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Economic decision-making behavior in the interactive games using brain imaging technology: A short review

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Abstract: *Decision-making is an important part of human behavior. With the progress of brain imaging technology in human behavior, a new field called neuroeconomics has emerged recently and attracted wide attention. A large number of studies have used brain imaging technology to study human decision-making behavior. This review emphasized findings obtained in experiments. In this paper, an overview of three popular brain imaging techniques was first provided. Then, this article presents and integrates several typical behavioral and neural experimental studies to further illustrate that the use of brain imaging technology can enhance our understanding of human decision-making behavior. Finally, this paper discusses the challenges at present and puts forward the prospects in neuroeconomics.*

Keywords: *decision-making, interactive games, neuroeconomics, brain imaging technology*

1. Introduction

Decision-making is a high-level cognitive process of human beings. Decision-making usually involves complex psychological and neural processes, which is mixed with emotions, intuition, insight, creative thinking, and other factors of decision-makers. Behavioral economists had explored a large number of models to describe, predict and guide decision-making behavior in the interactive economic games. Many studies have explored how people choose interactive strategies and the factors that influence their choices in the context of social interaction. But little is known about the brain activity of these psychological processes.

In recent years, the emergence of neuroeconomics has provided an innovative way to dynamically observe brain activity from different aspects and reveal the direct causes behind game behaviors. Neuroeconomic experiments use a mixture of brain monitoring or regulation tests in cognitive neuroscience and game theory tests in economics. Scholars point out that neuroeconomics research combines cognitive neuroscience and behavioral economics to explore how dynamic neural activities are related to rich decision-making processes, such as risk assessment and rewards (Camerer et al., 2005).

Brain imaging is currently the most popular neuroscientific technique. The noninvasive neuroimaging technique provides scholars with a developed tool to directly observe brain activity as participants implement various economic decision-making tasks. For example, the combination of neuroscience methods, such as functional magnetic resonance imaging (fMRI), electroencephalogram (EEG), functional near-infrared spectroscopy(fNIRS), and other brain imaging technologies, gives us a better way to explore the relationship between human brain activity and decision-making behavior. Here, the EEG, fMRI, and fNIRS were presented in this paper because they are the most widely used techniques.[1-3]

2. The overview of some brain imaging techniques

(1) Electroencephalography (EEG)

EEG measures brain activity using electrodes attached to the scalp. Especially, EEG can identify the activation of different parts of the brain. Event-related potential (ERP) is a common technique in EEG. ERP studies the neural activity of the subjects according to the waveform, latency, and other characteristics of EEG (Hu et al., 2020). The commonly used ERP components mainly include P2, N2,

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P3, N400, LPP, etc. These ERP components are related to the decision-making behavior of decision-makers, reflecting the information processing, risk information processing, decision-making attitude, etc.

(2) Functional magnetic resonance imaging (fMRI)

fMRI tracks blood flow related to neuronal activity in the human brain using dynamic changes in magnetic properties caused by blood oxygenation. At the same time, direct recording of brain processing and fMRI responses confirms that the BOLD signal reflects input to neurons and their processing. The goal of fMRI is to detect the brain with increased intensity at the time point of stimulus application in a more reliable and effective way.

(3) Functional near-infrared spectroscopy (fNIRS)

fNIRS is a new neuroimaging technology developed in recent years to dynamically detect the activity of nerve cells and realize the monitoring of brain function. It uses the blood volume and blood oxygen in brain tissue as information carriers to understand brain activity by measuring the magnetic changes caused by the changes of oxyhemoglobin in the process of brain cognition.

Each method has its advantages and disadvantages. EEG has a great temporal resolution (about one millisecond), but spatial resolution is poor and it can only measure activity in the outside part of the brain using some electrodes. fMRI has better spatial resolution than EEG and it has comprehensive coverage of the entire brain. However, the temporal resolution of fMRI is poorer than EEG because blood-flow to active regions of the brain has a random lag of a few seconds. Compared with fMRI, the spatial resolution of fNIRS cannot reach the level of fMRI, but it is better than fMRI in portability, operability, and non-invasiveness[4-9].

3. Literature review on decision-making behavior and brain imaging techniques

3.1. Decision-making behavior in experimental games

Traditionally, economic theory has relied on the “Homo Economicus” assumption, which holds that human behavior is governed by self-interested motives and that people are capable of making rational decisions. Many classical game theory analyses predict that rational, self-interested participants will make decisions to reach best outcomes, called Nash equilibrium, from which no participant can benefit by changing their strategies unilaterally.

Experimental games as a tool for analysis and empirical study have a long history in psychology, experimental economics, sociology, and other related disciplines. Since the 1960s, researchers have conducted a large number of experiments related to game behavior, such as the trust game, the ultimatum game, the public goods game, the dictator game, etc. Most of the above experiments challenge the “Homo Economicus” assumption in the preference theory, risk theory, expected utility theory, price theory, and game theory of traditional economics. A larger of experimental studies have found that decision-making behavior often quite deviates from the predictions of models (Henrich et al., 2001). They have indicated, decision-makers rarely act according to original theoretical equilibrium strategies, and they are usually less selfish and strategic as predicted by the mode. Particularly, they attach importance to social factors, such as reciprocity, such as reciprocity, cooperation, altruism, fairness, and equity.

Here, four classic and commonly used behavioral economics games were introduced in the following, which are often used by researchers to study social preferences for trustworthiness, fairness, altruism, or cooperation. Although the settings of these behavioral game experiments are relatively simple, they create an interesting and rich decision-making model[10-14].

(1) Behavioral Economics Research on the Ultimatum Game and the Dictator Game

In the ultimatum game, there are two participants, one as the proposer and the other as the responder. The proposer is provisionally distributed divisible money and makes an offer as to how this money would be split between the two participants. If the responder accepts the allocation, both participants receive the amount as proposed. If the responder rejects the allocation, neither receives any money (Güth, 1982; Henrich et al., 2001). According to theoretical predictions, a rational and self-interested responder should accept any amount offered by the proposer because this means at least there will be a gain, and knowing this, the proposer will provide the minimum nonzero amount (Civai et al.,2010). In fact, studies have shown that although participants accept fair, or close to fair, offers

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(40–50%), rejection rates gradually increase as the offer decreases (Gabay et al., 2014). This irrational decision-making behavior in the UG is often explained in terms of altruistic punishment (Fehr & Gachter, 2002).

The dictator game (DG) is the simplified version of the UG, in which responders have no chance to reject – they just get whatever the proposer dictates (Forsythe et al.,1994). Altruism has been modeled using the dictator game. In the absence of incentives, a proposer who offers an amount greater than zero is considered altruistic, and the magnitude of the proposal reflects the degree of altruism to the responder.

(2) Behavioral Economics Research on the Trust Game and the Prisoner's Dilemma Game

In the trust game, a player can choose to give (or invest) a sum of money to another person or keep the money for themselves and not invest. If he or she decides to give the money to the partner(trustee), the money is multiplied by some factor and the partner decides whether or not to share the profit with the investor. If the partner returns some of the money to the investor, both participants eventually get a higher monetary payoff than the initial endowment. However, if the partner chooses to keep the entire amount, the investor receives nothing (Berg et al., 1995). Game Theory predicts that a self-interest trustee will never share the profit with the investor. Therefore, a rational investor does not trust the partner to distribute the profits to him (or her) and they will invest zero in this transaction. In reality, a large number of investors do send some amount of money to the trustee, often approximately half of their endowment, and this trust is usually reciprocated (Camerer, 2003; Sanfer & Stallen, 2015).

The prisoner's dilemma game is similar to the trust game, except that both participants now simultaneously decide whether or not to trust each other, without knowing their partner's choice. Game Theory predicts that the equilibrium solution in the PD game is mutual betrayal, while the players actually show more trust than expected, with mutual cooperation occurring about 50% of the time (Camerer 2003).

3.2 The neural basis of economic decision-making in laboratory research

Here, four kinds of economic games are described - the trust game, the ultimatum game, the dictator game, and the prisoner's dilemma game - which are often used in the neuroeconomics research on human decision-making.

(1) Neuroeconomics Research on the Ultimatum Game and the Dictator Game

Up to now, the ultimatum game scenario is the most studied human decision-making task with brain imaging techniques. Sanfey et al. (2003) conducted an fMRI research to investigate the neural basis of economic decision-making in the ultimatum game. They were the first to study the neural mechanism of cognitive and emotional changes of actors in economic decision-making in the ultimatum game. They found that unfair money allocation activated the anterior insula and dorsolateral prefrontal cortex, providing insight into emotional and cognitive responses in managerial decision-making. A recent EEG study conducted by Li et al. (2020) indicated that compared to fair offers, unfair offers elicited a larger negative medial frontal negativity (MFN) in upward than parallel and downward comparisons, and unfair offers led to less positive P300 than fair offers in upward and downward comparisons relative to parallel comparison[15-17].

Yang et al. (2020) divided 546 people into 91 groups (three players in each group) for an inter-group competition. All participants participated in the dictator game experiment using functional near infrared spectroscopy (fNIRS) technology, and they found that individuals gave more money to the in-group members than to the out-group members after the intra-group bonding (relative to the control group).

(2) Neuroeconomics Research on the Trust Game and the Prisoner's Dilemma Game

In the classic article of King-Casas et al. (2005), in which the investor played 10 rounds with the same trustee in trust games, they used event-related fMRI to explore neural correlates of the expression and repayment of trust between interacting participants. And their results indicated that a specific brain region, the head of the caudate nucleus (part of the striatum) in the trustee's brain was strongly related to the "intention to trust," and its activity increased when the repayment of the trustee increased. Subsequently, a series of fMRI studies showed that when the truster made a trusted choice, the medial prefrontal cortex(mPFC), caudate nucleus, amygdala, insula, and dorsal prefrontal cortex(dlPFC) were significantly activated (Wang et al., 2015; Aimone, & Houser, 2012). Wang et al. (2015) used

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event-related potential technology to record the EEG components of twenty healthy subjects when they completed repeated trust game tasks in order to study the temporal dynamic characteristics of individual brain activity changes in trust interaction situations, and they found that distrust choice induced more positive P2 components compared with trust choice in the decision-making stage. Fu et al. (2018) studied the dynamic process of a universal trust game based on time-frequency analysis of EEG data, and analyzed trust and betrayal in trust games, and found that distrust decision induced more negative N2 component amplitude and smaller P3 component than trust decision[18-20].

Rilling et al. (2004) conducted a study that nineteen participants who simultaneously received event-related fMRI scans while playing repeated prisoner's dilemma games. And they found that in both the ventromedial prefrontal cortex and ventral striatum (reward-related areas), reciprocated and unreciprocated cooperation were related to positive and negative BOLD responses, respectively.

4. Conclusion

Economic decision-making tasks are an important model of the interaction, which are considered to involve psychological processes key to effective function. The influence of cognitive neuroscience has extended to various disciplines, such as sociology, economics, and management. Brain Imaging is a window into the mind. Neuroscience methods undoubtedly play an increasingly prominent role in economics and other disciplines. The research from neuroeconomics has the potential to shed light on the neural mechanisms of human decision-making. Although scholars in the field of neuroeconomics believe that the correlation between their field and the economic analysis of decision-making is self-evident. But there is still a long way to completely open the "black box" of the brain. Some scholars have suggested that the prospect of building a complete model of complex economic decision-making on a neural basis seems remote. At this point. Even if such a model were assembled, it might not be particularly useful (see a comment by Bernheim, 2009). However, neuroeconomics still has high value and will play an indispensable role in future human decision-making research.

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