INTRODUCTION TO INTELLECTUAL ANALYSIS OF CHRONOBIOLOGICAL PROCESSES IN THE DEVELOPMENT OF THE STUDENT'S MENTAL ABILITIES

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Abstract. In this research work, a new approach to traditional educational practices was taken, and the issues of deeper intellectual research into the ways of cognitive processes formation of circadian rhythms were considered. Based on IoT signals, including smart watch data, the aim is to research subtle ways in which Circadian rhythms can strengthen students' memory, focus, and general cognitive performance. The methods of intellectual analysis of chronobiology are researched, and as a result of the research, it is aimed not only at clarifying technologies for teachers to adjust their approach to the individual needs of students, but also at innovative scientific-practical research on the integration of science and education.

Keywords. Cognitive development, chronobiological processes, circadian rhythm, physiological functions, chronotype, IoT, smartwatch, photoplethysmography, heart rate, electrocardiogram.

INTRODUCTION

In an effort to create a favorable environment for optimal learning and cognitive development, educators and researchers increasingly pay attention to the complex relationship between chronobiological processes and intellectual growth of students [1-9]. This intellectual analysis explores the unique interplay between biology and cognition, [1]seeking to uncover the profound impact that research on circadian rhythms has on students' intellectual development.

Circadian rhythms are the internal biological clocks that govern our physiological functions on a 24-hour cycle (over a day, 24 hours and 11 minutes) and play an important role in regulating sleep-wake patterns, hormone release, and cognitive peaks and troughs. Recognizing the importance of these biological rhythms in the intellectual domain opens new avenues for understanding how students learn, retain information, and solve the academic challenges they face [1,7,8].

This research takes us beyond traditional educational practices and prompts a deeper intellectual exploration of the ways in which circadian rhythms shape cognitive processes. From the optimal timing of lessons to the strategic planning of exams, every aspect of the educational model is subject to the influence of these biological rhythms.

[1]Circadian rhythm - Latin *circa* "around, within" + *dies* "day".

Thus, the intellectual analysis of chronobiological processes becomes a lens through which we can reimagine and strengthen the foundations of our educational systems.

This article aims to reveal the subtle ways in which circadian rhythms influence memory, focus, and general cognitive performance. The intellectual analysis of chronobiology is researched, and the result of the research is aimed not only at clarifying the technologies for teachers to adapt their approach to the individual needs of students, but also at innovative scientific-practical research on the integration of science and education.

The impact of intellectual analysis of chronobiological processes on the development of students' mental abilities was studied. Through this analysis, it is envisioned to develop effective and practical teaching methods that not only recognize the biological rhythms of students, but also use them to develop a richer and more intellectually lively learning experience.

Chronobiological processes are the body's natural rhythms that regulate various physiological functions, including sleep-wake cycles, hormone production, and metabolism. These processes are influenced by external factors such as light and temperature and are essential for maintaining optimal physical and mental health.

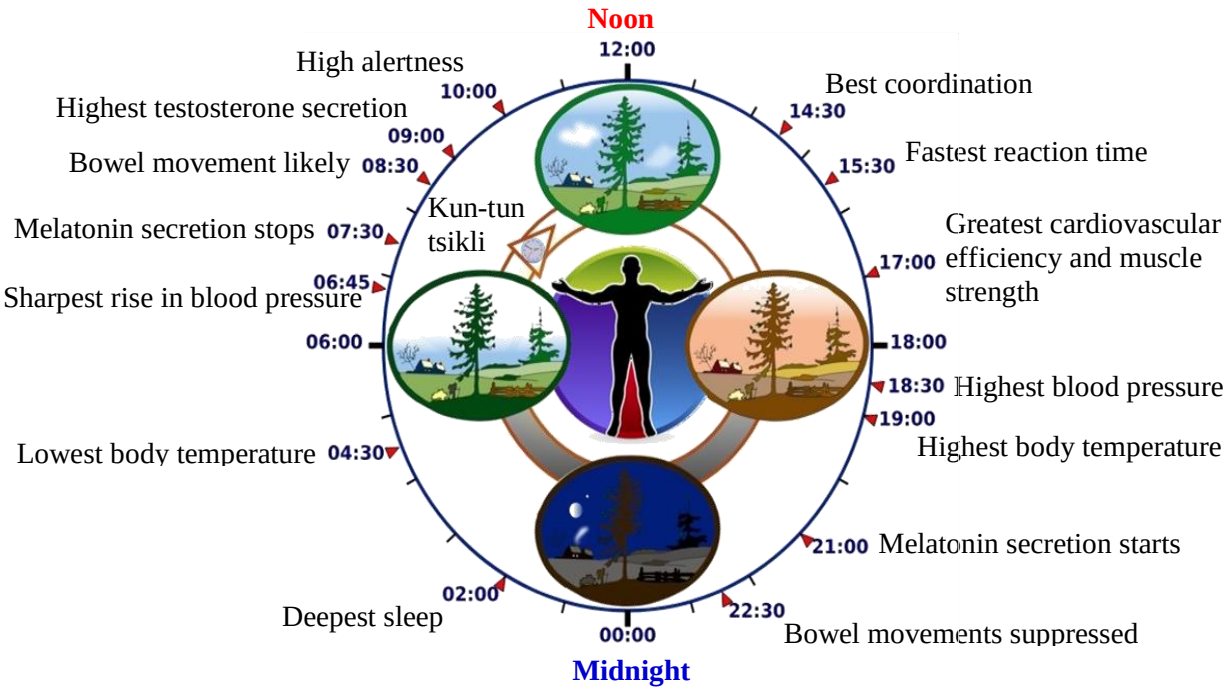

Figure 1. Circadian rhythm characteristic of an early riser: eats lunch at noon and goes to bed at 10:00 p.m. [20].

Studies have shown [17] that disruption of these natural rhythms can negatively affect cognitive function, including attention, memory, and learning. For example, irregular sleep patterns can lead to fatigue, decreased cognitive function, and mood disorders. Therefore, it is very important to analyze these processes in order to develop optimal mental abilities in students.

Therefore, understanding and analyzing these chronobiological processes may be crucial in developing optimal mental abilities in students. This includes developing strategies to promote healthy sleep habits, such as creating a consistent sleep schedule and taking steps to minimize exposure to electronic devices before bedtime [10,11,12]. Intellectual analysis of chronobiological processes involves studying the effects of these rhythms on cognitive function and developing strategies to optimize learning and academic performance. Through intellectual analysis of chronobiological processes, educators can identify students who may be at risk of cognitive problems due to disruptions in natural rhythms. By identifying these students early and taking appropriate measures, it helps them develop healthy habits and develop pedagogical methods aimed at maximizing their cognitive potential.

Intellectual analysis of chronobiological processes is very important for the development of optimal mental abilities in students. By understanding and regulating these natural rhythms, educators can help students develop healthy habits and reach their full potential academically and personally.

Methods of analysis of chronobiological processes in the development of mental abilities

Studying the results of the analysis of chronobiological processes in people, it can be concluded that the maturation of a person is a biological process that cannot be achieved by force. That is, personal growth and the development of educational competence are complex processes that include biological, psychological and environmental factors. These processes and their importance can be highlighted separately.

Personal growth refers to the continuous development of a person's potential, abilities, understanding of himself and the world. It includes emotional, intellectual and sometimes spiritual development. This process is influenced by a combination of genetic factors, life experiences, and the environment [14].

Educational competence includes the ability to acquire, understand and apply knowledge and skills. It includes both formal learning (with a teacher) and informal learning (without a teacher) experiences.

Biological process, that is, biological factors such as genetics and brain development, play an important role in the formation of the ability and potential of a person to acquire knowledge. For example, cognitive development, which is crucial to student learning, is influenced by biological processes in the brain.

The fact that personal development cannot be achieved by force means that personal growth and learning abilities cannot be easily imposed or imposed on the individual. Instead, these processes require a supportive and enabling environment that fosters learning and personal development.

Creating an environment that fosters natural development, curiosity and a love of learning is essential to facilitate these processes. Educational systems that recognize

and respect the individual's pace of learning and personal development can positively contribute to these outcomes.

For this, it is necessary to consider the following:

- Circadian rhythms strongly influence the sleep-wake cycle. The quality and quantity of sleep, in turn, affects cognitive functions such as memory, attention, and problem solving;
- The human circadian rhythm cycle has optimal times for learning and memory consolidation. Learning during wakefulness and consolidating memories during sleep are essential for cognitive development;
- Cortisol levels fluctuate in the circadian rhythm cycle . Cortisol helps to adapt to stressful situations and changing environmental conditions. The highest values of the cortisol level compared to the norm correspond to an increase in cognitive activity;
- Melatonin, which is released in response to darkness, helps regulate the sleep-wake cycle. Disruptions in melatonin production can affect sleep quality and consequently cognitive performance;
- Age-related changes, circadian rhythms change throughout life. For example, teenagers often change their preferences during the day, which leads to later bedtimes and waking times. This shift may affect academic performance due to misalignment with school schedules;
- The timing of learning activities can affect learning outcomes. It has been proposed to adjust class schedule times to accommodate the natural daily preferences of different age groups to increase learning efficiency;
- Cognitive impairment in shift work - Individuals who work shift work, which disrupts natural circadian rhythms, may experience cognitive impairment. This is especially relevant for professions that require constant attention and critical decision-making;
- A degree of flexibility and tolerance can be determined in circadian disruptions. However, chronic disruption of circadian rhythms can have lasting negative consequences for cognitive function and health;
- Individual diversity - chronotypes. People have different chronotypes, which represent when they prefer to be active and alert. Morning types (birds) and evening types (owls) may experience changes in cognitive performance at different times of the day.

Understanding these rhythms helps to develop strategies to optimize cognitive functions, educational practices, and work (lesson) schedules so that they are consistent with natural biological patterns and contribute to overall well-being.

Table 1.

Analysis and significance of chronobiological processes

T/r	Process	Factors	Results
1	Choosing the optimal time for training	Circadian rhythms and cognitive peaks	It allows you to schedule activities and lessons during the periods when students are most alert and focused.
		Coordination of the lesson schedule	Adapting class schedules to students' natural circadian preferences can improve attendance, engagement, and academic performance.
2	Memory and concentration	Sleep-wake cycles and memory consolidation	Circadian rhythms affect sleep patterns and memory consolidation. Aligning study times with optimal sleep times can enhance retention of learned material
		Awareness and attention	Circadian changes in alertness can affect attention
3	Changes in puberty	Understanding Developmental Change	Adolescents often change their circadian preferences, resulting in later bedtimes and wake times. Recognizing and accepting these changes can contribute to better academic performance and well-being
		Class schedule times	Academic performance, attendance, and overall health can be improved by aligning school schedules with teens' sleep-wake patterns, research shows.
4	Reducing academic depression	Optimization of exam schedules	Circadian rhythms can affect cognitive performance during exams. Scheduling exams during periods of peak alertness can reduce stress and improve performance
		Balancing the study load	Recognizing times of day when cognitive abilities may be naturally lower can inform the design of schedules that balance workload throughout the day.
5	Individual approaches	Consider chronotypes* *Chronotypes: early ("toragai"), intermediate ("pigeons") and late ("owls").*	Students have different chronotypes that represent their individual preferences for activity and alertness. Taking these individual differences into account allows for more personalized and effective teaching strategies
		Customized Education:	Teaching methods can be adapted to the optimal time for each student, which can increase understanding and engagement
6	Prevention of fatigue and exhaustion	Do not overload	Being aware of circadian rhythms can help teachers avoid scheduling

			intense or demanding activities during periods when students are most likely to be tired or fatigued.
		Promoting well-being	Prioritizing breaks and allowing breaks during periods of low alertness can contribute to students' overall well-being and mental health

*People with an early chronotype go to sleep and wake up an average of two hours earlier than night owls and are at their peak of intellectual and physical activity in the first half of the day. In people belonging to the evening chronotype, the maximum mental and physical performance occurs in the afternoon. Among men and young people in their twenties, night owls predominate, while children and elderly people often get up early [21].

Table 1 shows that the analysis of chronobiological processes is an integral part of creating an educational system that is not only academically rigorous, but also takes into account biological and psychological factors that affect students' mental abilities. By aligning educational practices with these natural processes, students can create environments that promote optimal learning, cognitive development, and overall well-being.

Instrumental tools used in the analysis of personal chronobiological processes

Analyzing chronobiological processes based on data obtained through IoT (Internet of Things) in the development of optimal decision-making systems for the development of mental abilities in students - includes rare hardware and software complexes and algorithmic support.

1. IoT Sensors:

- Wearable sensors are smart watches, fitness bands or special wearable devices equipped with sensors for monitoring heart rate, sleep mode, body temperature and physical activity;

- Environmental sensors - the user can monitor light conditions, temperature, humidity and noise level in the environment;

- Biometric sensors - sensors for measuring physiological parameters, for example, EEG (Electroencephalogram) for brain wave activity, ECG (Electrocardiogram) for heart rate, etc.;

- Activity sensors – accelerometers and gyroscopes to track physical movements and movements.

2. Data collection and transfer . IoT devices collect data from these sensors and transmit it to a central data processing center via a secure and reliable communication network such as Wi-Fi, Bluetooth, or cellular.

3. Data storage. Data must be stored securely. Cloud-based storage solutions can be used to efficiently store and manage collected data. Services such as AWS, Azure or Google Cloud can be considered.

4. Data preprocessing. Preprocessing is often required to clean, filter, and normalize poorly formatted sensor data. This step helps ensure the accuracy and reliability of the data.

5. Chronobiological algorithm. Development of algorithms for analysis of chronobiological processes. This includes:

- Circadian rhythm analysis – determination of the user's circadian rhythms, including sleep and wake cycles;

- Mental state analysis – linking data obtained from EEG or other brain wave sensors with cognitive states and mental abilities;

- Recognizing patterns – identifying patterns or anomalies in chronobiological data that may affect cognitive abilities.

6. Machine learning and artificial intelligence. Machine learning models help predict and analyze patterns in data [15,16]. For example:

- regression analysis - prediction of mental alertness or performance based on user's chronobiological data.

- personalized recommendations - recommended activities or activities to optimize mental abilities based on individual information.

7. Human-computer communication interface. Develop a user-friendly interface, perhaps in the form of a mobile app or web dashboard, to present the analyzed data to users. This can include real-time feedback on their mental state and recommendations for improvement.

8. Data Security and Privacy. Ensure that collected data is stored and transmitted securely and that user privacy is protected. Compliance with data protection regulations such as GDPR is essential.

9. Supervision and recommendations. Implement mechanisms to provide feedback to users and provide recommendations where appropriate. These recommendations may take the form of guidelines, lifestyle changes, or cognitive training exercises.

10. Life cycle. Algorithms and programs should be regularly updated and improved based on user feedback and new research results.

11. Cooperation. Collaborate with health professionals and researchers in the fields of chronobiology and cognitive science to test the effectiveness of your system.

12. Trial and evaluation. Thorough testing and evaluation of the system to ensure that it delivers the desired results in terms of cognitive development.

13. Compliance with Regulations. Ensure compliance with applicable medical device and data privacy regulations, depending on location and nature of data collected.

This is a complex and interdisciplinary endeavor, requiring expertise in IoT hardware, data science, machine learning, and chronobiology and cognitive science.

Nowadays, smart watches offer the possibility of measuring the physiological parameters of a person. Therefore, we rely on the conclusions of the work [13,22], which comprehensively evaluated the accuracy of heart rate and heart rate variability of Samsung smart-watches.

Photoplethysmography (PPG) is an inexpensive and easy-to-perform technique for measuring vital signs, including heart rate (HR) and heart rate variability (PRV), replacing heart rate variability (HRV). widely used as a suppressor. However, PPG is very sensitive to motion artifacts and environmental noise.

[13] evaluated the accuracy of PPG signals collected by the Samsung Gear Sport smartwatch against a medical-grade chest electrocardiogram (ECG) monitor in terms of HR and HRV frequency parameters in the time-domain. The study was conducted on 28 participants (14 men and 14 women) who went about their daily activities with 24-hour monitoring using a Samsung Gear Sport smartwatch and a Shimmer3 ECG device. The researchers evaluated HR and HRV parameters during sleep and wakefulness. The smartwatch-derived parameters were compared with the ECG reference using the Pearson correlation coefficient, Bland-Altman plot, and linear regression methods (Table 2).

Table 2.

Comparative analysis of data from Samsung Smartwatch and Shimmer3 devices

Parameter	Pearson correlation coefficient	P-value	Confidence interval (95%)	Average deviation	r^2	Mean absolute error
HR	0.941	< 0.001	[-7.53, 6.77]	-0.38	0.882	1.06
AVNN	0.960	< 0.001	[-83.87, 108.59]	12.36 *ms*	0.909	19.79
RMSSD	0.778	< 0.001	[-68.49, 32.01]	-18.24 *ms*	0.405	22.44
SDNN	0.802	< 0.001	[-72.66, 28.29]	-22.19 *ms*	0.246	23.31
PNN50	0.964	< 0.001	[-13.21, 11.58]	-0.81	0.926	4.31
LF	0.784	< 0.001	[-1763.66, 834.77]	-464.45 ms^2	0.206	476.13
HF	0.782	< 0.001	[-1188.67, 693.23]	-247.72 ms^2	0.462	299.77
LF/HF ratio	0.622	< 0.001	[-2.24, 1.72]	-0.26	0.216	0.693

As a result, it has been proven that Samsung smart watches provide acceptable values of HR frequency, HRV in time domain, low frequency power (LF) and high frequency power (HF) during sleep. In contrast, AVN and HRV during wakefulness demonstrate satisfactory accuracy, and other HRV parameters have been reported to have high errors [13].

Conducted test-experience

Four first-year graduate students were selected for the experiment. Students' participation and learning in the educational process was monitored through the www.hemis.samtuit.uz (https://hemis.uz) platform [23]. They were given the Galaxy Watch SM-R800 smart watch with constant wear, timely charging and special settings. The smartwatch includes sensors such as heart rate monitor, accelerometer, gyroscope, barometer and ambient light sensor. It has a number of fitness tracking features, such as starting a workout, quickly viewing activities, tracking sleep, measuring heart rate and stress levels. The Galaxy Watch is designed to work with Android smartphones and can be set up and viewed via the smartphone. Table 3 shows data on students' daily sleep, number of walking steps, and heart rate using this smart watch.

Table 3.

Smart-watch information about students' daily sleep, number of walking steps, heart rate

Personal ID	Date	Sleep Start	Sleep End	Sleep Duration (hours)	Sleep Quality	Movement (steps)	Average Heart Rate
P1	01.04.2023	22:00	06:30	8.5	Good	7500	72
P1	02.04.2023	23:00	06:15	7.25	Fair	5200	80
P1	04/03/2023	22:30	06:00	7.5	Excellent	9200	69
P1	04.04.2023	22:45	06:15	7.5	Good	6500	76
P1	04/05/2023	23:15	06:00	6.75	Fair	5500	81
P1	06.04.2023	22:15	06:15	8	Excellent	7200	70
P1	04/07/2023	22:30	06:00	7.5	Good	8200	72
P1	04/08/2023	23:15	06:15	7	Fair	5200	80
P1	04/09/2023	22:00	06:00	8	Excellent	9500	69
P1	10.04.2023	22:45	06:15	7	Good	6700	76
P1	11.04.2023	23:15	06:00	6.75	Fair	5800	81
P1	12.04.2023	22:15	06:15	8	Excellent	7100	70
P2	01.04.2023	23:30	07:00	7.5	Fair	6000	78
P2	02.04.2023	22:45	06:30	7.75	Excellent	7800	70
P2	04/03/2023	22:00	06:45	8.75	Good	7000	73
P2	04.04.2023	23:30	07:00	7.5	Fair	7200	78
P2	04/05/2023	22:30	06:45	8.25	Excellent	7600	69
P2	06.04.2023	22:45	06:30	7.75	Good	8500	75
P2	04/07/2023	23:00	06:45	7.75	Fair	7500	78
P2	04/08/2023	22:45	06:30	7.75	Excellent	8000	68
P2	04/09/2023	22:15	06:45	8.75	Good	7300	73
P2	10.04.2023	23:30	07:00	7	Fair	7400	78
P2	11.04.2023	22:30	06:45	8.25	Excellent	7600	69
P2	12.04.2023	22:45	06:30	7.75	Good	8400	75
P3	01.04.2023	21:45	05:30	7.75	Excellent	8500	68
P3	02.04.2023	21:30	05:45	8.25	Good	8700	74
P3	04/03/2023	23:45	07:30	7.75	Fair	5800	79
P3	04.04.2023	22:00	06:45	8.75	Excellent	9500	68
P3	04/05/2023	21:30	07:15	9	Good	8900	73

P3	06.04.2023	21:00	05:45	8.75	Fair	9400	76
P3	04/07/2023	22:15	07:15	8	Excellent	6800	70
P3	04/08/2023	21:30	05:45	8.5	Good	7700	74
P3	04/09/2023	23:45	07:15	7.5	Fair	6500	79
P3	10.04.2023	22:00	06:45	8.75	Excellent	8900	68
P3	11.04.2023	21:30	07:15	9	Good	8800	73
P3	12.04.2023	21:00	05:45	8.75	Fair	9300	76
P4	01.04.2023	22:15	06:45	8.5	Good	9000	75
P4	02.04.2023	23:15	07:15	8	Fair	6500	77
P4	04/03/2023	21:15	05:30	8.25	Excellent	8000	71
P4	04.04.2023	21:45	05:30	7.75	Good	8300	74
P4	04/05/2023	23:00	07:30	8.5	Fair	6800	77
P4	06.04.2023	23:30	07:00	7.5	Excellent	6300	79
P4	04/07/2023	21:45	07:30	8.75	Good	9000	73
P4	04/08/2023	23:00	07:00	8	Fair	6900	77
P4	04/09/2023	21:15	05:30	8.5	Excellent	8100	71
P4	10.04.2023	21:45	05:30	7.75	Good	8500	74
P4	11.04.2023	23:00	07:30	8.5	Fair	6600	77
P4	12.04.2023	23:30	07:00	7.5	Excellent	6100	79

This data, it is possible to analyze the daily activities of students. For example, the duration of sleep. It is known that there is a strong connection between the duration of sleep and memory. Sleep plays an important role in the consolidation of memories, which involves the transfer of information from short-term memory to long-term memory. When we sleep, our brain processes and consolidates the information we learned during the day, which helps us remember it better [17].

Research has shown that sleep deprivation can impair memory consolidation, leading to difficulty learning and retaining new information. On the contrary, adequate sleep helps to strengthen memory and improve cognitive performance [18,24].

The exact amount of sleep needed for optimal memory development varies from person to person, but most adults require 7-9 hours of sleep per night. Adolescents and children may need more sleep for healthy brain development and memory consolidation [18].

In general, getting enough sleep is essential for maintaining good cognitive function and memory. If a student is experiencing memory or learning difficulties, sleep habits should be monitored and recommendations should be made to ensure that they are getting enough quality sleep.

If we pay attention to the fact that movement during the day is determined by the number of steps, a lot of movement can be usefully calculated. However, it is possible to think about how much time a student spends after class preparing for class, or playing sports, or working after class. A useful conclusion can be reached by examining the relationship between this information and classroom readiness.

The relationship between heart rate and mental performance is complex and multifaceted. [19] noted that heart rate, a measure of the number of heartbeats per minute, can be affected by a variety of factors, including physical activity, stress, emotions, and general health. It is believed that elevated stress levels can impair cognitive function, making it difficult to concentrate, make decisions, and solve problems. In some cases, the average increase in heart rate is associated with increased alertness and wakefulness, which may enhance certain aspects of mental functioning, such as reaction time and alertness. However, excessively high heart rates or elevated heart rates for long periods of time can have the opposite effect and lead to decreased cognitive performance.

Conclusion

In conclusion, the in-depth study of the intellectual analysis of chronobiological processes in the development of mental abilities of the student gives deep information about the complex relationship between biological rhythms and cognitive activity. Through this study, we found significant effects of circadian rhythms, sleep patterns, and biological clocks on cognitive performance, memory consolidation, and overall academic achievement. Recognizing these connections opens up ways to optimize learning environments and schedules to fully utilize students' intellectual abilities.

In addition, this intellectual research emphasizes the importance of holistic approaches to education that take into account the biological basis of cognitive development. By aligning learning strategies with natural biological rhythms, teachers and administrators can create an environment conducive to improved learning outcomes and mental well-being.

Considering the continuous development of education, it is necessary to integrate the principles of chronobiology into pedagogical practice. Not only does this give students the opportunity to reach their intellectual peak, but it also lays the groundwork for a lifelong appreciation of their biological rhythms and cognitive abilities. Thus, we are trying to conduct research towards a more enlightened, effective and harmonious approach to education, which corresponds to the innate rhythm of human perception.

Analysis of chronobiological processes is necessary to optimize students' mental abilities by adjusting their learning and daily activities to their natural biological rhythms. Adapting teaching and learning schedules to individual chronotypes and cognitive performance patterns can help students reach their full potential and increase academic success. In addition, promoting healthy sleep habits and eliminating disruptions in circadian rhythms can help improve mental abilities and overall well-being.

The methods of machine learning and deep learning help to solve a number of issues in intellectual analysis of chronobiological processes in the development of mental abilities of the student. Machine learning algorithms are used to clean and process data, extract relevant features, and process missing or noisy data. Helps analyze

the relationship between sleep quality, duration and cognitive performance. Machine learning models can provide students with real-time feedback on their cognitive performance based on their current physiological state, helping them make adjustments to their study habits.

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