expectation of uncertainty or risk that is discontinuously different from the other two investors' expectations when the offers from the other investors are split (i.e. they offer different prices), resulting in a change in their decision-making principle. This leads to a reduced trading return for the medium informed investors.

The best informed investors feel pressure to dominate the market by taking advantage of the large amount of information they have, and cannot afford to earn a relatively low return. The least informed investors with the smallest areas of the brain activated continue to make simple investment decisions. This leads to them earning an average return.

Figure 8 summarizes the essence of the facts established by the fMRI experiment.

Figure 8 Changes in Return Structure

New Hypothesis on Investment Decision Making by Medium Informed Investors

This paper is aimed at developing a hypothetical decision-making rule for medium informed investors based on our laboratory and fMRI experimental results; the rule is literally a hypothesis. In conventional economics, investors engage in securities trading with the aim of maximizing their return. According to the efficient market hypothesis, information is instantaneously disseminated to investors who have not received it, and all investors end up possessing the same level of information. Under this premise, two cases are possible and are depicted in Figure 1 as EMH1 and EMH2. The difference between the two is whether it is possible to use the new information to earn an excess return that is not necessarily constant, even on only one occasion. However, it is not possible for medium informed investors to earn the lowest return under the EMH.

On the other hand, less informed investors who possess little or no information will make their decisions based on portfolio theory under a certain formulation, and as a result, will earn the average market return. Therefore, the game is actually played between

medium informed and best informed investors, leading to victory for the latter and resulting in the medium informed investors earning a below-market level return. The results of our fMRI experiment suggest a counterargument for this explanation. Our fMRI experiment resulted in a V-shaped rather than J-shaped return structure, indicating that only investors holding an medium level of information engage in trading based on a different decision-making rule. We should remember that our experiment in laboratory did not employ the trend reversal pattern of provided dividend information. So there must exist an another important reason why the medium informed investors suffer from relatively lower returns. The aim of this section is to formulate this specific trading rule as a hypothetical reason.

We assume that the well informed and the least informed engage in normal investment behavior, i.e., maximization of expected utility. Using the same behavior principle, the theoretical return structure will be the EMH1 or the EMH2, but the critical question is how to interpret the decision-making rule of the medium informed. Our assumption is that the medium informed investor makes decisions using the matching law. In other words, when executing auction trades, based on his/her information and the information the others possess, the medium informed is uncertain about whether bid and ask prices are issued by the least informed or by the best informed. This leads to the following assumptions. It is possible that the medium informed may act so he/she can earn a certain average return under two states of nature, that is, act according to the matching rule (see Sakai and Fukai 2008). The fact that the medium informed makes investment decisions in accordance with the matching law leads to an increase in the number of his/her trades and a decrease in

his/her return. In psychology, the matching law states that the allocation rate of behavior is equal to the reinforcement rate (R.J.Herrnstein,1997). This is expressed by formula (2)

$$R_1/R_2=r_1/r_2 \quad (2)$$

where R_1: number of trades on the bid side;

R_2: number of trades on the ask side;

r_1: return on the bid side;

r_2: return on the ask side.

Finally, only when each subject has taken the role of the medium informed investor and has been faced with such an information holding structure is the specific area of the brain considered to have become active in order to change the decision-making rule.

V. Conclusion

In this paper, we first employ the results of a laboratory experiment to confirm that the dissemination of information, price fluctuations and the distribution of returns in the securities market do not follow the patterns envisioned by the efficient market hypothesis. We suggest that the cause of this discrepancy is the possibility that in securities markets, an increase in the information level leads to an increase in uncertainty, thereby causing changes in decision-making rules followed for securities investment due to the maximization of expected utility under normal conditions, a normal phenomenon supported by economics. Of course, if the investor receives more additional information to become

the best informed, it is considered that he/she reverts to the rule of maximizing expected utility and engages in further securities transactions.

The results of the fMRI neuroscientific experiment provide evidence corroborating this hypothesis. The fMRI experiment, which operates under the same principle as the earlier laboratory experiment but is a simplified form of the same, inspires us with an understanding that in securities markets, uncertainty among medium informed investors increases, leading to activity in certain areas of the brain, which suggests the possibility that a particular decision-making rule different from that employed in other securities transactions is adopted.

We also suggest the hypothetical possibility that the medium informed investor may have adopted the matching law consisting of precepts different from the expected utility maximization rule envisioned by conventional economics. It is assumed that this law negatively affects the return gained by the medium informed investor.

Finally we should recommend that accounting policy regulators must pay attention to such effect of investors' psychological change over the informationally inefficient pricing of securities markets.

References

Arrow, J.K., 1971. *Essays in the Theory of Risk Bearing*, North-Holland Pu.co. Amsterdam.

Ball, R., 1978. Anomalies in relationships between securities' yields and yield-surrogates. *Journal of Financial Economics*, .6 (June-September): 103-126 .

Bloomfield, R. and R. Libby, R., 1996. Market reaction to differentially available information in laboratory. *Journal of Accounting Research*, 34 (Autumn):.183-207.

Brown, J.W., and T.S. Braver,2005. Learned Predictions of Error Likelihood in the Anterior Circulate Cortex, *Science*, 307, 1118-1121.

Camerer, C. F. 2009. Behavioral Game Theory and the Neural Basis of Strategic Choice. Chapter13, *Neuroeconomics: Decision making and the brain*, Eds. by P.W. Glimcher, C. F.Camerer, E.Fehr and R.A.Poldrack, Academic Press, London.

Fama, E.F. 1970. Efficient Market Hypothesis; A Review of Theory and Empirical Work. *Journal of Finance.* 25 (May): 383-417.

--------- and K.R.French. 1993. Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics.*33: 3-56.

Glimcher, P.W., C. F.Camerer, E.Fehr and R.A.Poldrack eds. 2009. *Neuroeconomics: Decision making and the brain*, Academic Press London.

Glimcher, P.W., and A.Rustichini. 2004. Neuroeconomics: The Consilience of Brain and Decision. *Science*, 306 (15 October): 447-452 .

Grossman, S.J. and J.E. Stiglitz. 1980. On the Impossibility of Informationally Efficient Markets. *The American Economic Review.* 70 (June): 393-408.

Herrnstein, R.J., 1997. *The Matching Law, Papers in Psychology and Economics*, Harverd University Press.

Herwig, U., T. Kaffenberger, T. Baumgartner and L.Jänckeb. 2007. Neural correlates of a 'pessimistic' attitude when anticipating events of unknown emotional valence. *NeuroImage* 34: 848–858.

Hirshleifer, D. 2001. Investor Psychology and Asset Pricing. *The Journal of Finance* 56 (August): 1533-1597.

Huber, J. 2007. J'-shaped returns to timing advantage in access to information-Experimental evidence and a tentative explanation. *Journal of Economic Dynamics & Control*..31 : 2536-2572.

Huber, J. M. Kirchler and M. Sutter. 2008a. Is more information always better ? Experimental financial markets with cumulative information. *Journal of Economic Behavior & Organization*, 65 : 86-104.

Huber, J. 2008b. J-shaped returns to timing advantage in access to information – Experimental evidence and a tentative explanation," *Working paper at Yale University*.

Kirsten G. V., I.Ricarda, D.Schubotz and Yves von Cramon. 2005. Variants of Uncertainty in Decision-Making and their Neural Correlates. *Brain Research Bulletin* 67 :403–412.

Kyle, A.S. 1985. Auctions and Insider Trading. *Econometrica.* 53 (November): 1315-1335.

Lucas, R.E., and T.J. Sargent, eds., 1981. *Rational Expectations and Econometric Practice.* The University of Minnesota Press, MN.

Lundholm, R.J. 1991. What affects the Efficiency of a Market ? Some Answers from the Laboratory. *The Accounting Review*. 66 (July): 486-515.

Muth, J.F. 1961. Rational Expectations and the Theory of Price Movements. *Econometrica,* 29 (July): 315-335.

O'Hara, M. 1995. *Market Microstructure Theory,* Blackwell Pu., MA.

Ou, J.A., and S.H.Penman. 1989. Financial Statement Analysis and the Prediction of Stock Returns. *Journal of Accounting and Economics.* 11 : 295-329.

Plott, C. R., and S. Sunder. 1982. Efficiency of Experimental Security markets with Insider Information: An Application of Rational-Expectations Models. *Journal of Political Economy*. 90 (August): 663-698 .

--------- and ---------. 1988. Rational Expectations and the Aggregation of Diverse Information in Laboratory Security Markets. *Econometrica*.56. (September): 1085-1118.

Sakai, Y.and T. Fukai, 2008. When Does Reward Maximization Lead to Matching Law ?. *PLoS One*, .3, (11) (November): 1-7.

Samuelson, P. 1965. Proof that Properly Anticipated Prices Fluctuate Randomly. *Industrial Management Review*, 6, (Spring): 41-49.

Sanfey, A. G., J.K. Rilling, J.A. Aaronson, L.E. Nystrom and Cohen, J. D. 2003. The Neural Basis of Economic Decision Making: An fMRI Investigation of the Ultimatum Game. *Science* **300** (5626): 1755-58.

Sheffrin, S.M., *Rational Expectations*, Cambridge University Press, New York, 1983.

Simon, H. 1957. Behavioral Model of Rational Choice," in *Models of Man, Social and Rational: Mathematical Essays on Rational Human Behavior in a Social Setting*. New York. Wiley.

Smith, V. 1976. Experimental Economics: Induced Value Theory. *The American Economic Review.* 66 (May): 274-279.

---------- 2008. *Rationality in Economics-Constructivist and Ecological Forms-*, Cambridge University Press. New York.

Spulber, D. F. 1999. *Market Microstructure; Intermediaries and the Theory of Firm*. Cambridge University Press. New York.

Yamaji, H., and M. Gotoh. 2010. Cognitive Bias in the Laboratory Security Marke. *Computational Economic*s. 35 (2): 101-126.

Yamasaki, H., K. S. LaBar, and G. MaCarthy 2002. Dissociable prefrontal brain

systems for attention and emotion. *PNAS* 99 (17): 11447-11451.

Young, L., F. Cushman, M. Hauser and R.Saxe. 2007. The neural basis of the interaction between theory of mind and moral judgment. *PANS.* 104 (20): 8235-8240.

Volz, K. G., I. Ricarda, D. Schubotz and Yves von Cramon. 2005. Variants of uncertainty in decision-making and their neural correlates. *Brain Research Bulletin* 67 : 403–412.

Appendix 1: Instructions for Laboratory Experiment Subjects

You will play one type of game with six investors (subjects) in which you buy and sell one stock.

1) The six investors each have a different information level: One trader knows the dividend for the current period; the second trader knows the dividend for the current period plus the dividend for the next period, and so on. The sixth trader knows the dividend for the current period plus the dividends for the five following periods shown in Extra-Figure 1.

2) Each investor is endowed with 40 securities and 1600 Francs at the beginning of the trading game.

3) The initial tentative price of the security is 100 Francs. A risk-free interest rate of 5% is paid for cash holdings in each period. Trading time per period is one minute. One experiment consists of 15 to 25 consecutive periods. The number of periods until termination is decided by the subjects.

4) A certain dividend stream will be used throughout each trading experiment treatment. Each investor has the possibility of experiencing the four types of information level during four trading experiment treatments. For every experiment treatment, the six investors are ranked according to their Franc-denominated returns. Using the Franc/Yen exchange rate, the return is converted into Yen for actual payment of the experiment return[14].

5) The image on the PC screen display seen by the investor (subject) during the game is shown in Extra-Figure 2.

[14] Based on the induced value theory by Smith (1971).

Suppose a subject has received dividend information for three periods by random choice; the PC screen displayed will look like Extra-Figure 2. The screen shows his/her dividend information for period X, i.e., the dividend for the current period, the next period, and the period after the next period. In the next period, period X+1, the information shifts by one period. What used to be the dividend for "the next period" now becomes that for the current period, that for "the period after the next period" becomes that for the following period, and new dividend information (7.0 Francs) appears on the screen as the dividend for the period after the next period. The subject who receives three periods of information will see three pieces of dividend information on the PC screen shown in Extra-Figure 2 throughout one experiment treatment to make investment decisions and trade securities. Trading is conducted in such conditions in order to compare the earnings of the six subjects (market participants).

Extra-Figure 1: Information sStructure of the mMarket

(Method for disclosure of dividend information)

Extra-Figure 2: Screen Image Viewed by the Subjects

Appendix 2: Instructions for fMRI Experiment Subjects

Tables and Figures

Table 1 Relationship between Quantity of Information and Profit Ranking

	The results of 16 experiments (in Francs)				normalized data		
	Least informed	Medium informed	Best informed		Least informed	Medium informed	Best informed
1	252050	242169	256799	1	0.33530	-1.60142	1.26613
2	271946	262459	249274	2	1.38629	0.15941	-1.54570
3	200714	186274	190077	3	1.66161	-1.20879	-0.45282
4	249402	247263	254498	4	-0.04918	-0.15592	0.20510
5	257086	263126	263343	5	-1.16565	0.55197	0.61368
6	192599	192380	192575	6	0.02290	-0.21144	0.18854
7	252872	252657	246305	7	0.28513	-0.14377	-0.14136
8	247784	281682	254329	8	-1.27541	1.93162	-0.65620
9	188785	174135	213821	9	-0.24658	-1.29004	1.53663
10	245952	248259	256566	10	-0.98968	-0.45957	1.44925
11	283350	224214	253722	11	1.99335	-1.99066	-0.00269
12	192243	170996	194472	12	0.40668	-0.95635	0.54967
13	258172	239801	246603	13	1.86434	-1.56750	-0.29684
14	262190	260770	260790	14	0.16538	-1.31954	1.15415
15	186146	190915	200061	15	-1.45457	-0.34075	1.79533
16	247447	251794	252050	16	-1.21824	0.55685	0.66139
average	235262.8	231191.8	234950.2		0.10760	-0.50287	0.39527
S.D.	32654.8	35701.0	27519.3		1.15359	1.01678	0.91092

Table 2 Results of Statistical Tests

Class	Observations	Average	Variance
Least informed	16	0.1076044	1.3307777
Medium informed	16	-0.5028687	1.0338526
Best informed	16	0.3952662	0.8297917

Classes	t value	P value
Least informed and medium informed	1.673309	0.10120534
Least informed and best informed	0.788482	0.43454910
Medium informed and best informed	2.461791	0.01772162

Figure 1: Rate of return per information level based on different hypotheses

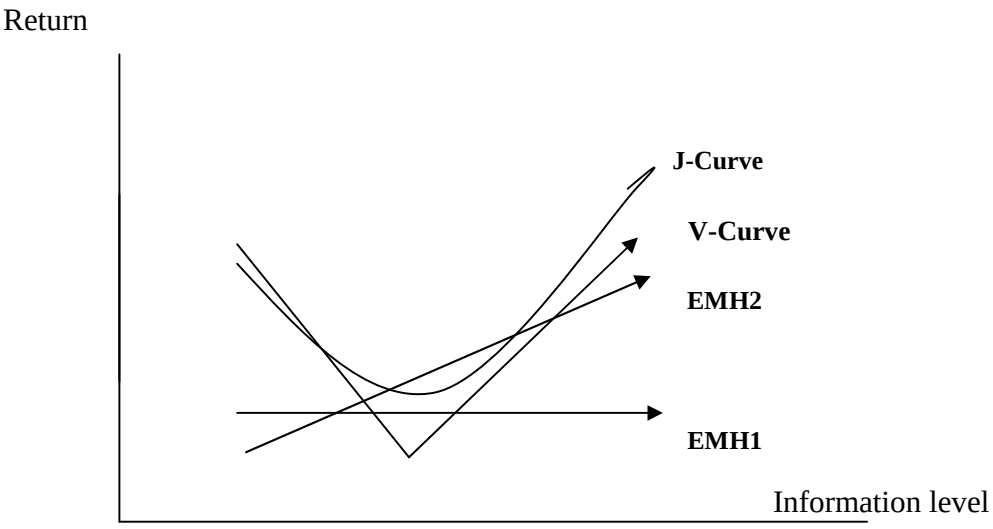


Figure 2 Relative Frequency of Number of Trades According to Information Level

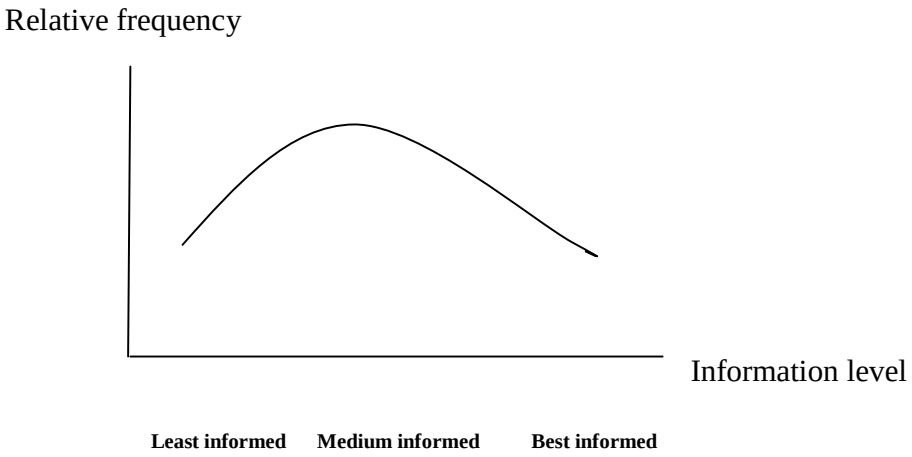


Figure 3: Concept of FMRI Experiment

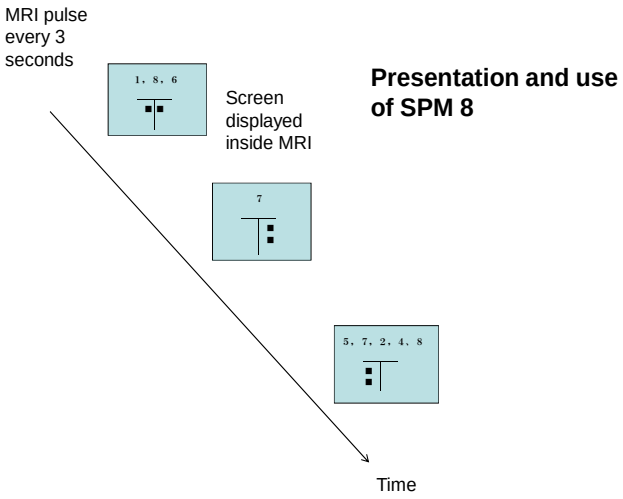


Figure 4. Elapsed Time, fMRI Imaging, Pictures Watched by Subjects and Onset

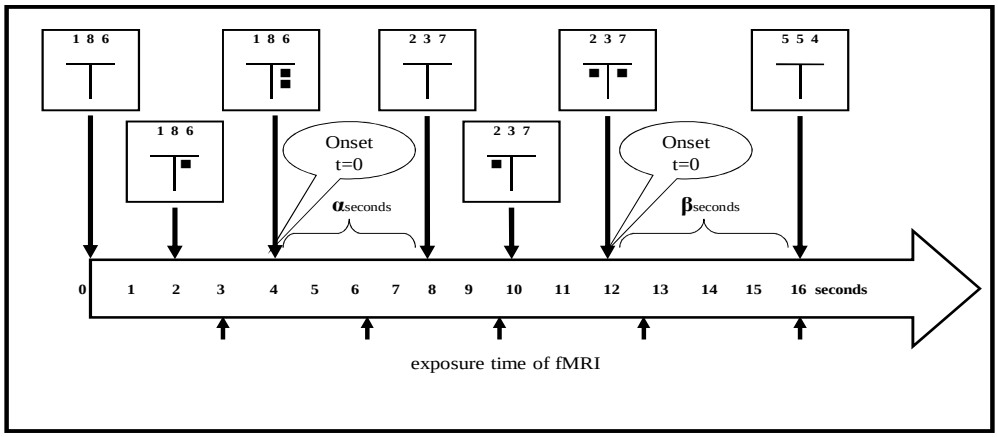


Figure 5: Active Areas of the Brain in Case (S4-S3)

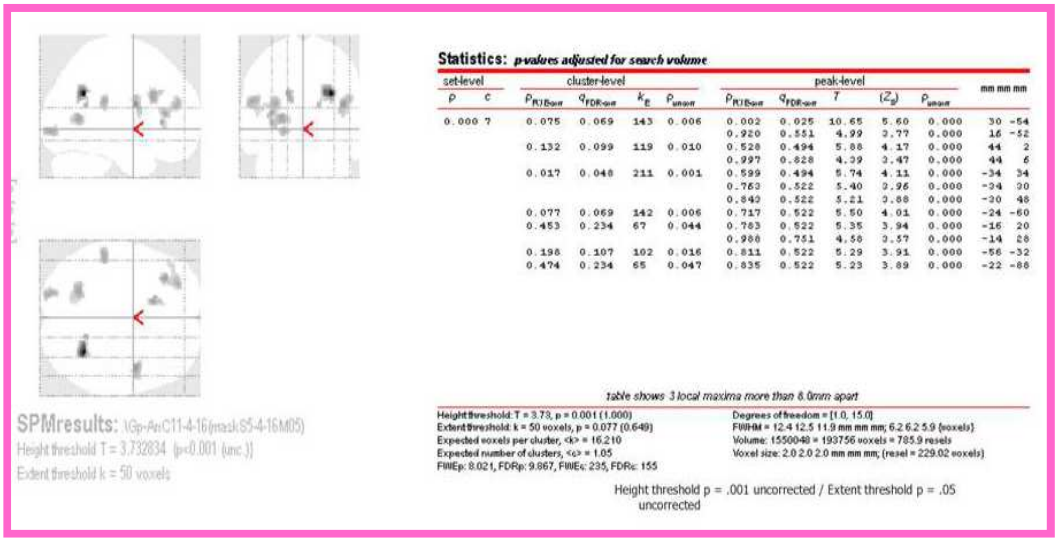


Figure 6: Active Areas of the Brain in Case ((S5+S6) - (S1+S2))

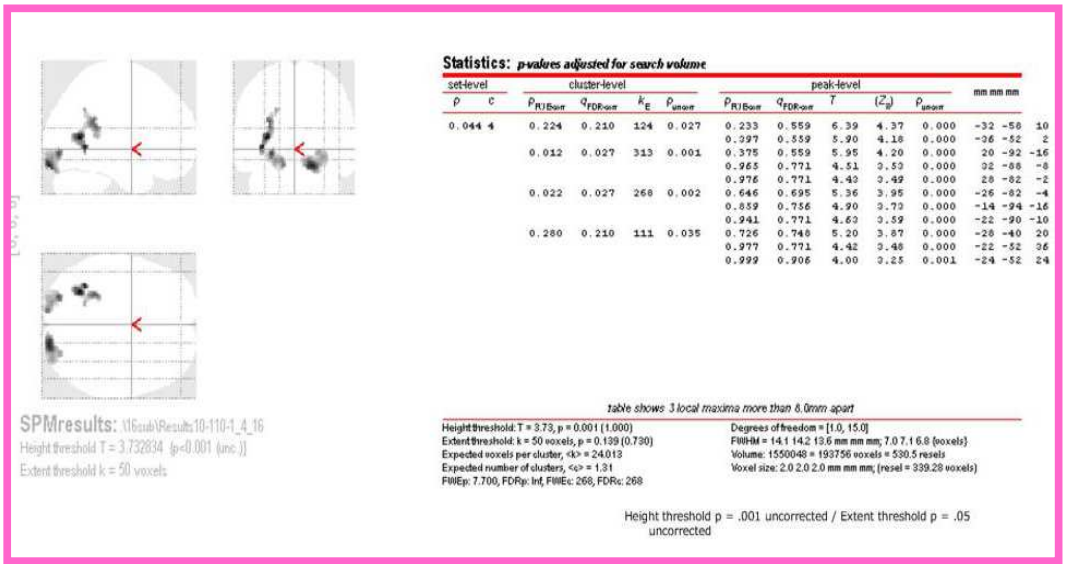


Figure 7　Brain Mechanism of Investment Decision Making in Economic and Social Situations（T=4）

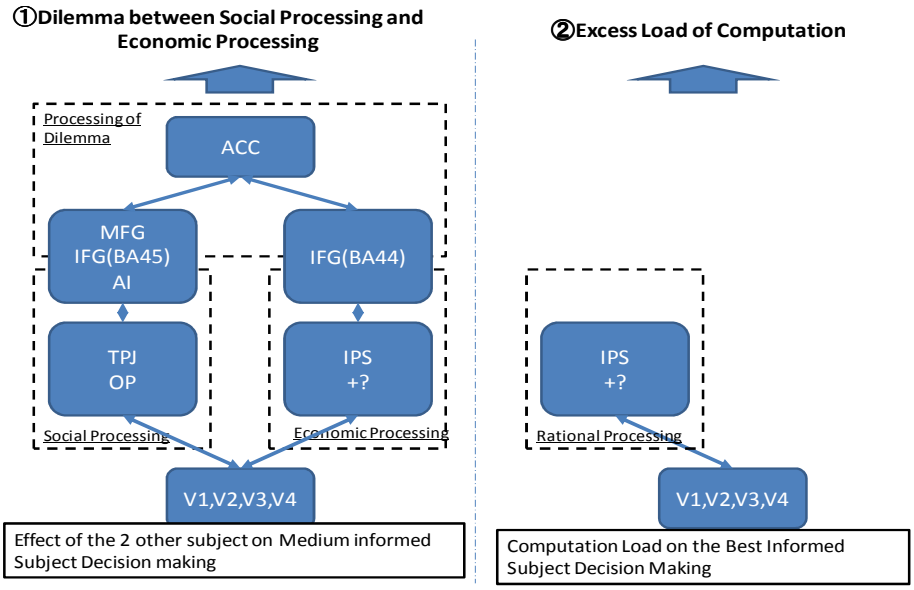
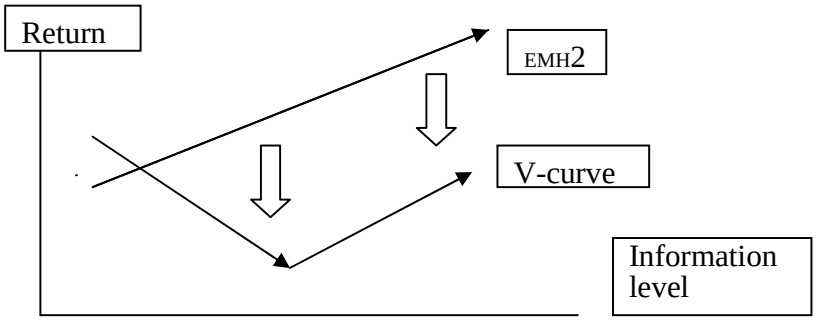
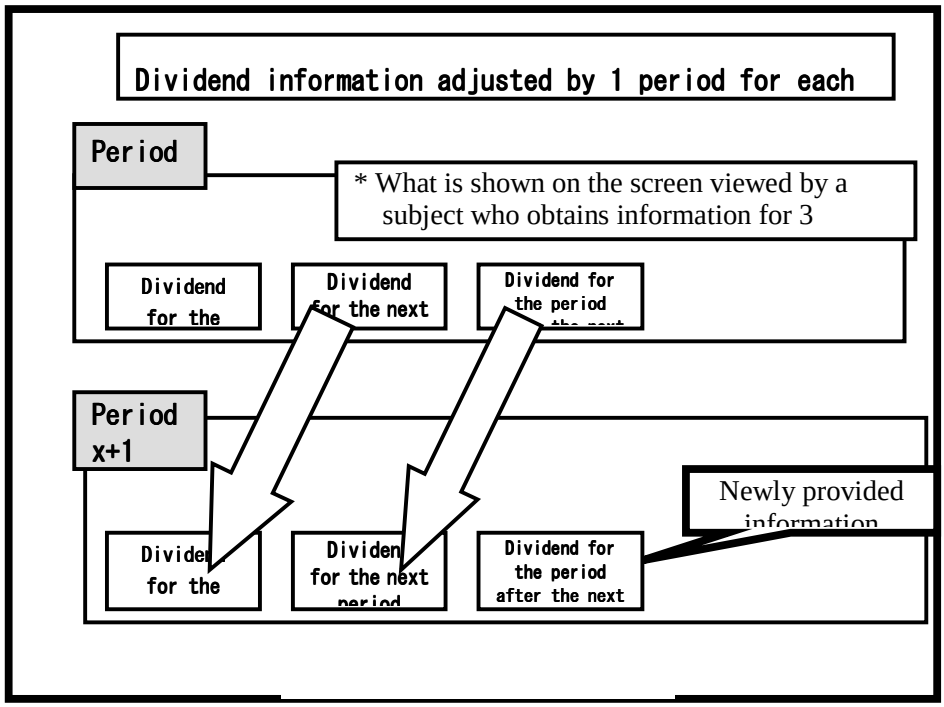


Figure 8 Changes in Return Structure

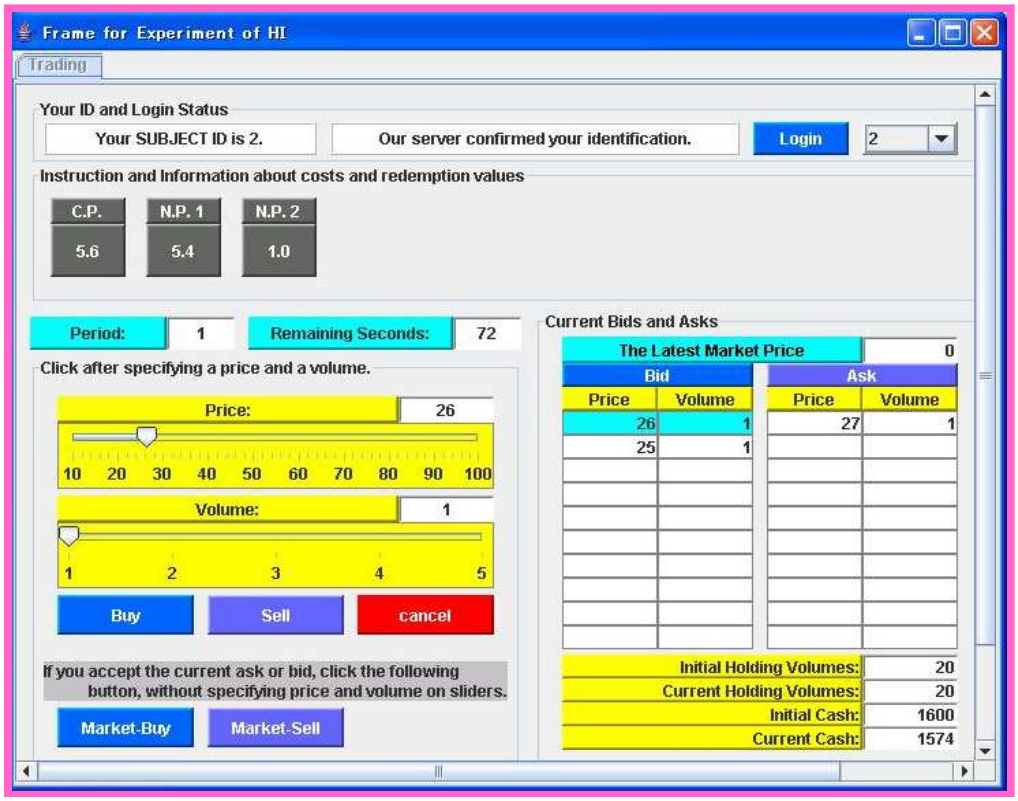


Extra-Figure 1: Information Structure of the Market

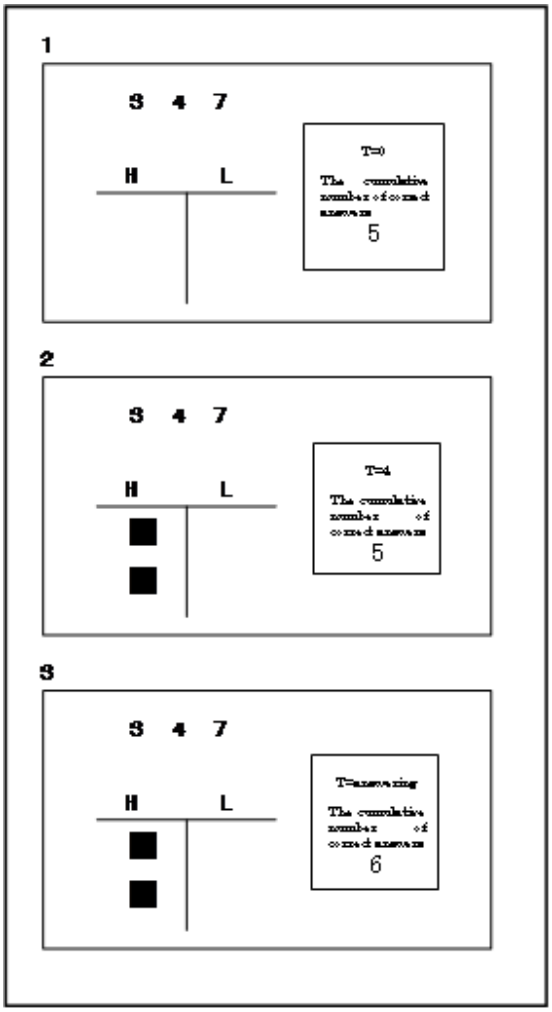
(Method for disclosure of dividend information)



Extra-Figure 2: Screen Image Viewed by the Subjects



Appendix 2: Instructions for fMRI Experiment Subjects



There are three participants in this game. At the start of the game (Display 1: T = 0) you are looking at three (or 1 or 5) numerical value(s) selected from a set of six numbers. Next, as additional information, the assessments of the other two players are shown for two seconds just after two seconds into the game (Display 2 : T = 4). (The assessments of the two other participants have been pre-installed in the computer. In the above example, one player can see five numbers and the other one number.) The subject is required to answer whether the average of the six numbers is higher (H) or lower (L) than five. The subject can answer by

using one of two buttons (one button is for high and the other is for low). If the subject answers correctly, the cumulative number of correct answers on his display is increased by one (Display 3). A new game starts soon after he gives his answer.