

FRONTAL DECISION-MAKING SYSTEM

FRONTALNI SISTEM DONOŠENJA ODLUKA

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Abstract: *Frontal decision making system is both deliberative and automatic. Cognitive part of this system is mediated by prefrontal areas and emotive by limbic system and amygdala. Dopaminergic system is important in this function. The decision making process is constantly adjusted. Orbitofrontal cortex constantly evaluates the desirability of each action and adjusts decision-making strategy according to the current situation. If the environment is rapidly changing or is uncertain, the anterior cingulate cortex includes in decision-making. Interaction between prefrontal cortex and basal ganglia is necessary for decision-making. Autoactivation is mediated by medial prefrontal cortex and internal pallidum. Apathy is a result of disruption of prefrontal decision-making system that consists of prefrontal cortex and prefrontal-subcortical neuronal circuits. Theory of mind (ToM) describes our ability to understand the mental state of others and to appreciate how it differs from our mental state and to predict their behavior. It is believed that the cellular level of ToM are mirror neurons. Impairment of the ToM leads to problems in social relations, providing adequate information, commenting on the conversation, thought disturbance and results in poor communication skills.*

Key words: *Frontal decision- making system, apathy, theory of mind*

Sažetak: *Frontalni sistem donošenja odluka je i svesni i automatski. Kognitivni deo ovog sistema je posredovan prefrontalnim oblastima, a emotivni limbičkim sistemom i amigdalom. Dopaminergički sistem je važan za ovu funkciju. Proces donošenja odluka se neprestano prilagođava. Orbitofrontalna kora stalno ocenjuje poželjnost svake akcije i podešava strategiju odlučivanja prema trenutnoj situaciji. Ako se okruženje brzo menja, ili je neizvesno, prednja cingularna kora se uključuje u donošenje odluka. Interakcija između prefrontalnog korteksa i bazalnih ganglija je neophodna za donošenje odluka. Autoaktivacija je posredovana medijalnim prefrontalnim korteksom i unutrašnjim palidumom. Apatija je posledica prekida prefrontalnog sistema odlučivanja koji se sastoji od prefrontalni korteks i prefrontalni-subkortikalnim neuronskih kola. Teorija uma opisuje našu sposobnost da razumemo mentalno stanje drugih i da procenjujemo kako se razlikuje od našeg mentalnog stanja te da se predvidi njihovo ponašanje. Veruje se da je na ćelijskom nivou teorija uma posredovana ogledalskim neuronima. Poremećaj teorije uma dovo-*

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di do problema u društvenim odnosima, pružanja odgovarajućih informacija, komentarisanja konverzacije, poremećaja misli i dovodi do loših socijalnih veština.

Ključne reči: : Frontalni sistem donošenja odluka, apatija, teorija uma

INTRODUCTION

Psychological models hypothesize that there are two systems of decision making: a bottom-up system and a top-down system (1). The bottom-up system is automatic, emotional and implicit while top-down system is deliberative, cognitive and explicit and both can be used for the same task. While the prefrontal regions would be in charge of the cognitive system, limbic reward system would mediate the emotional system (especially the amygdala). Dual model has many weaknesses and is very simplistic. The abovementioned systems work together. There are multiple computations going on in the brain to choose a presumably right decision (2). Deliberate choice is supposedly mediated by attractor neuronal network that is a group of interconnected cells with a stable firing pattern. Prefrontal system can oppose bottom-up system and amplify alternative options. They can interact with dopaminergic reinforcement signals (3). The prefrontal system has to relay on both the long term probabilities and recent data to develop a model of a real world and make a final decision how to act. Lesions of the prefrontal cortex lead to decreased ability to make choices (2).

Anatomo-functional correlation

Decision-making system is the function of the lateral frontal cortex, orbitofrontal cortex and anterior cingulate cortex (4). The lateral prefrontal cortex reveals optimal actions in accordance with a given environment. Orbitofrontal cortex monitors possible effects of sensory stimuli, and the anterior cingulate cortex evaluates alternative actions. This includes decision making in social context. Decision making is a process in which an individual chooses a particular response based on the as-

essment of potential costs and benefits associated with alternative actions. The decision making process is dynamic and constantly adjusted according to individual experience.

In order to achieve any action external and internal determinants are necessary and they drive the motivation, the choice of goals, creating plan for action, its initiation, execution and assessment of the effects of activities in relation to the original target (5). This is actually paraphrasing Luria's principles of thinking i.e. problem solving that depend on the prefrontal cortex (6).

Orbitofrontal cortex constantly evaluates the desirability of each action and adjusts decision-making strategy according to the current situation or when previously successful actions are no longer an advantage. It is thought that decision-making disturbances originate from orbitofrontal cortex lesions as seen in patients with frontotemporal dementia and addicts (7). Experiments in lower primates have shown that the orbitofrontal cortex estimated expected reward and penalty. But in judging of the reward in stimuli of similar value both dorsomedial and dorsolateral cortices are activated (8). Dorsomedial cortex would detect the conflict while dorsolateral cortex is involved in resolving conflict influencing attention. At the bottom end, inferior frontal gyrus would select an appropriate motor response.

If the environment is rapidly changing or is uncertain, the anterior cingulate cortex (ACC) includes in decision-making (9). Neurons in this area evaluate the outcomes of actions and modulate the behavior according to the observed errors. By comparing the old successful responses and current actions new strategies are constantly generat-

ed. Also it is the ACC that combine information about costs and benefits.

Decision making is extremely important in a social context because the environment is dynamic, and the reactions of other people are not always predictable. Orbitofrontal cortex lesions lead to loss of social dominance with increased aversion and decreasing aggression in threatening situations (10). Lesions of the anterior cingulate cortex in animals lead to reduced interest in gathering information about social stimuli (11).

Interaction between prefrontal cortex and basal ganglia is necessary for decision-making. Disruption of connections between these structures leads to apathy. The emotional aspects of an activity depend on ventromedial prefrontal cortex, ventral striatum and amygdala. The cognitive aspects of behavior are processed in the lateral prefrontal cortex and dorsal caudate and is necessary for the implementation of activities.

The third neural system is necessary for autoactivation and consists of medial prefrontal cortex and internal palidum. Disruption of any of the three circuits can lead to apathy. The basal ganglia can determine the important information from the available information and suppress the noise. It is believed that dopamine is of particular importance for decision making (5).

Apathy

Apathy is defined as a lack of motivation that can not be attributed to the reduction of consciousness, cognitive disorder, or emotional distress (12). Reduction occurs in the area of voluntary self-initiated activities and purposeful activities (13). Apathy is a result of disruption of prefrontal decision-making system that consists of prefrontal cortex and prefrontal-subcortical neuronal circuits. Apathy occurs in the course of dementia and is the most common neuropsychiatric symptom in these diseases (5). Sometimes apathy is seen already in the stage of mild cognitive impairment, probably due to development of pathology in ventromedial frontal structures disrupting emotional circuit namely the amygdala and nucle-

us accumbens. Also of significance is the pathology of the orbitofrontal cortex and ACC.

Differential diagnosis of apathy encompass depression but apathy lacks negative thoughts, sadness, and somatic complaints. Antidepressants are not effective in apathy, and selective serotonin reuptake inhibitors can even make it worse.

Theory of mind

One of the important functions of the prefrontal cortex is "theory of mind" (ToM) (14). It is important for making decisions with social consequences. Theory of mind is a psychological construct that describes our ability to understand the mental state of others and to appreciate how it differs from our mental state and to predict their behavior. The ability of ToM is necessary for normal social functioning.

Anatomical basis of ToM is a special area of the medial prefrontal cortex (intentions, desires, beliefs), predominantly right hemisphere for visual stimuli, and the area of the upper temporal sulcus, which deals with explicit information about the behavior. The upper temporal sulcus integrates visual information from posterior parietal area that recognizes the position of objects in space, and the lower temporal area that recognizes objects. So the posterior area perceives other persons, and anterior/frontal generates assumptions about their intentions. Certain structures are common to the ToM and executive function, although these are separate neuropsychological functions. It is believed that the cellular level of ToM are mirror neurons that are active when a person performs a particular action but also when another person performs the same action.

Impairment of the ToM leads to problems in social relations, providing adequate information, commenting on the conversation, thought disturbance and results in poor communication skills. Such individuals have difficulty to put themselves into others point of view, to predict outcomes and identify others' intentions. Patients with schizophrenia have difficulties in communication and have delusions of control due to disruptions of ToM abilities. Problems of this type are present also in individuals with autism and in Asperger syndrome.

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