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Comparative assessment of changes in the psycho-physiological indicators of the organism resulting from desynchronosis

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ABSTRACT

Prolonged reliance on administrative time, rather than natural (solar) time, alters the human body and can negatively affect the psychophysiological health of children and adolescents. Our research aims to assess the psychophysiological state of schoolchildren in regions where geographic time does not align with administrative time. A study of 200 students in grades 9–10 was conducted in two region to compare how desynchronosis affects their psychophysiological state. The regions differed in the gap between official and natural time: in one region, the difference was 45 minutes, and in the other, it was 1 hour and 30 minutes. In the study, participants completed a questionnaire that included socio-demographic information, characteristics of sleep and wakefulness, items from the adolescent-adapted Horne–Östberg questionnaire to determine chronotype, and questions on their subjective experience of forgetfulness and emotional state. In addition, the "NS Psychotest" computer system was used to obtain objective measures of cognitive functions and attention. Current data show that the interrelationships among sleep duration, chronotype, and social jetlag in adolescents systematically affect academic achievement and cognitive functioning. These findings highlight the need to reconsider institutional parameters of the education system (such as school start times and study load) from a biologically grounded perspective. The results highlight the importance of considering regional chronobiological characteristics when organizing the educational process.

Keyword: Adolescent psychophysiological health, Desynchronosis, Biological rhythm, Time zone, Administrative time, Natural time.
Article type: Research Article.

INTRODUCTION

Adolescence is a critical phase of social and neurocognitive development. During this period, adolescents rapidly develop stable study skills, attentional and memory organization, and executive functions. At the same time, increasing academic and extracurricular workloads at school intensify the strain on the sleep-wake system. In modern urban societies, adolescents' sleep is frequently shortened and fragmented, and this phenomenon undoubtedly has a direct impact on cognitive efficiency and mental well-being (Blakemore & Mills 2014; Dewald-Kaufmann *et al.* 2014; Shochat *et al.* 2014). According to the recommendations of the American Academy of Sleep Medicine (AASM), adolescents aged 13-18 should aim for 8-10 hours of sleep per day for optimal physical, emotional, and cognitive functioning (Paruthi *et al.* 2016). However, studies conducted in several countries reveal that the majority of adolescents do not systematically comply with this requirement. In many large cohort studies, it has been found that more than 60-70% of adolescents sleep less than 7-8 hours on school days (Olds *et al.* 2010; Short *et al.* 2013; Short *et al.* 2013; Dewald-Kaufmann *et al.* 2014). Chronic sleep deprivation is closely associated not only with obesity, metabolic dysfunction, increased depressive symptoms and anxiety, but also with a decrease in academic achievement, attention, and a range of executive functions (Curcio *et al.* 2006; Shochat *et al.* 2014; Dewald-Kaufmann & Meijer 2014; Owens & Weiss, 2017). During the adolescent stage, significant biological

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reconstruction occurs in the regulation of sleep and wakefulness. The most significant one of these is the shift of the circadian phase to later times. This change is characterized by a slowing of the rate at which sleepiness accumulates in the evening hours and a tendency to form a "late" sleep mode (Carskadon *et al.* 2004; Hagenauer & Lee 2012). Along with puberty, changes also occur in the sleep–wake pattern, and circadian markers, especially, systematic delay in DLMO (the onset of endogenous melatonin secretion; Crowley *et al.* 2007). In the case of early class start time, these changes lead to a clear mismatch between the biological time and the socially imposed schedule (Roenneberg *et al.* 2012). Chronotype is the main concept that describes individual differences in the daily organization of activity. Chronotype is a person's stable preference for certain sleep-wake times and daily peak of cognitive performance. The Morningness–Eveningness Questionnaire (MEQ) proposed by J.A. Horne and O. Östberg is widely used to assess chronotype, classifying individuals along a continuum as "morning" types ("lark"), "intermediate" types ("pigeon"), and "evening" ("owl") types (Horne & Östberg 1976). Research shows that the late (evening) chronotype is especially common among adolescents and young people, and that group is particularly prone to sleep deprivation (Randler & Frech 2006; Vollmer *et al.* 2013). One of the main consequences of a late chronotype is social jetlag. M. Wittmann and colleagues, who linked it to the difference in sleep phases between workdays and days off (Wittmann *et al.* 2006), introduced this concept. Social jetlag reflects a mismatch between endogenous circadian rhythms and social demands, and is associated with a late chronotype, especially in adolescents. High levels of social jetlag are associated with worsened mood, poorer sleep, emotional instability, and behavioral problems (Levandovski *et al.* 2011; Touitou *et al.* 2015; Díaz-Morales & Escribano 2015). The early start of school lessons can be considered one of the institutional factors that contribute to sleep deprivation and social jetlag. According to the American Academy of Pediatrics, starting classes earlier than 8:30 AM in middle and high schools is associated with chronic sleep deprivation among adolescents and with adverse consequences for their health and academic performance (Owens *et al.* 2014). Studies and meta-analyses on later school start times show that beginning classes later is linked to longer sleep duration, reduced daytime napping, improved well-being, and better individual academic performance (Minges & Redeker 2016; Bowers & Moyer 2017; Marx *et al.* 2017). Moreover, other studies have also shown that short sleep duration is associated with poor school performance and memory problems in children and young adults (Dewald-Kaufmann *et al.* 2014; Dewald-Kaufmann & Meijer 2014). Sleep duration, sleep quality, and severity of sleepiness are each independently associated with academic performance, and the strength of these associations is small to moderate in magnitude (Dewald-Kaufmann *et al.* 2014). Experimental studies complement these epidemiological data. Studies that model partial sleep deprivation in high school students have shown that even a single week of reduced sleep can lead to a gradual decline in attention, reaction time, working memory, and mood (Voderholzer *et al.* 2011; Preckel *et al.* 2011; Lo *et al.* 2012). In addition, studies show that the following "sleep recovery" period does not fully restore neurocognitive functioning to its original level (Voderholzer *et al.* 2011). Importantly, the chronotype is not just a descriptive characteristic but also a moderator of the relationship between sleep and cognitive efficiency. Several studies have shown that, even after accounting for factors such as IQ, motivation, and socioeconomic status, students with a morning chronotype tend to achieve higher academic outcomes. In contrast, those with an evening chronotype tend to have relatively poorer learning outcomes (Vollmer *et al.* 2013; Zerbini 2017). The classic study titled «The lark has an advantage over the owl at high school» showed that, under the standard early school schedule, students with a morning chronotype have a statistically significant advantage in grades compared to their peers with an evening chronotype (Vollmer *et al.* 2013). Similar results have been obtained in school and university samples in various countries (Díaz-Morales & Escribano 2015). Thus, current data suggest that the interrelationships among sleep duration, chronotype, and social jetlag systematically affect both academic achievement and cognitive functioning in adolescents. This issue highlights the need to reconsider the institutional parameters of the education system (class start times and academic workload) from a biologically grounded perspective. Kazakhstan has been known to have switched to a unique administration time UTC+5 from March 2024. Until now, the western regions of the country have been 1.5-2 hours ahead of natural time (the natural time is UTC+4, UTC+3). Therefore, we consider it relevant to conduct research in these areas (Atyrau region). Moreover, the Kostanay region used the UTC+6 administrative time zone until 2024, when it switched to UTC+5. Kostanay region's natural time zone is UTC+4. Kazakhstan currently uses a single UCT+5 administrative time zone introduced in 2024. Therefore, the administrative time zone in Atyrau and Kostanay is UTC+5. Astronomical time depends on geographical longitude, for every 15^0 degrees of longitude =1 hour. The central meridian of the UTC+5 time zone is 75^0 East longitude.

The exact longitude of cities is Atyrau ≈ 51.9° E, and Kostanay ≈ 63.6°E.
The formula for determining the difference from the astronomical time:
Δ t= (longitude−75°)/15\Delta t = (longitude - 75°) / 15Δt = (longitude −75°)/15
According to this calculation, in Atyrau, the administrative time is approximately 1 hour 30 minutes ahead of natural (astronomical) time.
(51.9−75)/15=−23.1/15≈−1.54 hour (51.9 - 75) / 15 = -23.1 / 15 ≈ -1.54
Hour (51.9−75)/15=−23.1/15≈−1.54 hour
That is, when it is 12:00 PM by administrative time, the solar time is approximately 10:30 AM.
While in Kostanay City:
(63.6−75)/15=−11.4/15≈−0.76 hour (63.6 - 75) / 15 = -11.4 / 15 ≈ -0.76
Hour (63.6−75)/15=−11.4/15≈−0.76 hour
In Kostanay, official time is about 45-50 minutes ahead of solar time.
That is, when it is 12:00 PM by official time, the solar time is approximately 11:10–11:15 AM. Chronic use of official time ahead of natural time will undoubtedly cause several changes in the human body. It has a significantly negative impact, especially on children and young adolescents. After examining these issues, the main goal of our research was to assess the psychophysiological state of school students in regions where geographical and administrative time do not coincide.

MATERIALS AND METHODS

Ethical considerations. The research was conducted in strict accordance with international and national bioethical standards, as well as the principles of the 2013 Declaration of Helsinki. The study protocol was approved by the Ethics Committee of the RSE "Institute of Genetics and Physiology", Ministry of Science and Higher Education Republic of Kazakhstan (excerpt from Protocol No. 3 dated October 30, 2023), and by the Scientific Ethics Committee of the JSC "Kazakh National Women's Teacher Training University" (excerpt from Protocol No.6 dated October 10, 2024). Parents of all participants provided written informed consent for their children to take part in the study. Before the study began, the students also provided written consent (via a confirmation form) and oral consent.

Study design. This was a cross-sectional, observational, and descriptive study with no intervention or randomization.

Places and conditions. Data collection took place between November and December 2024-2025 at general secondary schools in the cities of Atyrau and Kostanay. The observations were conducted under normal learning conditions in the first half of the day (8:30 am-12.00 pm) in specially prepared classrooms with standard lighting, a comfortable temperature, and minimal distracting factors. This allowed assessment of the adolescents' psychophysiological state under conditions that were favorable for them and aligned with the school day schedule.

Research participants

Inclusion criteria for the study. The study included students under the following conditions:
Age 15–16 years old.
Full-time study at the comprehensive school according to the standard 11-year program;
Normal psychological development according to data from school medical staff;
Permanent residence in the cities of Atyrau and Kostanay.
Participation in the research and undergoing psychophysiological testing requires the written informed consent of the parents (legal guardians)
Adolescents' oral consent.

Exclusion criteria for the study. The following conditions under which students were not enrolled:
The presence of severe neurological, psychiatric, or marked cognitive disorders;
Taking psychotropic drugs at the time of examination;
The presence of acute illnesses or exacerbation of chronic diseases on the test day.
Refusal to participate by students or parents.

Sampling formation

Sampling continued until the required sample size was reached. Students who did not meet the inclusion and exclusion criteria were excluded from the sample. A total of 200 adolescents studying in grades 9-10 were included in the final analysis.

Research procedure

The purpose of the study, the procedures, and the approximate duration of the examination were explained to the participant, and their consent to participate was reconfirmed.

Under the researcher's supervision, students complete a standardized questionnaire that includes the following information:

Social-demographic data (age, gender);

Sleep and weakness characteristics (time of falling asleep and waking up, sleep duration, subjective assessment of morning alertness, and fatigue).

Questions for determining chronotype using the Horne and Ostberg questionnaire adapted for adolescents.

Subjective evaluation of forgetfulness and emotional state.

Objective evaluation of cognitive function and attention parameters was performed using the Neurosoft software package "NS Psychotest". "NS Psychotest" includes several hundred standardized methods, supports individual and group testing, and uses a database of normative values to compare cognitive functions in healthy and clinical groups. This is a specialized system for conducting psychophysiological tests that record vegetative and emotional reactions, as well as the automated processing of results. All measurements were performed automatically in the units specified by the system's software, which ensured the comparability of results across participants. In the NS-Psychotest complex, several subtests were administered to assess cognitive functions and attention, including numeric and visual memory, visuomotor reaction, attention stability, and error frequency. The conditions, such as seated posture at the desk, distance to the monitor, and lighting level, were kept the same for all participants. After the computer-based testing was completed, the adolescents filled out a self-assessment test using the Kovalev method.

The approximate duration of examining each participant was 60-70 minutes. All instructions and procedures were strictly standardized and applied equally to all students. The research team did not introduce any additional interventions or make any changes to the usual school-day routine.

Tools and variables. The survey was conducted using a standardized self-report questionnaire that included questions about age, gender, bedtimes, and wake-up times on weekdays, duration of nighttime sleep, and the subjective assessment of morning alertness and fatigue. The private section was devoted to subjective forgetfulness and emotional states such as anxiety, irritability, low mood, and others.

To assess chronotype, we used the adolescent-adapted version of the Horne-Östberg Morningness–Eveningness Questionnaire (MEQ), based on the original scale for determining daily preferences and widely used in circadian rhythm research (Curcio *et al.* 2006).

Using the questionnaire with an adolescent sample was based on evidence showing that the modified MEQ versions for children and adolescents have satisfactory and external validity.

Based on the total score, adolescents were classified by chronotype as follows:

Evening type - 5–27 points,

Intermediate type - 28–44 points,

Morning type - 45–69 points.

This category was later used to compare cognitive and personality indicators across the groups.

The level of self-esteem was assessed using Kovalev's test method, "Determining the levels of Self-Esteem". This method is widely used in adolescent and school psychodiagnostics to quantitatively evaluate reliability, emotional stability, and the degree of personality integration. The test consists of a set of statements with graded response options. The total score was classified into three levels: a low level of self-esteem (1.0-2.3 points), a medium level of self-esteem (2.4-3.1 points), and a high level of self-esteem (3.2-4.0 points). These categories were then used for group comparisons and for analyzing the relationships between self-esteem, chronotype, and cognitive indicators. Additionally, we considered gender, sleep, and wakefulness parameters (bedtime and wake-up time, sleep duration, subjective fatigue) as well as subjective forgetfulness and emotional state. It was planned to compare cognitive and personality characteristics among groups with different chronotypes, and to analyze the associations of chronotype with sleep characteristics and subjective state. When comparing numerical indicators among the three chronotypes (morning, intermediate, and evening groups), we used one-way analysis of variance (ANOVA). If the assumption of normal or equal variances was not satisfied, we instead used the Kruskal-Wallis test. To assess the relationship between cognitive indicators (memory, reaction time, and stability

of attention) and chronotype, a Spearman correlation analysis was conducted. For all tests, the levels of statistical significance were set at $p < 0.05$ (two-tailed test).

RESULTS

The study involved 200 adolescents aged 15-16 years. The mean age was 15.48 ± 0.51 years (95% CI: 15.38–15.58). A post hoc evaluation of the statistical power of the sample, assuming an expected effect size of $\eta^2 \geq 0.08$, indicated a statistical power of 0.86, which corresponds to the commonly accepted threshold of adequate power in cross-sectional studies. The gender distribution was relatively balanced: girls comprised 55% of the sample and boys 45%. Table 1 presents the distribution of self-esteem levels according to the Kovalev test. In Atyrau, adolescents showed the following self-esteem levels: high – 60% (expected frequency 50.9), medium– 36% (expected frequency 36.7), and low – 4% (expected frequency 3.1). In Kostanay, the corresponding values were 51%, 47%, and 2%, respectively. The distribution of self-esteem levels differed statistically significantly from a uniform distribution.

Table 1. Self-esteem levels according to the Kovalev test (n = 200).

Cities	**Atyrau**			**Kostanay**		
Self-esteem levels	%	Expected frequency (E)	χ^2 portion	%	Expected frequency (E)	χ^2 portion
High	59.6	50.9	+18.2	51	50.9	+0.2
Medium	36.5	36.7	−1.9	47	36.7	+28.1
Low	3.9	3.1	+29.7	2	3.1	-35.5

According to the data in the table, the levels of self-esteem among adolescents in the cities of Atyrau and Kostanay are expressed differently. An important factor in explaining of these differences is the discrepancy between administrative time and natural geographical time. In Atyrau, the administrative time was 1.5 hours ahead of natural time, while in Kostanay, this difference was only 45 minutes. Scientific literature shows that the gap between the time zone and social time directly affects adolescents' sleep patterns, mood, energy levels, and self-esteem. In Atyrau, the number of adolescents with high self-esteem is significantly higher than expected frequency (+18.2%). The proportion with a medium level has decreased slightly (-1.9%), while the proportion with a low level was considerably higher (+29.7%). Considering these indicators, the large time difference (1.5 hours) appears to cause stress or circadian rhythm disruption in some adolescents, exacerbating low self-esteem. Additionally, in some groups, high self-esteem has been maintained. This condition can be explained by the fact that desynchronosis causes increased irritability and anxiety, disrupted sleep patterns, and heightened emotional instability, which in turn distort self-esteem and lead to a compensatory overstatement. In Kostanay, the proportion of adolescents with a medium level of self-esteem is significantly higher than expected (+28.1%). The proportion with a low level has decreased substantially (-35.5%), while the proportion with a high level is within the expected range (+0.2%). This suggests that the small-time difference (45 minutes) helps keep adolescents' circadian rhythm close to their natural rhythm, reduces stress, and increases average self-esteem. The small difference between administrative time and natural geographical time (in Kostanay) helps maintain the stability and medium level of self-esteem among adolescents. On the contrary, a large difference (in Atyrau, more than 1.5 hours) increases the proportion of adolescents with low self-esteem, which may negatively affect their psycho-emotional state. Therefore, when studying the factors that influence self-esteem in adolescents, it is important to consider the time zone and social/administrative time difference. In secondary schools of Atyrau, adolescents show a pronounced shift toward non-morning chronotypes (Table 2). The morning chronotype was identified in only 3.8% of adolescents, while the intermediate and evening types accounted for 69.8% and 26.4%, respectively. The distribution is statistically non-uniform ($\chi^2 = 82.41$; $p < 0.001$; Cramer's V = 0.64). There is a significant mismatch for most adolescents between their natural sleep rhythms and biological rhythms and the current school schedule. This is shown by their shorter sleep duration (6.3 hours) and the longer time it takes them to fall asleep. A statistically significant difference in the distribution of adolescents' chronotypes was found between the cities of Atyrau and Kostanay ($\chi^2 = 9.08$; df = 2; $p = 0.011$). The largest χ^2 contribution was observed in the "lark" chronotype, meaning that the main differences between the cities were due to the proportion of early chronotypes. In terms of administrative and geographical natural time differences: in Atyrau (where administrative time is +1.5

hours relative to natural time), the proportion of early chronotypes was low (3.8%; 95% CI: 1.0–9.7), while the proportion of late chronotypes was high (26.4%; 95% CI: 18.0–36.4). In Kostanay (a difference of +45 minutes), a higher proportion of early chronotypes was observed (17%; 95% CI: 10.2–26.4). This indicates that the mismatch between administrative time and the natural light cycle delays adolescents' circadian rhythms.

Table 2. Chronotype groups according to the Horne - Ostberg questionnaire (n = 200).

Cities	**Atyrau**			**Kostanay**		
Chronotype	%	For portion 95% CI,	χ^2 portion	%	For portion 95% CI,	χ^2 portion
Larks	3.8	1.0 – 9.7	4.02	17	10.2 – 26.4	4.02
Pigeons	69.8	59.4 – 78.8	0.47	59	48.5 – 69.9	0.47
Owls	26.4	18.0 – 36.4	0.04	24	16.2 – 33.2	0.04
Total	100		4.53	100		4.53
Overall: 9,08 / df = 2 / p = 0.011						

During the study, the levels of memory for numbers and images (pictures) in adolescents were assessed based on their performance (Tables 3 and 4). Analysis of visual memory indicators for images (n = 200) revealed the following pattern: in Atyrau, the average number of correct answers was 9.03 ± 2.06, which corresponds to approximately 56%. This value reflects a below-average level of visual memory performance. Adolescents exhibit overall difficulties in memory for visual images and demonstrate a high tendency to make errors. The comparative analysis shows statistically significant differences ($p < 0.05$–0.001) in the visual memory indicators of adolescents living in Atyrau and Kostanay cities (Table 3). These differences are likely related to disruptions in circadian rhythms caused by a mismatch between geographical location and the administrative time zone. Atyrau is geographically farther west (UTC+4, +3) but officially follows Kazakhstan's unified time zone (UTC+5). As a result, there is a mismatch between the astronomical sunrise time and the social time set by school schedules. This difference causes "social jetlag" and can disrupt adolescents' sleep–wake cycles, hormonal regulation (especially melatonin and cortisol secretion), and cognitive function.

A comparative analysis was conducted among adolescents in Kostanay City to examine key indicators, including the number of correct answers and memory capacity. The results were as follows:

The number of correct answers is high (10.37 ± 2.23 vs 9.03 ± 2.06),

The memory capacity is also significantly higher (55.72 ± 19.34 vs 42.79 ± 20.11),

Based on the point-based assessment, the memory level is also high (3.20 ± 1.2 vs 2.38 ± 1.40).

This data indicates that adolescents in Kostanay have a more effective ability to encode and reproduce visual information.

In terms of the number of mistakes and the forgetfulness index in Atyrau:

The number of mistakes is high (2.18 ± 1.91 v/s 1.4 ± 1.02).

The forgetfulness index is also high (3.61 ± 1.40 v/s 2.79 ± 1.2).

These indicators represent a decrease in attentional stability and short-term memory under conditions of cognitive load.

Given the effects of geographic and temporal factors, Atyrau, farther west in longitude, experiences sunrise later than Kostanay. However, since schooling is organized according to a unified administrative time, adolescents in Atyrau are, from a biological perspective, required to begin their classes at a relatively "earlier" time.

This condition leads to:

Reduced sleep,

A decrease in morning cognitive performance,

A deterioration in visual memory and attention indicators.

In Kosatanay, geographical time and social time are more closely aligned, which helps the circadian system function more steadily, and as a result, memory performance remains at a higher level. This study provides a comprehensive analysis of adolescents' numerical memory performance in cities, accounting for differences in geographical location and administrative time zones (Table 4). As shown in Table 4, the digital short-term memory

and recall abilities of adolescents in Atyrau and Kostanay differ significantly from expected indicators ($p < 0.05$). These differences may be linked to disrupted circadian rhythms and social jetlag arising from a mismatch between geographical and administrative time zones.

Table 3. The level of picture memory in adolescents.

	Indicators of visual memory (n = 200)						
	Number of correct answers	**Total number of selected images**	**Number of given images**	**Number of mistakes**	**Amount of memory**	**Memory on a point scale [1-5]: 1 is low, 5 is high**	**Forgetfullness index [1-5] 5 is high**
Atyrau	9.03 ± 2.06	11.22 ± 2.28	16 ± 0	2.18 ± 1.91	42.79 ± 20.11	2.38 ± 1.40	3.61 ± 1.40
Kostanay	10.37 ± 2.23	11.83 ± 2.12	16 ± 0	1.4 ± 1.02	55.72 ± 19.34	3.20 ± 1.2	2.79 ± 1.2
	The accuracy of deviations from the expected level for the city of Atyrau					$p < 0.05$	$p < 0.001$

As for the number of correct answers and memory capacity, among adolescents in Kostanay, it follows:
Number of correct answers (8.043 ± 1.25 vs 7.51 ± 1.51),
High memory capacity (52.39 ± 16.98 vs 44.25 ± 18.89),
A result higher than the expected level was recorded on a 5-point scale (4.12 ± 0.31 v/s 3.93 ± 0.30). These indicators suggest that adolescents in Kostanay have more efficient processes for encoding, storing, and reproducing numerical information.
In this case, the error rate was higher in Atyrau (2.20 ± 1.38) and lower in Kostanay (1.76 ± 1.21). The increase in the number of mistakes is directly related to reduced attentional stability, cognitive fatigue, and decreased working memory efficiency. About the time allotted for completing the task in both cities:
The time given to complete the task is identical (60 ± 0 seconds),
The number of presented figures is also identical (12 ± 0).
Thus, the equality of methodological conditions indicates that the identified differences are related not to external factors but to physiological and chronobiological characteristics. As mentioned above, the mismatch between astronomical and social time disrupts the sleep-wake rhythm, delays melatonin secretion, and consequently reduces morning cognitive activity and weakens short-term and working memory. Since the neuroendocrine system is restructuring during adolescence, circadian desynchronization has especially strong effects. Among adolescents in Atyrau, this results in less efficient memorization of numerical information and more errors. In contrast, in Kostanay, where geographical and social time are relatively well aligned, the circadian system remains stable, and cognitive functions, including numerical memory, are higher.

Table 4. Adolescents' level of number memorization.

	Indicators of number memorization (n = 200)							
Location	**Number of correct answers**	**Selected numbers**	**Time allowed to choose**	**Number of given numbers**	**Number of mistakes**	**Amount of memory**	**Number of correct answers**	**Expected points, 5-high**
Atyrau	7.51 ± 1.51	9.72 ± 1.72	60 ± 0	12 ± 0	2.20 ± 1.38	44.25 ± 18.89	7.51 ± 1.51	3.93 ± 0.30
Kostanay	8.043 ± 1.25	9.798 ± 1.42	60 ± 0	12 ± 0	1.76 ± 1.21	52.39 ± 16.98	8.043 ± 1.24	4.12 ± 0.31
	The accuracy of deviations from the expected level for Atyrau City							$p < 0.05$

In this study, we compared psychophysiological indicators of visual-motor reaction in adolescents from Atyrau and Kostanay and identified certain differences between the two regions (Table 5). Visual-motor reaction is an important overall indicator that reflects the functional state of the central nervous system, sensorimotor coordination, and attention stability. The similar number of characters in both cities (Atyrau – 69.51 ± 0.55; Kostanay – 69.65 ± 0.50) suggests that the research method was standardized and that the observed differences represent the participants' functional state rather than task difficulty. However, the error pattern displayed region-specific features. Among adolescents in Atyrau, the number of premature button presses was higher (3.34 ± 2.33 vs. 2.68 ± 2.00), suggesting more frequent impulsive responses and weaker inhibitory control. The total number

of errors was also greater in Atyrau (4.76 ± 3.30 vs. 4.20 ± 3.08). Together, these findings indicate a reduced efficiency of the neurophysiological mechanisms that regulate visuomotor reactions and maintain stable attention. An analysis of the quartile indices (K25% and K75%) revealed greater variability in Atyrau compared to Kostanay. The value of (K75%–K25%)/2 was higher in Atyrau (25.85 ± 9.82) than in Kostanay (22.71 ± 6.20). This difference suggests that Atyrau may exhibit less stable functional responses, which could be linked to higher levels of central nervous system fatigue and disturbances in circadian regulation. From both a geographical and chronobiological perspective, this situation can result in reduced psychophysiological activity in adolescents during the morning. This phenomenon, known as "social jetlag," has been linked to slower and less accurate sensorimotor reactions, as described in the literature. The indicators used to assess work capacity based on reaction speed are similar in both cities, with Atyrau measuring at 231.29 ± 30.38 and Kostanay at 231.9 ± 27.4. However, Atyrau showed comparatively lower results for functional mobility (FM) and reaction stability (RS). This suggests that adolescents in Atyrau may experience a decline in their ability to coordinate the timing between receiving information and responding to it. The lower Whipple accuracy coefficient observed in Atyrau (0.93 ± 0.04 vs. 0.95 ± 0.03) suggests reduced accuracy and reliability during visuomotor tasks. This coefficient is a key indicator of attentional stability and sensorimotor coordination. A decrease in this value reflects a diminished ability to adapt to cognitive load.

Table 5. The level of visual-motor reaction in adolescents.

	Indicator of visiual-motor reaction, n=200											
	Number of characters	**Number of missing marks**	**Count of early button press**	**Total number of mistakes**	**K(25%)**	**K(75%)**	**(K75%-K25%)/2**	**Assessing functional capacity by reaction time**	**Assessment of work capacity according to FM**	**Assessment of working capacity by RS**	**Assessment of working capacity by FM**	**Whipple accuracy coefficient**
Atyrau	69.51 ± 0.55	1.42 ± 1.32	3.34 ± 2.33	4.76 ± 3.30	186.39 ± 15.38	238.11 ± 29.99	25.85 ± 9.82	231.29 ± 30.38	4.40 ± 0.29	1.77 ± 0.42	3.38 ± 0.47	0.93 ± 0.04
Kostanay	69.65 ± 0.5	1.521 ± 1.31	2.681 ± 2.00	4.202 ± 3.08	189.3 ± 14.75	234.7 ± 22.39	22.71 ± 6.20	231.9 ± 27.4	4.378 ± 0.29	1.728 ± 0.37	3.33 ± 0.425	0.95 ± 0.03

Data analysis

The research showed that the discrepancy between administrative and natural geographic time significantly affects adolescents' chronotype structure and self-esteem. Statistically significant differences were observed in both self-esteem levels and chronotype distribution among adolescents in Atyrau and Kostanay. In Atyrau, where the time zone is shifted by +1.5 hours relative to natural time, adolescents show fewer early chronotypes, more late chronotypes, and a polarized pattern of self-esteem, with increases in both low and compensatory high levels. Together, these findings indicate disrupted circadian rhythms and heightened social desynchronization (Wittmann *et al.* 2006; Roenneberg 2012). In regions where the difference between administrative and natural time is relatively small (e.g., Kostanay, +45 minutes), the chronotype structure of adolescents is more balanced, and a predominance of average and stable self-esteem levels is observed. This suggests that the harmony between biological and social rhythms creates favorable conditions for maintaining psycho-emotional stability. The study found that, in Atyrau, adolescents experience reduced sleep duration and later sleep onset times, which exacerbates the mismatch between school schedules and their biological rhythms. This chronic desynchronization negatively affects their psycho-emotional state, leading to lower self-esteem and increased emotional instability (Short *et al.* 2013; Owens & Weiss 2017). The results show that time zone and social time are key for assessing adolescents' psychophysiological well-being and planning prevention strategies. Adapting school schedules to regional time patterns, implementing preventive sleep hygiene programs, and applying chronotype-based individualized approaches may be an effective way to enhance adolescents' psycho-emotional stability. The research results can be used as a scientific basis for introducing a health-preserving chronobiological approach into the education system. According to the study results, the differences in the level of visual memory among adolescents in Atyrau and Kostanay are statistically significant (p < 0.005-0.001). These differences may be related to circadian

disruption caused by a mismatch between geographical location and official time zone. In Atyrau, adolescents show reduced visual memory, more errors, and greater forgetfulness due to difficulties aligning their biological rhythms with social time. In Kostanay, the mismatch is smaller, so cognitive performance remains comparatively higher. The results of Table 4 indicate that adolescents in Atyrau and Kostanay differ significantly in their number memorization ($p < 0.05$). Among adolescents in Atyrau, the number of correct answers was low, the memory capacity was limited, the error rates were high, and cognitive scores on a 5-point scale were low. In contrast, in Kostanay, these indicators remained at a high level (Fig. 1).

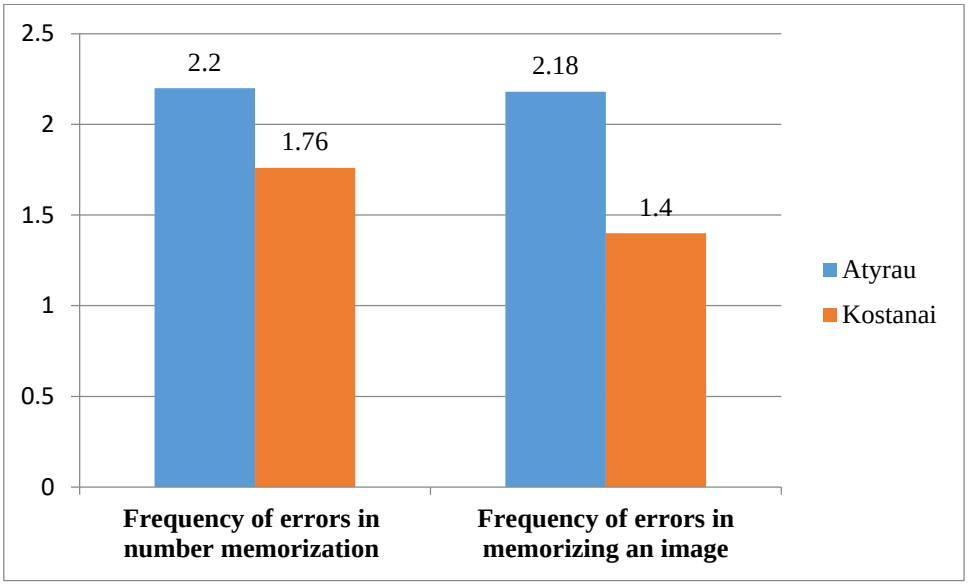

Fig. 1. Frequency of errors in memorizing numbers and images.

The observed differences suggest that circadian desynchrony and social jetlag caused by a mismatch between geographical location and the official time zone have a negative impact on adolescents' digital memory performance. In this study, we compared adolescents' short-term memory for numerical information in Atyrau and Kostanay and found statistically significant differences between the two groups ($p < 0.05$). Our findings indicate that circadian rhythm disturbances (circadian desynchronosis) resulting from a mismatch between geographical location and administrative time zone negatively affect adolescents' cognitive functions, including working memory and numerical memorization. Adolescents in Kostanay had more correct answers (8.04 ± 1.25) and a greater memory span (52.39 ± 16.98) than those in Atyrau (7.51 ± 1.51 and 44.25 ± 18.89, respectively), indicating more efficient encoding and reproduction of numerical information (Fig. 2). These differences were identified even though the time allotted to complete the task and the number of stimuli presented were the same in both cities. This suggests that the results are related not to methodological factors, but to functional and biological characteristics. In Atyrau, the higher number of errors (2.20 ± 1.38 vs. 1.76 ± 1.21) suggests reduced attention stability and decreased working memory efficiency. This may be due to insufficient psychophysiological readiness among adolescents when performing academic tasks in the early morning hours. It is well established that during adolescence, there is a physiological delay in melatonin secretion, and the misalignment between administrative (social) time and geographical (solar) time further exacerbates this process, leading to shorter sleep duration and chronic sleep deprivation (Crowley *et al.* 2007). Since Atyrau is located in Western Kazakhstan, the astronomical sunrise occurs later there than in Kostanay. However, schools in both cities operate according to the same social time. As a result, adolescents in Atyrau must begin school at a time when, biologically, they have not yet fully transitioned into the "wake phase." In the literature, this phenomenon is known as "social jetlag," and it is directly linked to reduced cognitive performance, particularly weaker short-term and working memory. Tasks involving memorizing numbers and processing visual information rely on the coordinated activity of the frontal and parietal brain regions. These brain areas are highly sensitive to circadian rhythms (Schmidt *et al.* 2007). When the circadian system becomes desynchronized, it disrupts neurotransmitter balance (including dopamine and serotonin) and alters cortisol secretion, thereby reducing the speed and accuracy of information processing. In this context, the lower performance observed among adolescents in Atyrau may be linked to temporal mismatches in

neurophysiological regulation. Our results are consistent with earlier studies demonstrating that misaligned time zones and disrupted sleep patterns are linked to reduced attention, weaker memory, and poorer academic performance in school-age children and adolescents. We extend this work by examining these associations across diverse geographical regions of Kazakhstan, thereby clarifying how regional variation may shape these outcomes. Thus, a mismatch between geographical and administrative time zones clearly affects adolescents' digital memory. The relatively low cognitive indicators among adolescents in Atyrau indicate difficulties in aligning their biological rhythms with social time. Together, these results point to the need to adjust school start times to regional geographical conditions and emphasize the value of chronobiological approaches for protecting adolescents' cognitive health.

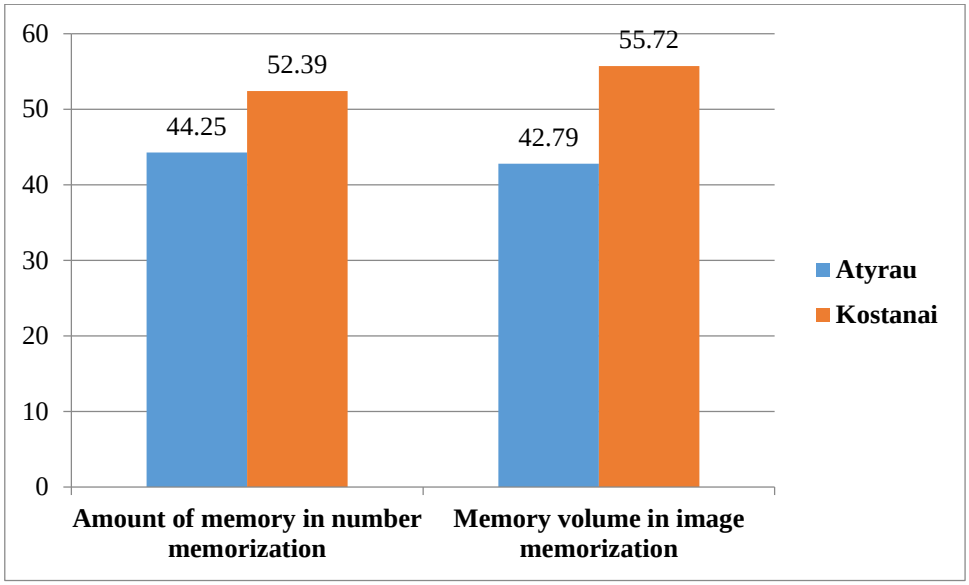

Fig. 2. Memory capacity for numerical and visual stimuli.

Compared with the data on memory for numbers and images, visuomotor reaction in adolescents from Atyrau City is also relatively low. This suggests that these cognitive functions and sensorimotor processes depend on the circadian system and are broadly disrupted under conditions of temporal desynchronosis. Thus, the results presented in Table 5 suggest that a mismatch between geographical location and official time zone negatively affects the accuracy, stability, and working capacity of adolescents' visuomotor reactions. In adolescents from Atyrau, a higher frequency of impulsive errors, greater reaction variability, and a lower accuracy coefficient collectively indicate an unstable functional state of the central nervous system. These data highlight the need to consider regional chronobiological characteristics when organizing the educational process and emphasize the importance of optimizing school start times. Furthermore, to preserve adolescents' psychophysiological health, it is crucial to regulate sleep hygiene, academic workload, and rest schedules in line with chronobiological principles. In this study, we conducted a comprehensive comparison of cognitive and psychophysiological indicators of visual memory, numerical memory, and visual-motor reaction in adolescents from Atyrau and Kostanay. We found clear differences that likely stem from a mismatch between geographical location and administrative time zone. Taken together, these results suggest that adolescents' cognitive functions and sensorimotor reactions depend strongly on the state of their circadian rhythms. According to Table 3, adolescents in Kostanay demonstrated higher visual memory scores than their peers in Atyrau. They provided more correct responses, had a larger memory span, and showed lower error rates and forgetfulness indices ($p < 0.05$–0.001), suggesting more efficient encoding and reproduction of visual information. Conversely, adolescents in Atyrau exhibited more errors and a reduced memory span, which indicates lower cognitive performance. The results presented in Table 4 also confirmed a similar pattern: in Kostanay, indicators of numerical information recall (number of correct responses, memory span, and rating on a 5-point scale) were higher, whereas in Atyrau, the number of errors was greater, and overall efficiency was lower ($p < 0.05$). These findings indicate that working memory and logical processing operations are also sensitive to circadian factors (Lim & Dinges 2010; Killgore 2010). Analysis of the data in Table 5 also revealed regional differences at the sensorimotor level. Among adolescents in Atyrau, the number of premature button presses and the total number of errors were higher, reaction

time variability was greater, and the Whipple accuracy coefficient was lower. This pattern indicates decreased functional stability of the central nervous system, as well as increased impulsivity and reduced attention (Van Dongen *et al.* 2003; Schmidt *et al.* 2007). In Kostanay, by contrast, the accuracy and stability of the reaction remained consistently high. The differences observed across the three tables, obtained under identical methodological conditions (task time, amount of material, and research procedure), appear to stem from biological and chronobiological mechanisms rather than external organizational factors.

CONCLUSION

The obtained results are consistent with international studies, which show that mismatched time zones, disrupted sleep patterns, and social jet lag are associated with decreased attention, impaired memory, and poorer academic performance among school-aged children and adolescents (Minges & Redeker 2016; Marx *et al.* 2017). Our data empirically confirm these across geographically diverse regions of Kazakhstan. By combining the results from Tables 3–5, we found that the mismatch between geographical and administrative time zones has a complex effect on adolescents' cognitive and psychophysiological functions. In adolescents from Atyrau, reduced visual and numerical memory, more errors, and lower accuracy and stability of visuomotor reactions indicate difficulties in adapting their biological rhythms to social time. These results demonstrate the importance of considering regional chronobiological characteristics when organizing the educational process. Optimizing school start times, creating conditions that enable adolescents to maintain proper sleep hygiene, and aligning academic workloads with circadian principles may be effective strategies for improving cognitive performance. In addition, the obtained data can serve as a scientific basis for developing measures to preserve adolescents' cognitive health and prevent its impairment.

Conflicts of interest. The authors declare that there is no conflict of interest.

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REFERENCES

Blakemore, SJ & Mills, KL 2014, Is adolescence a sensitive period for sociocultural processing? *Annual Review of Psychology*, 65: 187–207.

Bowers, JM & Moyer, A 2017, Effects of school start time on students' sleep duration, daytime sleepiness, and attendance: A meta-analysis. *Sleep Health*, 3(6): 423–431.

Carskadon, MA, Acebo, C & Jenni OG 2004, Regulation of adolescent sleep: implications for behavior. *Annals of the New York Academy of Sciences*, 1021: 276–291.

Crowley, SJ, Acebo, C & Carskadon, MA 2007, Sleep, circadian rhythms, and delayed phase in adolescence. *Sleep Medicine*, 8(6): 602–612.

Curcio, G, Ferrara, M & De Gennaro, L 2006, Sleep loss, learning capacity and academic performance. *Sleep Medicine Reviews*, 10(5): 323–337.

Díaz-Morales, JF & Escribano, C 2015, Social jetlag, academic achievement and cognitive performance: understanding gender differences. *Chronobiology International*, 32(6): 822–831.

Dewald-Kaufmann JF & Meijer AM 2014, Sleep duration, sleep quality, and academic performance in adolescents. *Journal of Child Psychology and Psychiatry*, 55(8):889–898.

Dewald-Kaufmann, JF, Oort, FJ & Meijer, AM 2014, The effects of sleep extension on sleep and cognitive performance in adolescents with chronic sleep reduction. *Nature and Science of Sleep*, 6: 1–11.

Hagenauer MH & Lee TM 2012, The neuroendocrine control of the circadian system in adolescence. *Frontiers in Neuroendocrinology*, 33(3): 211–229.

Horne, JA, Östberg, O 1976, A self-assessment questionnaire to determine morningness–eveningness in human circadian rhythms. *International Journal of Chronobiology*, 4: 97–110.

Killgore, WDS 2010, Effects of sleep deprivation on cognition. *Progress in Brain Research*, 185: 105–129.

Levandovski, R, Dantas, G, Fernandes, LC, Caumo, W, Torres, I, Roenneberg, T *et al.* 2011, Depression scores associate with chronotype and social jetlag in a rural population. *Chronobiology International*, 28(9): 771–778.

Lim, J & Dinges, D F 2010, A meta-analysis of the impact of short-term sleep deprivation on cognitive variables. *Psychological Bulletin*, 136(3): 375–389.

Lo, JC, Ong, JL, Leong, RLF, Gooley, JJ & Chee, MWL 2012, Effects of partial sleep deprivation on vigilance and affect in adolescents. *Sleep*, 35(12): 1673–1682.

Minges, KE & Redeker, NS 2016, Delayed school start times and adolescent sleep: a systematic review. *Sleep Medicine Reviews*, 28: 82–91.

Marx, R, Tanner-Smith, EE, Davison, CM, Ufholz, LA, Freeman, J, Shankar, R *et al.* 2017, Later school start times for supporting the education, health, and well-being of high school students. *Sleep Medicine Reviews*, 28: 82–91.

Olds, T, Blunden, S, Petkov, J & Forchino, F 2010, The relationships between sex, age, geography and time use in adolescents. Sleep Medicine Reviews. 14(6): 371–378.

Owens, JA, Weiss, MR, Insana, SP, Kirchner, HL & Dorsey, KB 2014, School start times for adolescents. *Pediatrics*, 134(3): 642–649.

Owens, J, A & Weiss, M R 2017, Insufficient sleep in adolescents: Causes and consequences. *Minerva Pediatrica*, 69(4): 326–336.

Paruthi, S, Brooks, LJ, D'Ambrosio, C, Hall, WA, Kotagal, S, Lloyd, RM *et al.* 2016, Recommended amount of sleep for pediatric populations: a consensus statement of the American Academy of Sleep Medicine. *Journal of Clinical Sleep Medicine*, 12(6): 785–786.

Preckel, F, Lipnevich, AA, Schneider, S & Roberts, RD 2011, Chronotype, cognitive abilities, and academic achievement: A meta-analytic investigation. *Learning and Individual Differences*, 21(5): 483–492.

Randler C & Frech D 2006, Correlation between morningness–eveningness and final school leaving grades. *Biological Rhythm Research*, 37(3): 233–239.

Roenneberg, T, Allebrandt, KV, Merrow, M & Vetter, C 2012, Social jetlag and obesity. *Current Biology*, 22(10): 939–943.

Schmidt, C, Collette, F, Cajochen, C & Peigneux, P 2007, A time to think: Circadian rhythms in human cognition. *Cognitive Neuropsychology*, 24(7): 755–789.

Shochat, T, Tavor, O, Tirosh E & Epstein R 2014, Sleep characteristics, weekday sleep restriction and weekend recovery in adolescents. *Nature and Science of Sleep*, 6: 123–132.

Short, M, A, Gradisar, M, Gill, J & Camfferman, D, 2013, Identifying adolescent sleep problems. Sleep Medicine Reviews, 17(2), 87–95.

Short, MA, Gradisar, M, Gill, J, Camfferman, D 2013, Sleep duration and academic performance: cross-cultural comparisons. *Sleep*, 36(8): 1195–1203.

Touitou Y, Touitou D, Reinberg A 2013, Disruption of adolescents' circadian clock: the vicious circle of media use, exposure to light at night, sleep loss and risk behaviors. *Journal of Physiology-Paris*, 107(4): 352–364.

Van Dongen, HPA, Maislin, G, Mullington, JM & Dinges, DF 2003, The cumulative cost of additional wakefulness: Dose–response effects on neurobehavioral functions. *Sleep*, 26(2): 117–126.

Voderholzer, U, Piosczyk, H, Holz, J, Feige, B, Loessl, B, Kopasz, M *et al.* 2011, Sleep restriction and recovery sleep in adolescents. *Journal of Sleep Research*, 20(4): 593–602.

Vollmer, C, Michel, U & Randler, C 2013, Outdoor light at night is correlated with eveningness in adolescents. *Chronobiology International*, 29(4): 502–508.

Wittmann, M, Dinich, J, Merrow, M & Roenneberg, T, 2006, Social jetlag: Misalignment of biological and social time. *Chronobiology International*, 23(1–2): 497–509.

Zerbini, G, Winnebeck, EC & Merrow, M 2017, Weekly social jetlag is associated with poor academic performance in adolescents. *Scientific Reports*, 7: 16923.

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