# Brain Mechanism of Economic Management Risk Decision Based on Kahneman's Prospect Theory

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**ABSTRACT**

Risk decision-making under uncertain circumstances is a complicated process, which has always been the focus of economic management research and attention. With the intersection of decision-making neurology and various disciplines, it is possible to open the "black box" of human brain. Based on Kahneman's prospect theory, this research takes the brain mechanism of economic management decision as the research goal and adopts literature research method, neuroscience experiment method, data analysis and other research methods, to study behavior data of "risk avoidance" and "risk seeking" decision-making and the related activation brain regions and brain mechanisms under two different uncertain risk decision-making situations of "gain" and "loss." It is found that N2 and P3 components of frontal lobe, parietal lobe and central region are activated in both risk situations (gain and loss), N2 component is related to the preliminary processing of risk decision-making, P3 component can reflect the cognitive processing mechanism of managers' risk decision-making behavior, and the managers' decision-making behavior and risk preference are obviously influenced by the situation factors.

**Key Words:** Managers' Risk Decision-making, Prospect Theory, Risk Avoidance, Risk Seeking, Brain Mechanisms

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## Introduction

In the field of economic management, managers are usually faced with two uncertain risk decision situations of gain and loss (Liu *et al.*, 2011), and need to make decisions in two risk situations according to the existing information, experience and common sense, so as to achieve the goal of reducing loss and obtaining the maximum profit. Because of the influence of external and psychological factors as well as personal abilities, this decision-making process is a complex process. Therefore, risk decision-making under uncertain circumstances has always been the focus of economic management research and attention.

By referring to the related references (Li *et al.*, 2016), the previous researches mainly studied and explained the behavior of risk decision-making in uncertain situations from the cognitive aspect on the basis of "expected utility theory" and "prospect theory" (Krain *et al.*, 2006). However, there is little research on its neurocognitive mechanism. With the development of decision-making neuroscience and brain imaging technology, researchers have begun to study the neural mechanism of risk decision-making behavior of managers by means of cognitive nerve, and found that the risk preference of managers in uncertain situations can activate different brain regions and other physiological mechanisms related to risk decision-making in uncertain situations (Kolling *et al.*, 2014; Ferruzzi *et al.*, 2017).

Based on the above analysis and Kahneman's prospect theory, this research introduces the technique of event-related potential analysis (Xie *et al.*, 2011) in

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neuroscience experiments and focuses on the brain mechanism of risk decision-making under the uncertain circumstances of gain and loss faced by managers in the risk decision-making of economic management. By making the subjects complete the game program simulating the real situation of risk gain and loss, the research collects the behavior data and event-related potential EEG component data of the subjects in the course of experiment, and analyzes the related brain regions and neural mechanisms of risk avoidance and risk seeking decisions made by managers under the two uncertain situations. Finally, it is concluded that the N2 and P3 components of frontal lobe, parietal lobe and central region are related to the cognition, processing and decision-making process of risk decision-making in two uncertain situations, and in the risk-gain situation, managers are more inclined to risk-avoiding decision-making but risk-seeking decision-making in the risk-loss situation (Schirillo and Stone, 2005). The results can provide scientific and objective experimental basis for risk-seeking decision-making management in economy field.

## Relevant Theories

### *Kahneman's prospect theory*

Kahneman's prospect theory holds that (Kim *et al.*, 2012), people's risk decision-making process is actually the choice process of "prospect" (alternative plan), and in the risk decision-making, managers are of "limited rationality". Managers choose according to their expected criteria (reference points), so because of the different reference points of each person, there are changes of "profit" and "loss" after decision-making, "profit" will bring happiness, "loss" will bring pain, the decision-making behavior of managers will also change due to such changes. Therefore, the prospect theory holds that gain and loss are not absolute concepts, but relative to the reference point, and the gain and loss curves together form the S-shaped value function (Chen *et al.*, 2015). Figure 1 shows that people's disgust of loss is higher than the happiness brought by profit. Therefore, most managers choose risk avoidance in the gain situation and risk seeking in the loss situation (Nina *et al.*, 2012).

### *Economic management risk decision-making*

(1). Risk decision-making and cognitive factors of economic management

Economic management risk decision-making refers to the complicated psychological process that managers need to make decisions when facing two or more schemes, and the consequences of decision-making are often uncertain, especially when it is possible to have negative consequences (Linkov *et al.*, 2006). In different risk situations, in addition to the influence of genetic and cognitive habits, different managers may make decisions with their own values and experience of success or failure, cognitive judgments on the acceptability of risks and the perception of problem architecture or problem descriptions (Heekren *et al.*, 2004). Cognitive factors directly affect people's behavior and results of risk decision-making. With the improvement of cognitive level, managers' judgment level on risk decision-making will be improved (Bode, 1998).

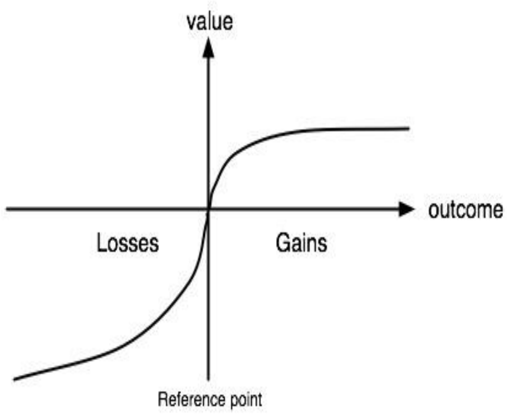


**Figure 1.** Value function

(2). Research on the neural mechanism of risk decision-making in economic management
With the development and maturity of cognitive neuroscience and its increasing intersection with other disciplines, the researchers began to study the neural mechanism of risk decision-making in different risk situations with the help of related EEG imaging equipment from the aspect of risk decision-making behavior, and proved the neurological basis of decision-makers' "limited rationality" from the point of view of brain science (Tsai and Chiou 2009). However, the research on the data mechanism of risk decision-making in economic management is still in the initial stage and needs further research.

## Brain Mechanism of Management Risk Decision

### *Selection of experimental objects*

According to the objectives and requirements of the experiment, 30 qualified adults are elected as paid subjects, including 22 males and 8 females, and 30 subjects are randomly divided into gain situation group and loss situation group.

*Experimental method*

In order to study the brain mechanism of managers' decision-making when they face the situation of gain and loss risk in the management process, this research simulates the real situation of risk decision-making, utilizes STTM2 software, and designs the game program of gain and loss situations (Minati *et al.*, 2012). The subjects are divided into groups in advance to complete the corresponding experiments in a professional cognitive electrophysiological laboratory, and they are informed that the final reward obtained is related to the amount of money earned by the completed experimental game. In order to facilitate the subjects to analyze the change of risk decision-making in the course of the test, the experiment is conducted in 3 rounds, and the subjects had 40 choices in each round, a total of 120 times.

(1) Gain situation game

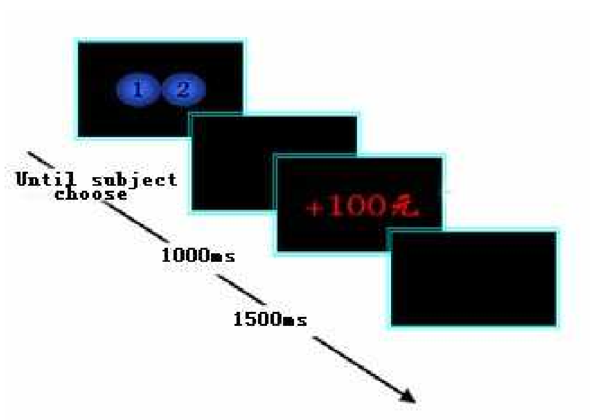


**Figure 2.** Gain situation game task

Figure 2 shows the game task paradigm of gain situation, subjects are required to select one of two blue balls representing risk avoidance (Ball 1) and risk seeking (Ball 2) on the computer screen. The subjects are sure to get 100 yuan of gain when selecting Ball 1 for risk avoidance, and the subjects may have 50% probability to losing the gain when selecting Ball 2 for risk seeking, namely 0 yuan of gain. There is no time limit in this selection process. The gain obtained after the selection will appear on the screen within 1,000ms after completion of selection, and the next round of selection starts after 1,500ms.

(2) Loss situation game

Figure 3 shows the game task paradigm of the loss situation, which is the same as the basic form of that of the gain situation. The difference is that the subjects will lose 100 yuan when selecting the risk avoidance (Ball 1) but have 50% probability of losing gain when selecting the risk seeking (Ball 2), namely 0 yuan of gain. The 50% probability will lose 200 yuan.

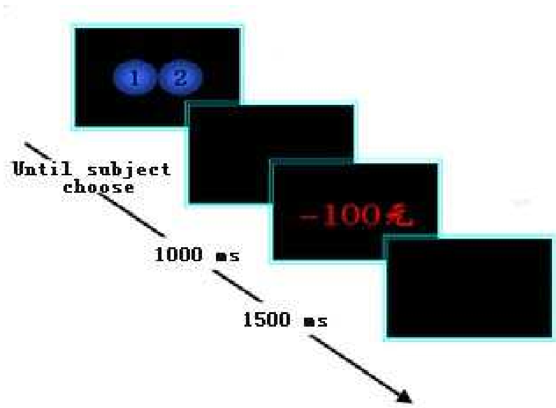


**Figure 3.** Loss situation game task

In the course of the experiment, the subjects wear electrode caps on the head, and the computer data of the subjects are collected with NeuroScan 128 leading to EEG/EP workstation, with the irrelevant potentials removed and 66 lead electrodes of EEG recorded as shown in Figure 4 (Ramakrishnan and Murthy, 2013). At the end of the experiment, APSS15.0 software is used to perform multi-factor variance analysis on the collected data (Oliveira and Rui, 2014).

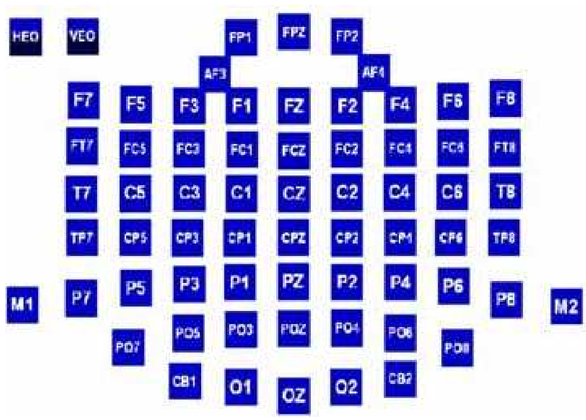


**Figure 4.** 66 lead brain electrode location map

*Analysis of experimental results*

(1). Analysis of behavioral results of managers' risk decision-making in gain and loss situations

**Table 1.** Risk decision behavior and average response time in two different decision situations

| —— | Revenue situation | | Loss situation | |
|---|---|---|---|---|
| | Risk aversion | Risk seeking | Risk aversion | Risk seeking |
| Risk preference (%) | 74.92 | 25.08 | 12.37 | 87.63 |
| Reaction time (ms) | 675.10±67.75 | 766.14±58.12 | 631.63±75.71 | 584.19±81.37 |

**Table 2.** N2 component average latency and amplitude

| Group | Risk preference | Latency ms | Amplitude uv |
|---|---|---|---|
| Revenue situation | Risk aversion | 244.01±21.03 | -14.48±2.86 |
| | Risk seeking | 244.88±23.40 | -9.19±3.34 |
| Loss situation | Risk aversion | 241.87±18.26 | -11.63±2.82 |
| | Risk seeking | 240.25±22.77 | -11.69±3.50 |

**Table 3.** N2 component frontal, parietal, and a central region mean latency

| **Group** | **Risk preference** | **FC** | **CR** | **PC** |
|---|---|---|---|---|
| | | **F3, FZ, F4** | **C3, CZ, C4** | **P3, PZ, P4** |
| Revenue situation | Risk aversion | 231.66±19.16 | 232.34±21.14 | 266.01±26.02 |
| | Risk seeking | 230.65±21.16 | 234.11±22.06 | 269.32±28.85 |
| Loss situation | Risk aversion | 232.34±17.16 | 234.68±22.01 | 261.34±23.68 |
| | Risk seeking | 227.68±23.33 | 229.35±23.04 | 264.66±26.55 |

**Table 4.** N2 component frontal, parietal, and a central region mean amplitude

| **Group** | **Risk preference** | **FC** | **CR** | **PC** |
|---|---|---|---|---|
| | | **F3, FZ, F4** | **C3, CZ, C4** | **P3, PZ, P4** |
| Revenue situation | Risk aversion | -14.55±2.03 | -14,88±1.26 | -14.01±0.91 |
| | Risk seeking | -9.07±2.55 | -9.16±1.22 | -9.34±3.14 |
| Loss situation | Risk aversion | -10.96±1.51 | -12.37±0.44 | -11.51±1.52 |
| | Risk seeking | -11.22±1.12 | -10.45±0.54 | -12.35±0.45 |

Table 1 shows the behavior and average reaction time of risk decision-making in two different decision situations. It can be seen from the table that the subjects' reaction time to the risk avoidance in the risk gain situation is lower than that of the risk seeking, and the subjects are more inclined to the risk avoidance decision, but the subjects' reaction time to the risk avoidance time in the risk loss situation is higher than that of the risk seeking, and the subjects are more inclined to risk-seeking decision-making. Comparing the two different decision-making situations, we can find that there is little difference in the reaction time of risk avoidance decision-making, while the reaction time of risk seeking decision-making in the gain situation is higher than that in the loss situation. The results of variance analysis show that the main effect of the two decision-making situations on risk decision-making (risk avoidance/seeking) is significant, but the main effect of risk decision-making is not significant.

By analyzing the EEG components of the subjects, it is found that two ERP components, N2 and P3, are activated in the frontal lobe (FC), parietal lobe (PC) and central region (CR) under two different risk decision situations. The N2 component is the negative wave appearing 200-300ms after stimulation, which may be related to the automatic discrimination processing of stimulation information, while the P3 component appears 300-500ms after stimulation, which may be related to the cognitive process of evaluation and decision-making of stimulation information. Therefore, the latency and amplitude of N2 and P3 components will be analyzed herein.

(1) Analysis of the latency and amplitude of N2 component

Table 2 shows the statistics of average latency and amplitude of N2 component, and Table 3 shows the statistics of average latency of N2 component in three brain regions. The results show that the latency of N2 component in three brain regions is ranked as frontal lobe, central region and parietal lobe. This suggests that managers firstly activate the N2 component of the frontal lobe when they make risk decisions.

Table 4 shows the statistical table of average amplitude of N2 component in three brain regions. According to the analysis of Table 2 and Table 4, the average amplitude of N2 component induced by risk avoidance decision-making and the average amplitude of N2 component induced in three brain regions are higher than that induced by risk seeking decision in the gain situation. The average amplitude of N2 component induced by the two risk decisions is not significantly different from the average

**Table 5.** P3 component average latency and amplitude

| Group | Risk preference | Latency ms | Amplitude uv |
|---|---|---|---|
| Revenue situation | Risk aversion | 341.44±21.83 | 8.31±4.71 |
| | Risk seeking | 336.42±16.42 | 13.44±5.75 |
| Loss situation | Risk aversion | 221.67±10.35 | 10.51±4.73 |
| | Risk seeking | 334.12±14.87 | 10.58±4.82 |

**Table 6.** P3 component frontal, parietal, and a central region mean amplitude

| Group | Risk preference | FC | CR | PC |
|---|---|---|---|---|
| | | F3, FZ, F4 | C3, CZ, C4 | P3, PZ, P4 |
| Revenue situation | Risk aversion | 10.62±1.20 | 5.09±1.55 | 9.13±3.88 |
| | Risk seeking | 14,59±0.82 | 8.82±1.19 | 13.99±1.43 |
| Loss situation | Risk aversion | 11.55±0.70 | 6.47±1.31 | 0.55±.47 |
| | Risk seeking | 11.22±1.23 | 7.46±1.75 | 9.87±1.13 |

amplitude of N2 component induced in three brain regions in the loss situation. The average amplitude of N2 component induced by risk avoidance decision-making and the average amplitude of N2 component induced in three brain regions in the gain situation are higher than that in the loss situation. The N2 amplitude induced by risk seeking decision in the loss situation is significantly higher than that in the gain situation.

(2) Analysis of the latency and amplitude of P3 component

Table 5 shows the average latency and amplitude of P3 component, and Table 6 shows the average amplitude of P3 component in three brain regions. The analysis of Table 5 and Table 6 indicates that the average amplitude of P3 component induced by risk avoidance decision-making and the average amplitude of P3 component induced in three brain regions in the gain situation are lower than that induced by risk seeking decision. The average amplitude of P3 component induced by the two risk decisions in the loss situation is not significantly different from the average amplitude of P3 component induced in the three brain regions. The average amplitude of P3 component induced by risk avoidance decision-making and the average amplitude of P3 component induced in three brain regions in the gain situation are lower than that induced in the loss situation. The amplitude of P3 component induced by the risk seeking decision in the loss situation is significantly lower than the amplitude of P3 component induced in the gain situation.

## Conclusions

Based on Kahneman's prospect theory, this research takes the brain mechanism of risk decision-making in economic management as the research goal and adopts ERP to study the brain mechanisms of making risk decision and risk seeking decision under two different risk decision-making situations of "gain" and "loss".

By analyzing the behavior data of the subjects, it is concluded that managers are more inclined to risk avoidance decision-making in the risk gain situation, while managers are more inclined to risk-seeking decision-making in the risk loss situation, which shows that managers' decision-making behavior and risk preference are obviously affected by situation factors.

Through ERP EEG data analysis, it is found that N2 component of frontal lobe, parietal lobe and central region are activated in both risk situations, and the latency and average amplitude of N2 component in risk avoidance and risk seeking decisions are further analyzed. The results showed that all three brain regions are involved in the preliminary processing of risk decision making, and frontal lobe, parietal lobe and central region are the main processing brain regions.

It is found that the P3 component of frontal lobe, parietal lobe and central region is activated in both risk situations, and the P3 component of risk avoidance and risk seeking decisions is also significantly different in different risk situations, indicating that the component could clearly reflect the cognitive processing mechanism of risk decision-making behavior of managers.



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