ISSN 2959-409X

Neural circuit mechanism and influencing factors of time perception

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Abstract:

Human perception of time depends on the subjective structure of the individual, so everyone is different. However, the performance of these time perceptions is also affected by objective neurological factors, such as biological rhythm, cortical striatum circuit, and circadian rhythm. This research has summarized a small part of some factors that affect the human body's time perception and looks for the connection between these factors. This research introduced how the pineal gland adjusts the biological rhythm through the received sunlight signal so that the biological rhythm of the body is consistent with the cycle of the environment. It introduced how the cortical striatum interacts with dopamine energy, and it can also explain how the coding reward prediction error (RPE) experiment proves that the cortical striatum and dopamine interaction helps us distinguish the difference between time intervals. Finally, this research introduced some areas of the brain that affect the circadian rhythm, including the prefrontal cortex, basal ganglion, and striatum, and induced the projection of dense parts from black matter. This research also introduced a mainstream neurological time perception model, and introduced through which brain areas the signal reaches the prefrontal cortex of the brain and finally makes "perception". The introduction of time perception in this research is not comprehensive, and the topic of the role of the nervous system in time perception also needs to be studied in more depth.

Keywords: Time perception; Neuroscience; Neural circuit; Mechanism; Stimulate.

1. Introduction

Time perception is the basis of all human cognitive activities and action skills [1]. Time perception is so large that it is related to the control of individual sleep, awakening, metabolism, and reproductive breeding. It is related to diet, exercise, and other life activities. It is so small that it affects the control of individual dynamics and the generation of language. Time in daily life can be divided into two types. One is the time of objective existence, which does not change because of human will. It can be understood as the time measured by tools, such as six o'clock in the morning. The other is the time that the individual subjectively feels, which is closely related to the individual's characteristics, emotions, and environment. On the same day, some people spend the day like a year, and some people feel a flash in time. The speed of this subjective perception of time is the perception of time. Huang Xiting defines time perception as the speed and length of time that individuals subjectively perceive when not using any timing tools. Individual time perception is formed and developed in society and is affected by many factors, such as the surrounding environment of the individual, the current emotional state of the individual, and the personality characteristics of the individual [2]. Research shows that time perception is a necessary basic ability for human beings and will affect the development of individual cognitive processes [3]. Hornik believes that time perception is the conversion between subjective and objective time or the match between the two [4].

The neural circuit is the foundation of the conduction of pulse signals in time reception. If the time reception in human bodies can be compared to the ratio of short-wave communication, the neural circuit, nerve cells with different characters and functions form the circuit via different types of complicated connections, can be the symbol of the medium of short-wave transmission. The pulse signals, however, are just like the messages we want to send to the other end of our communication. We stimulate the pacemaker (telephone), and the stimulation causes the pulse signal to be produced, which is then received by the other end and shown on the telephone screen. This leads us to the mainstream model of time perception in neurophysiology: the pacemaker produces the pulse signal, and then the signals are transmitted to each different part of the brain by the neuro circuit to be disposed of. Our brain makes the decision to perceive time [5]. In this process, the neurochemicals connect many parts of our brain, such as the basal ganglion, the corpus striatum, or the prefrontal cortex; at the same time, it is related to many neurotransmitters; the most important is dopamine.

This research is mainly about the neuro circuit mechanism and influential factors of time perception. This research will account for the different perceptual models and mechanisms. First, it will explain the time perception based on dopamine, which is secreted due to the simulation of emotion, medicine, or exercise, and the pacemaker-gate-totalizer modal. Second, owing to the difference in types and presentative time of external stimulation, the perception of time has differences. Third, the alternative of the sun‘s rays day and night can influence our time perception. Rays in the environment activate retinal specialized photoreceptor ganglion cells(ipRGCs), and then the optical information is transmitted to the pineal body by sympathetic ganglion neurons in the brainstem. Finally, the affected release of melatonin will regulate the perception of time.

2. Mechanism of time perception

2.1 The model of dopamine

Time perception due to dopamine is mostly related to the mechanisms of emotion, memory, and attention. Dopamine directly influences the emotions of organisms, and medicine, alcohol, exercise, and other factors may stimulate the secretion of dopamine and then the difference in time perception. This kind of time perception relies on the cooperation of encephalic regions. The current model in neuroscience shows several steps: pacemaker (makes the impulse), gate (regulates the threshold value of transmitting the information), and totalizer (stores the impulse). Specifically, the substantia spinal makes the rhythm signal as a pacemaker. The signal goes across the corpus striatum (gate) and arrives at the bursae interglobular pallidum (totalizer). The signal travels through the thalamus and to the prefrontal cortex. The prefrontal cortex compares it with the relevant memories to make the final „perception" [6]. The model of version-influenced time reception has a few of the same steps as the model of dopamine. But they have differences in the pacemaker. The pacemaker in the version-influenced time perception model can make more complicated impulses [7].

2.2 The neural circuits involved in time perception

The representation of time perception and time measurement depends on subjective structures, which change according to changes in our concepts, beliefs, social needs, and technological progress. Similarly, our perception of the past, future, and present is a subjective representation that depends on everyone‘s psychological time and biological time. Therefore, there is no single, one-size-all time; it is a different subjective time for everyone. It needs to acknowledge the existence of time between different individuals and the existence of time within individuals. According to the different reference systems, these times have different functions and different rhythms. However, the construction of these time perceptions and representations is affected by objective factors (physiology, physics, and cognition) related to neuroscience. However, regardless of the time reference system, several constants can be identified in the many representations of time and their corresponding measures. These include the concept of movement repeated in a stable rhythm mode, involving repetition at the same time interval. This allows us to define equal units of time with constant duration. This rhythm also exists at the physiological level and contributes to the existence of biological time through the circadian rhythm, especially the melatonin rhythm [8].

The regulation of the biological clock is based on many factors, among which the day and night change of sunlight is the most important. The pineal gland cannot directly receive light information, so the light of the environment will activate the retinal specialized photosensitive ganglion cells (ipRGCs), ipRGC through the retina-the hypothalamus pathway is projected into the suprachiasmatic nucleus (SCN) of the hypothalamus. The sympathetic ganglion neurons of the brain stem transmit light information to the pineal gland. The pineal gland will regulate the release of melatonin. After nightfall, light stimulation is weakened; under the action of the optic supranuclear, the enzyme activity of the pineal synthesized melatonin is enhanced, and its secretion is in the early morning. At 2-3 o‘clock, the point reaches its peak, and then gradually decreases until dawn. After sunrise, the secretion stops. The suprachiasmatic nucleus is a nerve center that can control melatonin secretion and affect the circadian rhythm. The neurons in the center have melatonin receptors. Melatonin can be used as an endogenous factor to act on the suprachiasmatic nucleus, adjust the biological rhythm, and make the cycle of the environment consistent with the biological rhythm of the body. Time perception from seconds to minutes is called interval timing and is essential for a variety of cognitive processes such as memory, learning, and decision-making. Involving corticostriatal circuitry through dopamine-the interaction of glutamate energy pathways [9]. The cortical tritium is involved in some time perception and processing in time perception. It helps us distinguish different periods, for example, to judge the difference between one minute and one hour. It plays a role in the formation and maintenance of the time interval: it helps us estimate the length of time, for example, to judge the time interval between two events.

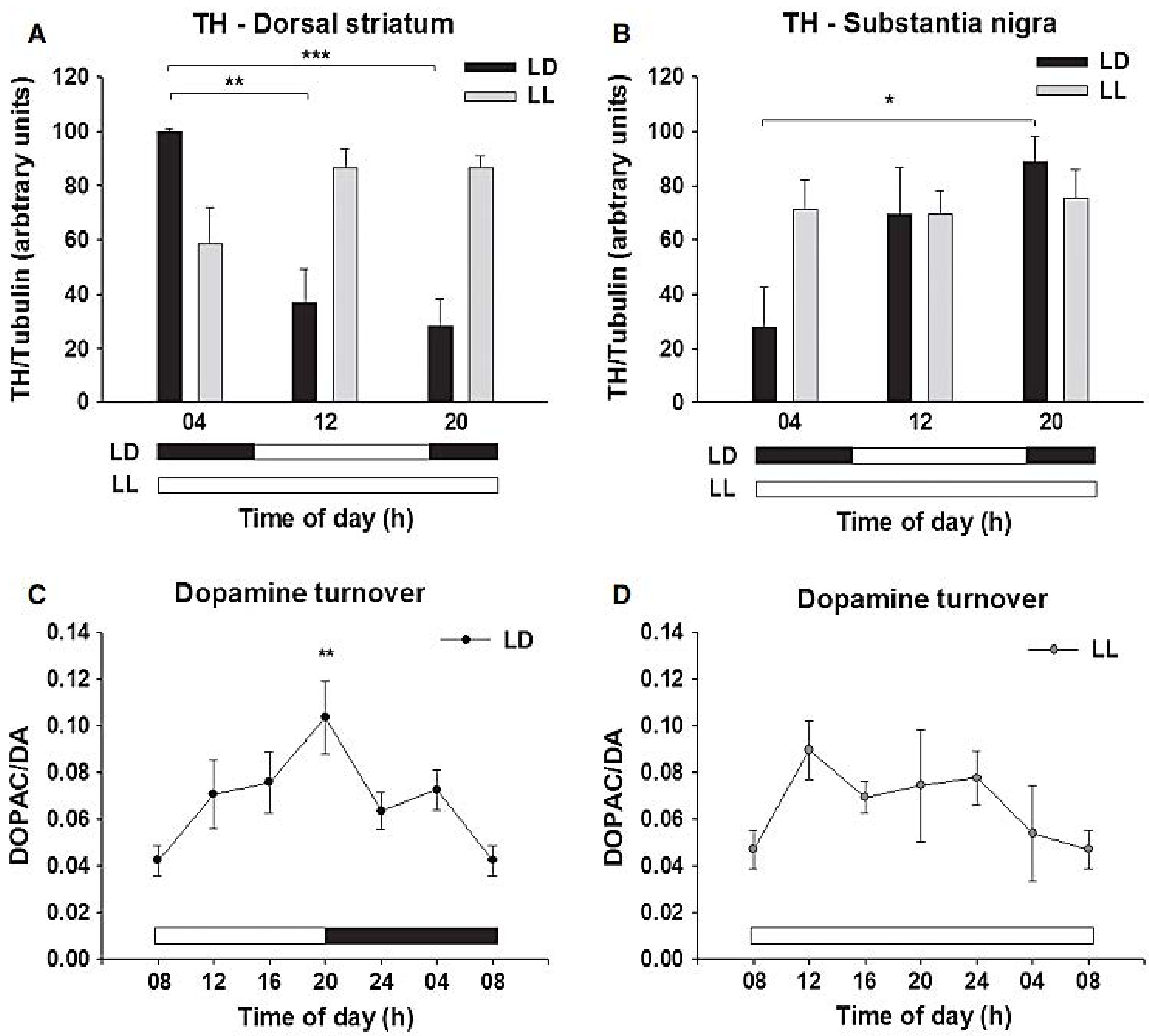

Fig. 1 The daily oscillations of dopamine (DA) synthesis and conversion. Levels of tyrosine hydroxylase (TH) protein during the day (A) striatum and (B) substantia nigra. (C) and (D) Conversion of DA in the striatum [10].

The basal ganglion is a group of interconnected subcortical nuclei that integrate information from multiple brain centers to regulate target orientation. The striatum is the main output structure of the basal ganglion, and a series of complex neurotransmitters and neuromodulators control its function. This includes dopamine (DA), which is covered by the ventral side of the middle brain (VTA) and the black matter dense part (SNC). The long-range axons produced by neurons are released in the striatum. DA neurons (DANs) are predicted by coding reward (RPE) to drive reinforcement learning; RPE is the error of dopamine activity coding for external stimuli or reward expectations, that is, the deviation or error between the actual reward obtained and the predicted time and reward size, and in terms of mechanism through the regulation of neurons and synaptic functions. When the reward (that is, there is a prediction error), the dopamine level increases, prompting people to maintain the previous behavior of reward. The experiment found that the greater the prediction error, the greater the degree of distortion of people‘s perception of time. This also explains how the cortical striatum interacts with DA energy and helps us distinguish the differences in time intervals.

In addition to interval timing, most organisms show a circadian rhythm in the following period. The cycle is close to 24 physiological, metabolic, and behavioral functions for hours. Experimental results show that some areas of the brain, including the prefrontal cortex, basal ganglion, striatum, and their inflow projection dense parts from black matter, are necessary for interval timing. DA function is also needed because increased DA availability will lead to the acceleration of the clock. Still, excessively high levels will lead to the reduction of the clock speed or the interruption of the timing mechanism. Because the change of DA corresponding transporter (DAT) will affect the mouse's perception of time, and when DAT is eliminated, the mice showed a complete loss of time control. DAT and tyrosine hydroxylase show a circadian rhythm in the medial prefrontal cortex, ambush nucleus, and striatum. Transient overexpression of D2 receptors in the striatum may also lead to impaired timing accuracy and precision through motivational effects. Because regulates the circadian rhythm oscillation of PER2 expression in the rat striatum through D2 receptors. As shown in Fig. 1, the circadian control of dopaminergic enzymes can be achieved through TH involvement in rhythm DA synthesis, rhythmic DA release, or rhythmic degradation [10].

3. Influencing factors of time perception

Not only are the internal and external factors of the body an important factor of time perception, but the stimulus factor is also an important factor of time perception [1]. Depending on the presentation time of a stimulus, there will also be a difference in its time perception. People underestimate the longer time interval and overestimate the shorter time interval [11]. The type of stimulus will also affect time perception; that is, the subject's perception of the duration of the digital stimulus will be affected by the numerical value of the number [11]. In detail, when the value and quantity of the stimulus are inconsistent with its duration, when the value and quantity of the stimulus are consistent with its presentation time, the response error rate of the subject is low [12]. The stimulus state affects time perception. Compared with static stimulation, the time presented by dynamic stimulation is overrated [13]. And the stimulus dimension also affects time perception. Compared with the stimulation of the small dimension, the subjects judged that the stimulation of the large dimension lasted longer [14].

Biological orientation hypothesizes that the processing of time information in the human body is like the watch [15]. There are time counters in the human body. Specifically, the time counter regulates the time in the body. The premise of this orientation is that the body has basic perceptual capacity. Because the body perceives the time through the internal watch, every variable that can influence the body, such as temperature and medicine, can impact the timing watch and let it overestimate or underestimate the time [16]. The level of physiological arousal also affects the internal clock [17].

Cognitive orientation states that the processing of time information is closely related to attention and memory. Compared to the biological orientation, the model in cognitive orientation has an additional time register module, which allows the information obtained by the totalizer to be stored provisionally and chunked, thus forming larger time units to expand the time information capacity [18].

4. Conclusion

Time perception is influenced by a variety of factors, such as cognitive attention, mood, DA, biological clock, and so on. When we study the mechanism of time perception, we simulate it into a time perception model, and temperature, drug emotion, and emotion are all influencing factors. The effects on time perception were analyzed from two perspectives: the DA striatal system and the circadian clock neural circuit. And the effects of corticostriatum and DA-influenced interval meter on brain time perception information processing. In this study, we analyze the influence of factors on time perception and summarize them. In this process, it can help us understand how human cognitive processes process information. Understanding time perception can help people optimize time management and thus improve time-related decisions. By studying time perception, it can provide new ideas and methods for psychological treatment and improve mental health and emotional state. The research on time perception can also provide new ideas and methods for the development of technology. With the development of brain science neuroscience, it can explore more deeply how the brain processes time perception. Using techniques such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG) can reveal aspects of the brain's neural activity patterns when processing time perception, among others. Future research could explore how psychological interventions and treatments can change people's perception of time to improve their mental health. For psychological problems such as anxiety and depression, the study of time perception can provide new methods and ideas.

Authors Contribution

All the authors contributed equally, and their names were listed alphabetically.

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