

The Impact of Sleep Chronotype on Psychological Well-being and its Underlying Neural Mechanisms

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Abstract. Biological rhythms have long been a focus of the investigation, and sleep chronotype is one study area. Many studies have shown that the morning-type sleep chronotype is a protective factor for psychological well-being, while the evening-type sleep chronotype is associated with psychological distress. This paper aims to summarize and elucidate recent research on the impact of sleep chronotype on psychological well-being and to explore possible underlying mechanisms at the neural level. Finally, directions for future research are highlighted.

1 INTRODUCTION

Biological rhythms refer to cyclical variations of specific physiological processes (such as sleep, appetite, and body temperature) within living organisms over time. Human biological rhythms are composed of both endogenous rhythms and exogenous rhythms. Endogenous rhythms are generated spontaneously within the organism, such as the 'endogenous sleep-wake regulation system' that periodically regulates sleep [10]. Differences in biological rhythms among individuals manifest as differences in sleep chronotypes or preferences for sleep and wake times. While the benefits of being an early riser have been established compared to other diurnal preferences for physical health [20], the underlying neural mechanisms and systematic explanations remain unclear. Changes in sleep patterns, particularly the habits of working overtime and staying up late, have become common in current society, especially among young people. However, such sleep patterns may pose a great hidden danger to individuals' physical and mental health. This paper aims to summarize and synthesize the impact of sleep chronotype on individual psychological well-being and the underlying potential neural mechanisms from a behavioral neuroscience perspective and to make prospects for future developments based on the limitations of current research.

2 SLEEP CHRONOTYPE

2.1 Definition and types of sleep chronotype

Sleep chronotype refers to an individual's sleep habits within a day, including wake, sleep times, and duration [21]. Sleep chronotype is influenced by endogenous rhythms within the individual and external factors such as social and work schedules and environmental light exposure [40]. Endogenous rhythms refer to the natural,

periodic changes in physiological functioning within the human body throughout the day [12]. Based on an individual's sleep chronotype, three types can be distinguished: morning, afternoon, and evening. Morning types tend to fall asleep before 9 pm and wake up after 6 am, afternoon types tend to fall asleep around 10 pm and wake up around 7 am, and evening types tend to fall asleep after midnight and wake up after 8 am [21]. This classification can also be distinguished by periodic physiological indicators such as body temperature and melatonin [1]. The type of sleep chronotype may be related to an individual's physiological characteristics, lifestyle, occupation, and cultural background [40]. For example, older individuals tend to be more inclined toward morning-type sleep chronotypes [41], while high school and university students tend to be more inclined toward evening-type sleep chronotypes [43]. Additionally, manual laborers perform physical tasks as a primary function (Occupational Safety and Health Administration, 2021). They tend to be more inclined towards the morning-type sleep chronotype [2], while white-collar workers tend to be more inclined towards the evening-type sleep chronotype [26]. Sleep chronotype is related to an individual's quality of life and health status [41]. For example, morning-type individuals are more prone to developing depression and anxiety [37], while evening-type individuals may have better memory and attention [41].

2.2 Measurement of sleep chronotype

Various methods for measuring sleep chronotypes include questionnaire surveys, self-report measures, and laboratory measurements. Questionnaire surveys involve the use of specific questionnaires, such as the Morningness-Eveningness Questionnaire (MCTQ) or the Sleep Chronotype Questionnaire (SCTQ) [21, 40], to measure an individual's sleep chronotype. These questionnaires typically include wake time, sleep time, sleep quality, and the number of awakenings. Self-report

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measures involve an individual reporting their sleep chronotype based on their perceptions, using tools such as sleep diaries, daily time records, and actigraphy. Actigraphy is a small, wrist-worn device that uses sensors to detect an individual's movement status (individual's ability to move their body or limbs in the desired way [28]) and determine whether they are in a sleep state (the different stages of sleep that an individual goes through during a sleep cycle [31]). The advantage of actigraphy is that it allows for continuous monitoring of an individual's sleep, providing more accurate results than questionnaire surveys [14]. Laboratory measurements involve measuring an individual's sleep chronotype in a laboratory setting using polysomnography [24]. Polysomnography is a sleep study conducted in a laboratory or sleep center. During polysomnography, a person sleeps while hooked up to equipment that measures brain waves, eye movements, muscle activity, and other physiological signals. Polysomnography can provide detailed information about an individual's sleep stages, sleep-wake patterns, and any sleep disorders they may be experiencing. With this information, the researchers can figure individual's sleep chronotype.

2.3 Influence on mental health

According to Hidalgo et al. (2009) [20], sleep chronotype can help individuals understand their biological clock or ability to perceive and regulate time. It can also help individuals understand their sleep habits, such as sleep duration, quality, and whether there are any sleep disorders. Sleep chronotype has a significant impact on an individual's mental health. According to Au and Reece (2017) [3], early risers perform well in learning and memory, while late risers tend to feel tired and have difficulty focusing. In addition, sleep chronotype can also affect an individual's emotions and cognitive abilities. According to Qiao et al. (2020) [34], early risers have more stable emotions, while late risers tend to feel anxious and depressed. In addition, sleep chronotype can also affect an individual's social skills and relationships. According to Fagnoli et al. (2018) [18], early risers excel in social skills and relationships, while late risers tend to feel isolated and rejected. The impact of sleep chronotypes on an individual's mental health is not only influenced by the individual, but also by environmental factors. According to Adan and Almirall (2016) [1], there is a close connection between sleep chronotype and social norms. If an individual's sleep chronotype does not match their surrounding environment, it can lead to sleep disorders, mood swings, and difficulty focusing. The impact of sleep chronotype on behavior is also related to an individual's profession and work environment. According to Roenneberg et al. (2007) [37], a sleep chronotype that matches social time is advantageous for an individual's career, while those that do not match may lead to problems such as absenteeism and accidents.

3 The neural mechanisms by which sleep chronotypes influence mental health

The term "neural level" refers to the level of analysis at which the nervous system is being studied. In other words, it refers to the level of detail at which the structure and function of the nervous system are being examined. With the continuous development and enrichment of research tools, some advanced cognitive neuroscience techniques have been widely used to examine the neurophysiological mechanisms behind human psychological and behavioral activities, and sleep chronotypes are no exception. Sleep chronotypes are related to dopamine levels in the body and cognitive function levels in individuals [1]. Dopamine is a neurotransmitter that plays a crucial role in regulating behavior and emotions, while cognitive function involves various aspects of cognitive processes such as attention, memory, and decision-making. Therefore, when sleep chronotype changes, an individual's dopamine levels, and cognitive function also undergo corresponding changes, which can impact their mental health. In addition, sleep chronotypes are related to neuropeptides in the brain [17], which are chemical substances composed of protein amino acid residues such as peptides and anti-depressant pept. The expression and secretion of these neurotransmitters and neuropeptides are influenced by sleep chronotypes and play a crucial role in regulating an individual's mental health.

Sleep chronotype is also related to the stability of endogenous rhythms [20]. The biological rhythm of the human body is composed of both endogenous rhythms and exogenous rhythms. Endogenous rhythms are spontaneously produced within the organism, such as the "endogenous sleep regulation system" that periodically regulates sleep [10]. Exogenous rhythms are the effects of environmental factors on the biological rhythms within the organism, such as the regulation of human physiological processes by sunlight [4]. Research has shown that endogenous rhythms are one of the main factors influencing sleep chronotype. Endogenous rhythms are mainly controlled by the "endogenous sleep regulation system," which has a rhythm period of about 24 hours and is called the "endogenous sleep-wake rhythm" [10]. Endogenous sleep regulatory systems refer to a set of intrinsic mechanisms that regulate individual sleep cycles. It comprises a group of neurons, biological rhythms, and chemicals that help individuals adjust their sleep-wake cycles to changes in the external environment. The endogenous sleep regulatory system is mainly composed of two parts: the biological clock in the brain and sleep homeostat [10]. A biological clock is a group of neurons in the brain that can regulate individual biological rhythms, such as circadian and seasonal rhythms. It is mainly regulated by genes such as variable loop transcription regulator (CLOCK), monocyclic keto kinase (PER), monocyclic keto kinase reaction chain (CRY), and variable loop transcription regulator reaction chain (REV-ERB). The expression of these genes can be affected by endogenous rhythms and external

environmental factors such as light. It can affect an individual's biological rhythm by regulating the expression of other genes [27]. Sleep homeostat is a group of neurons in the brain that can regulate the sleep needs of individuals. It is mainly composed of olfactory centers in the brain (olfactory bulbs), anterior thalamus (prefrontal cortex) and basal ganglia (basal hominins forebrain), and other parts [22, 39]. The sleep homeostat gradually accumulates sleep demands while the individual is awake and gradually clears them while the individual is asleep. Endogenous rhythms and external environmental factors such as exercise and diet influence the activity of sleep homeostat. It can influence individual sleep needs by regulating the expression of neurotransmitters and neuropeptides in the brain. Endogenous sleep regulatory systems can help individuals regulate the sleep-wake cycle to adapt to the changes in the external environment. However, disturbance of the endogenous sleep regulatory system, such as disrupting the circadian clock or damaging sleep homeostat, may lead to sleep disorders [10].

The mechanism of the endogenous sleep regulation system may also be related to certain chemical substances produced within the human body, such as melatonin and hypnotics. Melatonin may promote sleep, while hypnosis may inhibit sleep [10]. Melatonin is mainly produced in the pineal gland and promotes sleep by inhibiting the production of hypnotics [4]. Melatonin production is influenced by light exposure, with increased production in dark conditions and decreased production in light conditions. Therefore, maintaining moderate indoor lighting at night and avoiding electronic products may stimulate melatonin production and promote sleep. Hypnosis is another chemical substance produced within the body and is primarily produced in the hypnogenic area of the brain, inhibiting sleep by inhibiting melatonin production [4]. Light exposure also influences hypnotic production, with increased production in light conditions and decreased production in dark conditions. Therefore, maintaining adequate daylight may stimulate hypnotic production and inhibit sleep. The endogenous sleep regulation system is one of the essential factors influencing sleep chronotype, and melatonin and hypnotics are important chemical substances within it. By adjusting lifestyle and environmental factors, the endogenous sleep regulation system can be effectively influenced to adjust sleep chronotype.

4 Discussion

In recent years, more and more researchers have been studying the relationship between sleep chronotype and mental health and brain function and have made significant findings. This paper will discuss the effects of sleep chronotype on individual mental health and explore the possible mechanisms of this influence from a neurobiological perspective. At the same time, the paper will also identify the limitations and shortcomings of current research and suggest directions for future investigation.

1. Currently, research often uses a single behavioral measurement tool to describe the effects of sleep chronotype on mental health, which may lead to limitations in the results. For example, self-reporting sleep questionnaires to describe the effects of sleep chronotype on mental health may be influenced by individual self-report ability. Therefore, future research can consider using various behavioral measurement tools to describe the effects of sleep chronotype on mental health more accurately. Therefore, in future research, more accurate multimodal measurement techniques can be considered to assess an individual's sleep chronotype more accurately.
2. Many studies only describe the relationship between sleep chronotype and mental health, needing more in-depth exploration of the mechanisms of the effects of sleep chronotype on behavior. Future research can consider using brain imaging techniques (such as functional magnetic resonance imaging, fMRI) to explore the effects of sleep chronotype on behavior. These techniques can help researchers more accurately describe the effects of sleep chronotype on brain activity, assisting in better understanding the underlying mechanisms.
3. Current research often takes place in a Western cultural context, and the relationship between sleep chronotype and mental health may vary across cultural contexts. Therefore, future research can consider conducting cross-cultural studies to more accurately describe the relationship between sleep chronotype and mental health in different cultural contexts.
4. Future research can also explore the interactions between sleep chronotype and other factors such as gender, age, genetics, and lifestyle. According to Dijk and Czeisler (1995) [17], factors such as gender, age, and genetics may affect an individual's sleep chronotype. At the same time, lifestyle factors such as diet, exercise, and stress levels may also impact sleep chronotype. Therefore, understanding the impact of these factors on sleep chronotype can help us better regulate our sleep chronotype and improve physical and mental health.
5. Future research can also explore the effects of sleep chronotype on society and the economy. According to Roenneberg et al. (2004) [35], sleep chronotype may impact an individual's work efficiency and career development and may also affect the efficiency of society and the development of the economy. Therefore, understanding the effects of sleep chronotype on society and the economy can help develop effective policies to promote social development and economic growth.
6. Further advanced intervention research can improve individuals' sleep quality and efficiency. For example, many studies have shown that cognitive-behavioral therapy (CBT) is an effective sleep chronotype intervention method, helping individuals improve sleep habits and reduce the occurrence of sleep disorders [29]. In addition, future researchers can continue exploring

pharmacological intervention's effects on sleep chronotype. For example, some studies have shown that using melatonin-type drugs can improve sleep quality, but there are also concerns about their safety [38]. Therefore, future research will continue to study the effectiveness and safety of pharmacological interventions to find more effective solutions.

5 Conclusion

In summary, the effects of sleep chronotype on mental health still need further research. Future research can consider exploring from more angles to describe the effects of sleep chronotype on mental health more accurately. In addition, future research can also use a multi-disciplinary approach to better reveal the neurobiological mechanisms behind sleep chronotype and provide practical guidance for regulating sleep chronotype.

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