Progress of Intertemporal Choice in the Study of Mental Disorders

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ABSTRACT

Intertemporal choice is the decision-making and trade-off made by people for gains or losses at different time points or time buckets in the future. Researchers abroad have applied the intertemporal choice to the study of mental disorders, while the study in this field is still in its infancy in China. The measurement indicators of intertemporal choice can objectively measure the future discount rate of the patients with mental disorders. It is of an inspirational significance for the clinical studies to explore whether intertemporal decision-making mode can become a specific tool for identifying the types of mental disorders or judging the development and severity of the disease course.

Key Words: Intertemporal choice; Discount rate; Mental disorders

http://ijmf.qingres.com

OPEN ACCESS

DOI: 10.20900/ijmf.20170001

Received: September 16, 2017

Accepted: November 10, 2017

Published: December 20, 2017

1 DEFINITION OF INTERTEMPORAL CHOICE

Intertemporal decision-making is an estimate of one's own future and a sense of one's own control over the present and future and it belongs to a social cognition; it is associated with the self-control ability. The self-control ability plays a maintaining role in the mental disorders. For example, substance use disorder, pathological gambling, attention deficit/hyperactivity disorder (ADHD) and borderline personality disorder, etc. are all associated with the self-control ability. Hence, the intertemporal decision-making is usually used to measure the mental disorders related to self-control ability. Meanwhile, the hopelessness and helplessness of the brain's emotional circle over the future can also affect its outcome when dealing with the intertemporal decision-making. Therefore, the intertemporal choice is also used to measure the mental disorders in patients.

Measurement indicator of intertemporal choice is the discount rate, which is the ratio of missing or excessive amount to the future gain after the amount gained or lost at a future time is converted into the present amount. A typical intertemporal choice experiment is to allow the participants to choose between immediate gain and greater delay gain [1].

2 MEASUREMENT MODE OF INTERTEMPORAL CHOICE

Intertemporal choice requires the subjects to weigh or measure the pros and cons of different times, choose the tasks using computer software, manipulate a series of the combinations of amount and time points or time buckets so as to allow the subjects to choose different preferences. There are three programs for tasks. 1) fixed sequence program. The subjects were given a Large-Late (LL) amount with a fixed delay and a defined delay time, and the researchers presented the Small-Soon (SS) amount to the subjects in an increasing or decreasing sequence until the subjects produced the reversal of preferences; 2) titration program: the subjects were also given a fixed LL and a defined delay time. Each choice was half of increase or decrease of the last choice. After the determined number of titrations, psychological value of SS was consistent with the psychological value of LL at this moment, which is called Indifference Point; 3) Random program. A fixed LL, SS and a random combination of delay time points or time buckets were usually given to the subjects for choice.

3 NEURAL MECHANISM OF INTERTEMPORAL CHOICE

Three different neural models were proposed upon the studies on the neural mechanism of intertemporal choice: single-mechanism model, dual-mechanism model and self-control model. 1) The single-mechanism model argued that more than one region in the brain processed the subjective value of rewards, including ventromedial striatum, limbic cortex and medial prefrontal cortex (MPC), and meanwhile, the activities of these regions were also associated with the subjective values of the immediate and delayed gains [2]. 2) Dual-mechanism model argued that there were two processing systems in the brain. It is the “delta system (δ system)” that assesses the subjective value of delayed gain, including frontal lobe and parietal lobe; it is the limbic system “beta system (β system)” that assesses the immediate gains, including ventromedial striatum (VStr), medial orbitofrontal cortex (MOFC), posterior cingulate cortex (PCC) and medial prefrontal cortex (MPFC); the limbic system may be used to process the irrational emotions, while the frontal lobe region may be used to process the rational emotions [3]. In the intertemporal choice, the relative activation degree of two systems may judge the choice tendency of individuals. If the immediate profit is chosen, the activation of β system will increase and the activation of δ system will decrease; if the delayed reward is chosen, the two systems will have opposite activation degree. 3) Self-control model argued that human beings overestimated the immediate gains and underestimated the delayed gains. The self-control system allows human beings to choose the delayed gains. Impulsive decision-making and self-control decision-making affect each other in the neural mechanisms and processing systems of the brain. Brain imaging results of different intertemporal choice of rewards showed that the impulsive decision-making activated the midbrain dopamine neuron region, including middleprefrontal cortex, medial orbitofrontal cortex and nucleus accumbens (NAc); while the delayed choice activated the prefrontal lobe and posterior parietal cortex. The interpretation was made from two different perspectives: the self-control was associated with the regulation and suppression of different response targets, including basal ganglia and lateral prefrontal cortex (LPFC) [4]. The self worth was associated with the transformation of subjective value. The dorsolateral prefrontal cortex (DLPFC) was used to encode and evaluate the subjective value information [5].

4 PROGRESS OF INTERTEMPORAL CHOICE IN THE STUDY OF MENTAL DISORDERS

It is a form of impulsive behavior to choose the immediate profit, with a larger discount rate, that reflects the existence of patterns in clinical practice such as substance use disorders and pathological gambling. Perception of time is correlated with the level of impulsivity for self assessment and behavioral testing. Impulsive individuals are more likely to overestimate the duration of the time buckets, and therefore, they have a higher discount rate than the self-control individuals. Impulsive behavior is the core DSM-5 diagnostic feature of ADHD. The similar impulsive decision-making patterns were found in ADHD children and adolescents in terms of delayed discounting

and delayed fulfillment of tasks [6]. Impulsivity in intertemporal choice was highly correlated with the addiction and impulsivity was a fundamental feature of pathological gambling [7]. The increase of short-term and dependent impulsive behavior may increase the risk of drug use. Impulsive behavior may impair the self-control ability, while the loss of this ability will increase the risk of drug abuse. Substance dependent patients behave as a continuous preference for the immediate effect of the drugs. The direct effect of drugs on decision-making may in turn lead to the continuation or escalation of drug abuse. Smoking and drinking status may affect the individual behaviors. The study of the effect of smoking and drinking status on the social intertemporal choice is selective and the discount rate of the smokers and alcoholics was much higher than that of the normal controls. The neurogenic sequelae resulted from persistent chronic drugs may impair the inhibitory ability to thus result in the increased possibility of risk behavior [8].

Impulsive personality will affect the intertemporal choice, while the uncertainty about the future will also affect the decision-making. Depression patients may tend to the immediate gains in the face of bleak future prospects and despair symptom [9]. The discount rate of depression patients in time discounting is much lower than the normal controls. The study of senile depression patients showed that the discount rate could predict the impulsive suicidal behaviors in the elderly and the individuals with lower suicidal ideation or behavior showed an exaggerated preference for immediate gains compared with the patients with suicidal ideation or behaviors and the healthy controls in the control group [10]. Schizophrenia is one of the most common severe mental diseases in clinical practice and it has serious cognitive impairment and social function defects. Emotional cognitive disorder is the quality factor of schizophrenia patients, which was associated with the impulsive decision-making [11]. The schizophrenia patients with abnormal dopamine dysfunction may also tend to choose the immediate gain even if the choice of the latter (delayed gain) will be more beneficial to their interests [12]. The improvement of cognitive function may enhance their ability to make decisions for the future. When an intertemporal choice is needed due to the excessive self control, the individuals are more likely to prefer the delayed gains. The individuals with anorexia nervosa are generally considered to have excessive self control that leads to the further pathological process. Patients with anorexia nervosa may have the neuropsychological characteristics of higher delayed reward ability, promoting the sustained food restrictions. The neurocognitive exploration of eating disorders may elucidate the mechanisms that govern the abnormality of related behaviors and promote the development of custom-made therapy intervention. Ventral striatum, dorsal caudate and anterior cingulated cortex of normal people may be activated when they are hungry; while satiety may increase the activation of cognitive control circuit (ventrolateral prefrontal cortex) in the decision-making process. In contrast, there was no difference in the activities of reward and cognitive neural circuits when the AN patients were in a sense of hunger or satiety [13].

OCD patients with obsessive compulsive personality disorder (OCPD) had a higher level of depression and anxiety and a more severe obsessive-compulsive symptom than those only with obsessive compulsive disorder (OCD) [14]. OCD and OCPD could be differentiated by the excessive ability of OCPD delayed rewards and OCPD individuals showed a lower discount rate, suggesting that the OCPD has excessive self control [15].

Table 1. Literatures of Intertemporal Choice for the Study of Mental Disorders

Type		Amount and Time	Experiment Group X	Control Group Y	Result (Discount rate)
Substance use disorder	Alcohol dependence [8]	Amount: 16 - 850 USD Time: 10, 14, 20, 35, 45, 55, 60, 70, and 75 days	Alcoholics (n=26)	Mild social drinkers (n=523)	X > Y**
	Nicotine dependence [16]	Amount: 1 - 900 USD Time:1, 12, 36, 60, and 120 months	Current smoker (n=29)	Non-smoker (n=30)	X > Y**
	Psychoactive substance dependence [17]	Amount: 14.75 – 28.5 USD Time: 3-29d	Addicts for heroin (n=60)	Addicts for prescription opioids (n=25)	X > Y**
	Gambling dependence [7]	Amount: 1 - 1000 USD Time: 6h, 1d, 7d, 60d, 180d, 365d, and 1825d	Severe pathological gambling patients (n=24)	Mild sick gambling patients (n=38)	X > Y*

ADHD[6]		Amount: 1 - 10 cents Time: 13s, 25s	ADHD (n=17)	Healthy controls (n=24)	X > Y**
Depression [9]		Amount: SS, 25-35 Ib; Medium reward 50-60Ib; LL,75-85Ib Time: 7-186d	Patients with major depressive disorder (n=24)	Healthy controls (n=29)	LL group, X > Y**
Anxiety[18]		Amount: RMB 50-130Yuan Time: 2 weeks, and 1 Month	High-trait anxiety (n=26)	Low-trait anxiety (n=26)	X > Y*
Eating disorder	Anorexia nervosa [13]	Amount: 0.16-34.04 USD Time: 2 weeks, and 4 weeks	AN (n=23)	Healthy controls (n=17)	X < Y **
	Bulimia nervosa [19]	Amount: 50-130 Ib Time: 3 months	BN (n=29)	Healthy controls (n=53)	X > Y *
OCD [15]		Amount: 25-100 USD Time: 3 months	A. OCD B. OCPD C. OCD+OCP (n=25)	Healthy controls (n=25)	B < A**; C < A**; B < Y**; C < Y**;
Schizophrenia [12]		Amount: 400 - 800 USD Time: 2 weeks, 1 month, 6 months, 1 year, 3 years and 10 years	SZ (n=21)	Healthy controls (n=31)	X > Y ***

*p < 0.05, **p < 0.01, *** p < 0.001.

5 PROSPECTS

With the development of brain functional imaging technology, the cognitive process and neural mechanisms can be gradually discussed in detail. The irrational psychological characteristics are gradually integrated into the economic model of intertemporal choice. The choice of mankind in the tasks of intertemporal choice is affected not only by the attitude of time, but also other external factors that transcend the temporal preferences, including, personality, family accomplishment, education level, emotion and environment of different individuals, etc. The intertemporal choice is regarded as one of the criteria to evaluate the individual's rationality. As for the patients with substance addiction disorders, it has been proved that different physiological states (smoking, alcoholism, and insomnia), conditioned stimuli and intervention therapy (training work memory) can be used to regulate the occurrence of discount rate changes. However, there was no study on whether the long-term intervention would affect the discount rate of the patients. This may be the direction of future research. The time discount of intertemporal choice is associated with a series of mental disorders, such as, all kinds of addictions, eating disorders, etc. However, to explore whether the intertemporal choice results are the same among mental disorders, or whether the internal neural mechanisms are different will be one of the research directions in the future.

FUNDING SUPPORT

This paper was supported by Shanghai Jiao Tong University School of Medicine-Institute of Neuroscience Research Center for Brain Disorder (grant No.: 13dz2260500).

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