Objective Decision-making Brain Mechanism of Public-Private-Partnerships Project Risk Management Based on Decision Neuroscience Theory

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ABSTRACT

As a new financing mode, risk management and decision-making is always the focus of Public-Private-Partnerships (PPP) project management. This study takes the brain mechanism of objective decision-making of PPP project risk management as the research target. From the perspective of decision-making neuroscience, the study uses literature research method, decision-making neuroscience experiment method, inductive summary and others to introduce the event-related potential (ERP) technique and to analyze the ERP components of the subjects from exposure to the risk situation to decision making during the experiment. It is found that the ERP components related to the risk decision-making stage are mainly P2, N2 and P3, but there is no significant difference between P2 and P3 in different uncertainty risk decision situatios, and the amplitude of N2 component increases with the increase of uncertainty of risk information, which proves that the component is closely related to objective decision-making of project risk management. This research result is of practical significance for effective and scientific risk management and decision-making of managers.

Key Words: PPP Projects, Risk Management, Decision-making Neurology, Decision-making Brain Mechanism

DOI Number: 10.14704/nq.2018.16.5.1249 **NeuroQuantology 2018; 16(5):284-289**

Introduction

The PPP project is a new project financing mode, in which the government and private investors cooperate to complete public products or services (Seungho, 2010). At present, it is widely used in the field of public utilities, and there are many more successful projects internationally. However, due to the longer construction period and larger investment of PPP projects, there are many uncertainties, facing more and more complicated risks compared with general projects. There are also many cases in which PPP projects fail due to the lack of thorough risk analysis and underestimating the degree of risk impact in the process of project risk management, so PPP risk management and decision have been the focus of research.

It is found from foreign related literature that foreign research on PPP project risk management is more profound than domestic research, but both domestic and foreign research on PPP project focus on the theoretical framework and process of risk management such as risk identification, risk classification, evaluation and risk sharing (Xu *et al.,* 2010), and have achieved some results. However, because there are many uncertain factors in the course of PPP project risk management, the risk cannot be thoroughly analyzed simply by relying on these theories, which often understates the influence

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 20 February 2018; **Accepted:** 19 April 2018

degree of the risk, makes wrong decisions and causes losses to the whole project.

Decision-making neuroscience is a new branch crossing neuroscience, decision-making science, psychology and others, and is also a new field of risk management science. It can realize the interpretation of the operation mechanism of "black box" in the process of risk management decision-making (Kim *et al.,* 2012). Based on this, this paper attempts to study the uncertain risk decision-making mechanism in the course of PPP project risk management from the level of decision-making neuroscience and applies the Event-Related Potential (ERP) Technology in the neuroscience experiment (Wu *et al.,* 2012). By collecting the EEG components of decision-making by the subjects in the face of risk and analyzing the experimental data, the objective decision-making mechanism of PPP project risk management based on decision-making neuroscience theory is obtained, providing certain guiding significance for improving the efficiency of PPP project risk management.

PPP Project Risk Management

PPP project

PPP project financing mode, e.g., public-private joint venture, is a widely used financing mode both at home and abroad. This mode is a mode of cooperation between public sector and private investors to complete a project. It has the characteristics of sharing interests, sharing risks and making decisions together.

PPP project risk

PPP project risk refers to the uncertainties that may exist objectively in the whole life cycle of the project, which may cause the project to fail to achieve the desired effect due to other factors. This uncertainty may cause the project to suffer losses or failures.

Risk management is always throughout the project. Since PPP projects are usually large construction projects, the whole construction and operation cycle is relatively long, so the risks faced are more and larger than other projects. In order to facilitate the detailed risk management of the whole project, PPP project life cycle is divided into three stages: pre-stage, construction and operation handover (Bai *et al.,* 2017), in each of which will be faced with complex risk factors, PPP project risk classification from different angles and standards is also different. According to the whole life cycle of the project, this paper summarizes the risks that may be encountered in various stages of the PPP project, mainly including the policies, financing, contract signing or changing, financial risks in pre-stage, land relocation, compensation, and technical risks in construction period, and economic risks, market risks and environmental risks in operation handover period. The details are shown in Figure 1 (Adam and Husain, 2012). Some risks may go through the whole life cycle of the whole project.

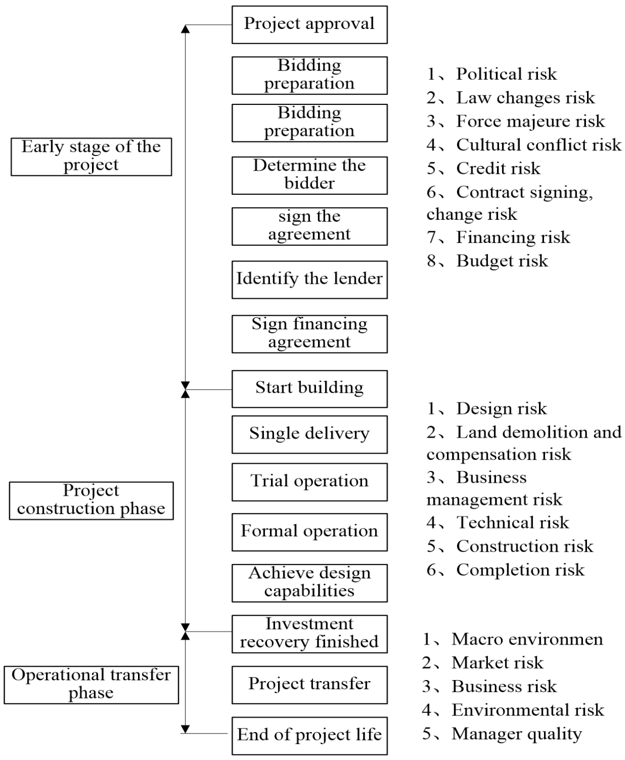


Figure 1. PPP financing project life cycle and risk factors

Theoretical Basis of Decision-Making Neuroscience

Development of decision-making research

Decision-making has always been the focus of attention in economics, management, psychology, etc. In the face of different stages of research, the concept of decision-making and the depth of research are constantly changing, and its research paradigm has developed from the original "systematic process" to the present "cognitive" process. Generally speaking, the development of decision-making can be summarized as three stages of science, behavioral decision-making and decision-making neuroscience (Krain *et al.,* 2006). The research purposes, research methods, research assumptions, research results and research bases of each stage are shown in Table 1 (Lin *et al.,* 2014).

Table 1. Three stages of decision research and development contrast

Development stage	Scientific decision-making	Behavioral decisions	Decision Neuroscience
Research purposes	How policymakers should do this	Describe and explain the decision-making behavior	Look for the neurological basis for decision-making
Research hypothesis	"Rational person"	Behavioral level "bounded rationality"	Neurological limited "rational"
Research methods	deduction	Behavioral experiment	Nerve, cognitive science experiment
Research result	Predict decision behavior through decision model	Reveal the cognitive and psychological decision-making behavior, describe the decision-making behavior	Reveal the neurological characteristics of decision-making behavior, explain the decision-making behavior
Research Foundation	Mathematical methods	Psychology	Neuroscience, Cognitive Science

The researches in three stages are not isolated. The research results of scientific and behavioral decision-making provide a theoretical framework for decision-making neuroscience to study the mechanism of decision-making behavior from three levels: brain, psychology and behavior (Minati *et al.,* 2012).

Neuroscience basis of decision-making dual-system theory

Psychology and decision-making neuroscience, as the dual-system theory in decision-making neuroscience, has aroused wide attention. Although many multiple primitive system theories have been put forward in decision-making research field and the names of the systems nominated by scholars are different, most of the models of the dual-system theories are similar. In this paper, system 1 and system 2 are used as research terms (Paulus *et al*., 2003).

The research focus of decision-making in decision-making neuroscience system is the influence of emotion and cognition on decision-making in dual-system model, which is similar to the processing process of system 1 and system 2. System 1 processes faster, depends more on human intuition, while system 2 depends more on reason, and processes slower (Weber and Huettel, 2008). By virtue of the dual-system theory, decision-making neuroscience can explain the process of decision-making behavior from the cranial nerve level, which breaks the previous two theories of science and behavior decision-making and proposes that decision-making is accomplished jointly by system 1 and system 2 (Engelmann and Tamir, 2009).

Study on ERP components related to decision-making

With the development of functional magnetic resonance imaging (fMRI), event-related potential (ERP) and other brain imaging techniques, the researchers found through the method of decision-making neuroscience experiment that the brain regions related to decision-making mainly include cingulate gyrus, insula, amygdala and prefrontal cortex (Gathmann *et al*., 2014). And some experiments show that when the subjects are stimulated to different degrees, the related brain regions could reflect to different degrees. In this paper, the event-related potential (ERP) technique with high temporal resolution is used to observe the brain nerve activities of the subjects induced by different-difficult decision-makings. It is found that the ERP components related to the objective decision-making of risk management are P2, N2 and P3 (Wang *et al*., 2015). Mainly distributed in the prefrontal region, P2 component can reflect the early processing of decision-making information, and the peak latency is between 150 and 350 ms, which is related to rapid emotional encoding (Chiu *et al*., 2012). Mainly distributed near the forehead and the central region, N2 component can control the processing of information. As an index of cognitive control and decision processing, it reflects the late processing of decision making with the peak latency of 200-350ms. P3 component reflects the time of stimulus evaluation and neuron activity during cognitive processing, with the peak latency of 300-600 ms, and is a related index of attitude and evaluation (Studer *et al*., 2016).

Research on the Brain Mechanism of Objective Decision-making of PPP Project Risk Management

Objective and method of the experiment

(a). Experimental objective

In order to study the brain mechanism of objective decision-making in PPP project risk management, the event-related potential (ERP) technique in decision-making neuroscience is adopted in this paper to analyze the behavioral and EEG signal characteristics of 18 college students (50% male and female respectively) under different uncertain risk decision-making situations.

(b). Experimental method
As shown in Figure 2, the high-difficult and low-difficult risk decision-making scenarios are designed as starting stimuli. Take the high-difficult risk decision-making stimulus material in the left figure as an example, there are 6 cards in total, red: blue is 2: 4, the two colors are relatively close to each other, and the right figure is low-risk decision-making stimulus material. It represents the color of the card randomly selected by the subject from 6 cards. When the subject judges that the color of the selected card is correct, they could get 10 points (1 corner). If wrong, they could get 0 point. The scores are the risk decision-making feedback stimuli of the subject, and the starting stimulus and the feedback stimulus constitute a stimulus pair.

During the experiment, the subjects sit in a professional ERP laboratory with sound insulation and magnetic isolation. The EEG is recorded by wearing Ag/AgCI electrode cap on the head. Figure 3 shows the environmental equipment and subjects of the laboratory. After the experiment starts, the subjects first see the "+" sign with the duration of 500ms appearing on the computer, which aims to draw the subjects' attention, then the stimulus materials of risk decision-making situation appear, and the duration is 1,500ms. The subjects make decision by pressing keys within the specified time, the data will be invalid if exceeding the test duration, and finally, the screen will show the stimulus pictures, that's, the score of the subject, with a duration of 1,00ms.

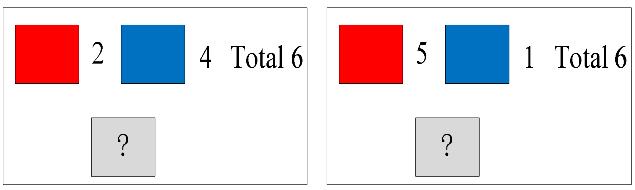


Figure 2. High, low risk decision making stimulus

After the experiment, the original EEG data are analyzed by off-line analysis, and finally the distribution map of EPR brain topography is obtained.

Figure 3. Laboratory environmental equipment and subjects

Experimental results and analysis

In the experiment, statistical analysis is carried out according to the time and accuracy of key-press reflection of the subject in high-difficult and low-difficult risk decision making, and the statistical results of behavior data of the subjects are shown in Table 2. From the table, it can be seen that:

(1) In term of key-press reflection time, high-difficult is longer than low-difficult risk decision, and after repeated variance test, the results show that there is significant main effect *(F(1,16)=18.173, p<0.015)* between the two.
(2) In term of accuracy, high-difficult is lower than low-difficult risk decision, and after repeated variance test, the results show that there is significant main effect *(F(1,16)=4.840, p<0.05)* between the two.
(3) Regardless of the high-difficult or the low-difficult risk decision-making, there is a significant correlation between the reflection time and the accuracy, and the higher the accuracy is, the longer the reflection time is required.

EEG data analysis

After analyzing the original EEG data, it is found that the EPR components related to the risk

Table 2. Descriptive statistics of high and low risk decision behavior data

Risk decision-making difficulty	Valid sample	Reflects the time mean	Reflects time standard deviation	Average accuracy	Standard deviation of accuracy
Difficult risk decision-making	18	512.97	98.07	54.73	6.67
Low risk decision making	18	489.54	82.56	59.45	4.79

decision-making stage are mainly P2, N2 and P3. Through repeated measurement and analysis of the experimental data, it is found that there is no significant difference between P2 and P3 in the high-difficult and low-difficult risk decision-making situations. Only the N2 component shows a large difference, as shown in Figure 4. Therefore, the data of N2 component will be analyzed in this paper.

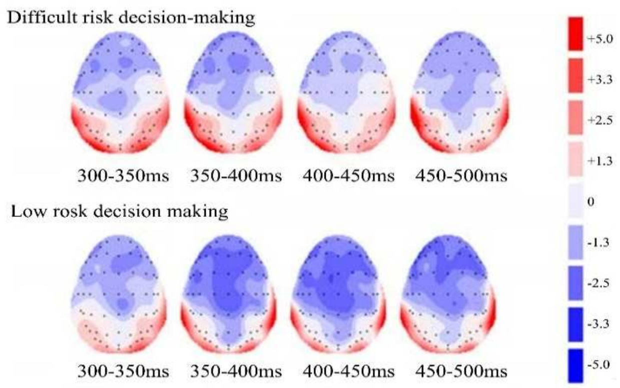


Figure 4. High and low risk decision making process of brain topography

As shown in Figure 5, 6 N2 component electrode points in the frontal region and the central frontal junction region related to risk decision are selected in this paper. The descriptive statistical results of their average amplitudes are shown in Table 3.

In terms of the frontal region, according to two different decision scenarios, 2 × 6 repeated measurement variance analysis on N2 component is carried out to eliminate invalid data. Figure 6 shows representative FZ and FCZ waveforms selected, and the average amplitude of 225-275ms is selected for analysis. The significant results of main effect are shown in Table 4.

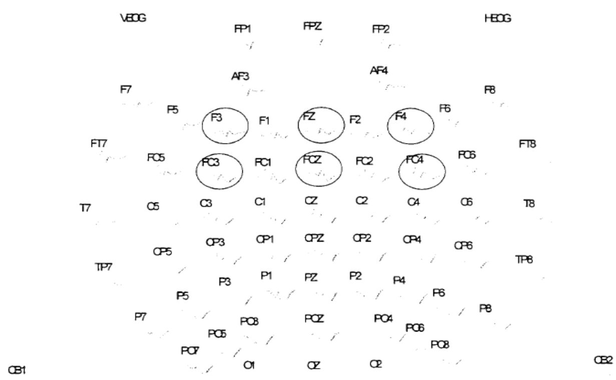


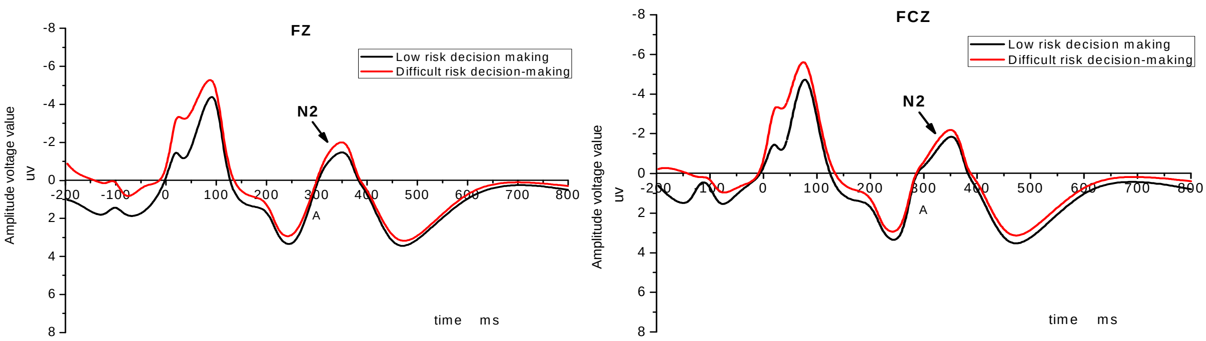
Figure 5. Overall distribution of 64 electrodes and N2 component analysis take point distribution

Table 3. Descriptive statistics of average amplitudes of N2 components in high and low risk decision making

Electrode point	Difficult risk decision-making			Low risk decision making		
	Mean	Standard deviation	Number of samples	Mean	Standard deviation	Number of samples
F3	-0.67	5.69	18	0.83	5.50	18
FZ	-2.13	6.17	18	-1.14	6.30	18
F4	-1.23	5.44	18	0.03	5.55	18
FC3	-1.11	5.34	18	-0.39	5.78	18
FCZ	-2.06	5.99	18	-1.99	7.08	18
FC4	-1.78	4.86	18	-0.77	5.65	18

Table 4. N2 The degree of risk and the significant point of the electrode

Significant degree	F	P
The main effect of decision-making type is significant	F(1,16)3.740	0.070
The main effect of the electrode	F(5,80)3.391	<0.01
The interactive effects of the type of decision and the electrode exist	F(5,80)2.551	<0.05



(a) (b)

Figure 6. High and low risk decision-making N2 component FZ, FCZ EPR waveform

As can be seen from the experimental results in Table 4 and Figure 6, the N2 amplitude of high risk degree is significantly higher than that of low risk, indicating that the amplitude of N2 component increases with increase in conflict of risk management decisions, and this component is closely related to objective decision-making of project risk management.

Conclusions

The study takes the brain mechanism of objective decision-making of PPP project risk management as the research object. Based on the theory of PPP project risk management and decision-making neuroscience, this study focuses on the brain mechanism of objective decision-making of PPP project risk management according to decision-making design theory, with the following conclusions:

(1) Through the analysis of the behavior data of the subjects, it is concluded that there is significant correlation between the reflection time and the accuracy rate of the subjects in two decision-making situations of different risk degree, and the time required for the high-difficult risk is greater than that of the low-difficult risk, while the accuracy rate of the high-difficult risk is lower than that of the low-difficult risk. It shows that in the process of project risk management, the uncertainty of risk information will affect the performance of decision-making.

(2) According to the EEG component analysis, the ERP EEG components related to risk management decision-making are P2, N2 and P3, but the difference between high and low risk decision-making is mainly reflected in N2 component.

(3) In the two decision-making situations with different risk levels, the N2 component has significant correlation, and the N2 amplitude of high risk level is significantly higher than that of low risk, which indicates that the N2 component amplitude will increase with the increase in conflict of risk management decision-making, and the N2 component is closely related to the objective decision-making of project risk management.

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