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Chronotype and Cognition: Comparison of Executive Functions, Sleepiness, and Fatigue According to Circadian Rhythm Preference

Kronotip ve Kognisyon: Sirkadiyen Ritim Tercihine Göre Yürütücü İşlevler, Uykululuk ve Yorgunluğun Karşılaştırılması

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Abstract

Objective: Individual differences in sleep-wakefulness and, activity timing of individuals are defined as chronotype. This study aimed to compare individuals with different chronotypes in terms of executive functions, sleepiness, fatigue, depression and anxiety.

Materials and Methods: A total of 180 people, 116 (64.4%) women and 64 (35.6%) men, aged 18-45 (23.24±7.20) years, were included in the study. Participants were administered a sociodemographic data form, the morningness-eveningness questionnaire (MEQ), Epworth Sleepiness Scale, Fatigue Severity Scale, Beck depression inventory, Beck anxiety inventory, Digit Span test, Stroop test, Verbal Fluency test, Trail Making test (TMT), and Tower of London test.

Results: Participants were divided into three groups using MEQ: morning-type (n=48), evening-type (n=42), and intermediate-type (n=90). According to the ANOVA findings conducted with the chronotype groups, there was a significant difference between the groups in terms of sleepiness, fatigue, depression, and anxiety scores, and there was a significant difference in favor of the evening-type only in the TMT-A time variable of the neuropsychological tests. According to the results of the correlation analysis, negative significant relationships were found between the scores from the MEQ, sleepiness, fatigue, depression, VFT-animals, and VFT-KAS. Therefore, it can be said that circadian typology has a limited effect on executive functions.

Conclusion: Chronotypes have been found to perform similarly in executive functions such as attention, working memory, verbal fluency, mental flexibility, resistance to interference, planning, and problem-solving.

Keywords: Chronotype, circadian rhythms, cognition, executive functions, fatigue, depression

Öz

Amaç: Bireylerin uyku-uyanıklılık ve aktivite zamanlamasındaki bireysel farklılıkları kronotip olarak tanımlanmaktadır. Bu çalışmada farklı kronotiplere sahip bireylerin yürütücü işlevler, uykululuk, yorgunluk, depresyon ve anksiyete açısından karşılaştırılması amaçlanmıştır.

Gereç ve Yöntem: Yaşları 18-45 (23,24±7,20) aralığında olan 116 (%64,4) kadın ve 64 (%35,6) erkek olmak üzere toplam 180 kişiden oluşan katılımcılara, sosyodemografik veri formu, Sabahlılık ve Akşamlılık Ölçeği (SAÖ) Epworth Uykululuk Ölçeği, Yorgunluk Şiddet Ölçeği, Beck depresyon envanteri, Beck anksiyete envanteri, Sayı Menzili testi, Stroop testi, Sözel Akıcılık testi, İz Sürme testi (İST) ve Londra Kulesi testi uygulanmıştır

Bulgular: Katılımcılar SAÖ kullanılarak sabahçıl tip (n=48), akşamcıl tip (n=42), ara tip (n=90) olarak üç gruba ayrılmıştır. Bu kronotip grupları ile yapılan ANOVA bulgularına göre uykululuk, yorgunluk, depresyon ve anksiyete puanları açısından gruplar arasında anlamlı düzeyde farklılık bulunmuşken nöropsikolojik testlerden sadece İST-A süre değişkeninde akşamcıl tip lehine anlamlı düzeyde bir farklılaşmanın olduğu tespit edilmiştir. Korelasyon analizi sonuçlarına göre SAÖ'den alınan puanlar ile uykululuk, yorgunluk, depresyon, SAT-hayvanlar ve SAT- KAS arasında negatif yönde anlamlı ilişkiler saptanmıştır.

Sonuç: Dikkat, çalışma belleği, sözel akıcılık, zihinsel esneklik, enterferansa direnç, planlama ve problem çözme gibi yürütücü işlevlerde kronotiplerin benzer performans gösterdikleri bulunmuştur. Dolayısıyla sirkadiyen tipolojinin yürütücü işlevler üzerinde sınırlı bir etkisinin olduğu söylenebilir.

Anahtar Kelimeler: Kronotip, sirkadiyen ritimler, biliş, yürütücü işlevler, yorgunluk, depresyon

Introduction

Circadian rhythms are cyclical changes in cellular, molecular, and biologic processes that repeat approximately every 24 hours.[1] Chronotype is a concept that expresses individual differences in sleep-wakefulness and activity timing in the circadian phase.[2] Chronotype is determined by both environmental and genetic factors.[3] Age and sex are also determining factors on

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chronotype.[4] There are studies suggesting that women are more morning-type and men are more evening-type, but there are others reporting that chronotope is independent of sex.[5] In addition, some studies found that the difference between the sexes decreases over time and that after the age of 40 years, both sexes tend to show morning person characteristics.[4]

Chronotypes are classified as morning, evening, and intermediate-types according to the sleep-wake cycle, rest-activity time, and preferred time for physical-mental performance.[6] Approximately 40% of the adult population falls into either the morning or evening-type, and 60% fall into the intermediate-type.[6] Individuals of the morning-type prefer to wake up early go to bed early, feel more awake earlier in the day, and reach their highest mental and physical performance in the morning.[7] By contrast, evening-types tend to sleep at night and wake up late in the morning, and show their highest mental and physical performance in the afternoon or evening.[6] Intermediate-types, positioned between the two ends of the continuum, have characteristics of both chronotypes and generally prefer the middle times of the day for physical and mental activities.[2]

The circadian clock controls 24-hour processes, from physiology to behavior, from gene expression to sleep timing.[3,8,9] Because sleep timing is largely under circadian rhythm control, chronotypes are expected to sleep and wake up on their own circadian clocks.[10] Although sleep and wake times are under the control of the circadian rhythm, individuals often use alarm clocks and/or medications to align their work hours, school schedules, and social activities.[9] The start time of school and work programs, which usually starts early in the day, is the most suitable for the sleep/wake times of morning chronotypes.[9,11] Because of this harmony between the social clock and the circadian clock, morning-types adapt more easily to environmental stimuli and perform better in academic and social areas.[6] Intermediate-types do not have difficulty adapting to external conditions such as social obligations.[10] The incompatibility between the circadian clock and the social clock, which occurs in conditions such as school and work life that require an early start to the day, is evident in evening-types. As a result of this condition, also called social jetlag, evening-types are more likely to experience chronic sleep loss, fatigue, sleepiness, and psychological and metabolic problems.[8]

Executive functions are defined as higher-level cognitive functions that include abilities such as working memory, set shifting, response inhibition, verbal fluency, abstraction, planning, and sustaining attention.[12] The relationship between chronotype and executive functions has been previously studied in the literature. Much of the literature is concerned with the synchrony effect, which refers to the situation where morning people perform better on cognitive tasks performed earlier in the day and evening people perform better on cognitive tasks performed later in the day. Chronotype has been shown to have a strong relationship with executive functioning, with each chronotype tending to perform better than the other at its optimum time (when the time of day is synchronized with one's circadian arousal).[13-16] However, it has also been reported that synchrony does not affect cognitive performance.[17] There are even literature findings that chronotypes perform better in some cognitive tasks outside of their optimum time (asynchrony/asynchronization effect) and that synchrony does not always yield better results.[18] It has been determined that morning people perform worse than evening people even when the tests are performed in the morning in the areas of working memory, processing speed, and visual-spatial areas.[19] It is suggested that the synchrony effect is more pronounced in evening chronotypes than in morning types.[20] It was even found that although there was a synchronization effect for evening people, this was not observed for morning people.[21]

Possible reasons for the conflicting results in studies examining the relationship between chronotype and executive functions include the synchrony effect, the test-repeat effect, homogeneous groups, small sample sizes, use of different cognitive tests, and the fact that circadian preferences in young and middle-aged adults are often dependent on school/work schedules.[22] In addition, it is known that executive functions are not a single function, but a whole of independent processes, and that these processes are affected differently depending on the time the test is taken.[23] As mentioned above, the relationship between chronotype and executive functions under the influence of synchrony has been studied sufficiently in the literature. However, fewer studies have been conducted without mandatory synchrony. In this context, study designs that do not require synchrony and take into account individual time planning have also been suggested in the literature to better understand the relationships between executive function components and chronotype.[24,25] Samples where individuals cannot directly choose their own sleep-wake times and working lives, such as students, and where there is an obligation to start the day early due to social demands are very important groups for this purpose.

The primary aim of this study was to compare the executive function performances of individuals with different chronotype preferences, such as attention, working memory, verbal fluency, mental flexibility, resistance to interference, planning, and problem-solving, as well as sleepiness, fatigue, depression and, anxiety levels. The secondary objective was to examine the relationships between chronotype, sleepiness, fatigue, depression, anxiety, and executive functions.

Materials and Methods

Participants

The participants of this study, in which the correlational survey method was used, consisted of a total of 180 people aged 18-45 (23.24±7.20) years, 116 (64.4%) women and 64 (35.6%) men. Twelve (6.7%) participants were primary school graduates, 7 (3.9%) were secondary school graduates, 8 (4.4%) were high school graduates, and 153 (85%) were university students and graduates. Of the participants, 7 (4%) stated that they used alcohol regularly, 24 (13.3%) stated that they had a coffee habit, 31 (17.3%) stated that they had a smoking habit, and 116 (64.4%) stated that they had no habits.

Procedure

This study was approved by the University of Health Sciences Turkey Hamidiye Scientific Research Ethics Committee (approval number: 14/38, date: 21.07.2023). The criteria for inclusion in the study were age 18-45 years, being at least a primary school graduate, and agreeing to participate in the study. Based on the information obtained from the sociodemographic data form, those with substance abuse, sleep problems, those using drugs that could potentially affect cognitive functions, and those reporting existing neurologic or psychiatric diseases were excluded from the study. Eleven people were excluded because they did not meet these criteria.

After the purpose and method of the study were explained, written informed consent was obtained from the participants. It was also stated that participation in the study was voluntary and that participants could withdraw from the study without giving any reasons. Participants were offered a wide time frame between 08:00 and 20:00, which they determined as the time to be tested for neuropsychological evaluation. Neuropsychological tests were performed by experienced psychologists. It took approximately 1 hour to complete the scales and perform the neuropsychological tests. Participants were administered a sociodemographic data form, the morningness-eveningness questionnaire (MEQ), Epworth Sleepiness Scale (ESS), Fatigue Severity Scale (FSS), Beck depression inventory (BDI), Beck anxiety inventory (BAI), Digit Span test (DST), Stroop test (ST), Verbal Fluency test (VFT), Trail Making test (TMT), and the Tower of London (TOL) test. Neuropsychological tests appropriate to the skills mentioned in the definition of executive functions in the introduction section were selected. After the study was completed, the chronotypes of the participants were determined according to the MEQ they had previously completed. Individuals with total scores between 16-41 were classified as evening-type, those with total scores between 42-58 were classified as intermediate-type, and those with total scores between 59-86 were classified as morning-type.

Assessment Tools

Sociodemographic Data Form: This form was prepared for the study and included information about the participants' age, sex, education level, employment status, sleep habits, psychiatric and medical disease history, and medication use.

Morningness-Eveningness Questionnaire (MEQ): MEQ was developed by Horne and Ostberg[26] in 1976. It is a self-report scale that separates individuals into chronotypes as "evening-type", "intermediate-type", and "morning-type" based on their sleep-wake patterns. It is the most frequently used scale to assess chronotype in both healthy individuals and patient samples. Total scores vary between 16 and 86. Participants who score 16-41 on the scale are classified as "evening-type", those who score 42-58 are classified as "intermediate-type", and those who score 59-86 are classified as "morning-type". The validity and reliability study of the Turkish version of the scale was conducted by Agargun et al.[27]

Epworth Sleepiness Scale (ESS): The ESS is a self-report scale developed by Johns[28] in 1991 that assesses excessive daytime sleepiness. The scale consists of eight questions in total and each question is evaluated in the range of 0-3 points. The highest score that can be obtained from the scale is 24, and scores of 10 and above indicate the presence of excessive daytime sleepiness. The validity and reliability study of the Turkish version of the scale was conducted by Ağargün et al.[29]

Fatigue Severity Scale (FSS): The FSS was developed by Krupp et al.[30] The scale consists of nine items and each item is scored between 1 and 7 (1= completely disagree, 7= completely agree). The total score varies between 9 and 63. A high score on the scale indicates severe fatigue. The validity and reliability study of the Turkish version of the scale was conducted by Armutlu et al.[31]

Beck Depression Inventory (BDI): The BDI was developed to determine the presence and severity of depressive symptoms in adults.[32] The scale consists of 21 items and each item is scored between 0 and 3. The total score varies between 0 and 63. Higher total scores indicate more severe depression. The cut-off score of the scale is 17. The validity and reliability study of the Turkish version has been conducted.[33]

Beck Anxiety Inventory (BAI): The BAI was developed to determine the frequency of anxiety symptoms in adults.[34] It consists of 21 items in total and each item is scored between 0 and 3. The highest score that can be obtained from the scale is 63. A high total score indicates a high level of anxiety experienced by the person. A validity and reliability study was conducted in Turkish.[35]

Digit Span Test (DST): The DST is used to evaluate simple attention and working memory. The test consists of two parts: forward and backward digit span. In both sections, numbers are read to the participant at a rate of one number per second. In the advanced number range, the participant is asked to repeat the numbers said in the same order. In the backward number range, the participant is asked to repeat the numbers from the last to the first. The number of digits in the last repeatable sequence constitutes the person's attention span. Test normative data were collected within the scope of the BILNOT battery.[36]

Stroop Test (ST): This test assesses the ability to change perceptual set-up under interference, the ability to resist the interference of automatic processes, focused attention, and speed of information processing.[37] The participant is asked to say the colors of the colored squares in the first stage and to read the color names in the second stage. After the participant has developed a tendency to read and say colors, in the third stage, the participant is asked not to read the color names written in color but to say in which color the word is printed. The duration of the section where the words are not read but the color is said is subtracted from the duration of the section where the words are read and the color is said. Thus the interference time is calculated. Spontaneous corrections and errors are recorded. A high interference period and a high number of errors and spontaneous corrections indicate that the participant's attention is easily distracted, and that the person has difficulty suppressing inappropriate response tendencies. Test normative data were collected within the scope of the BILNOT battery. [36]

Verbal Fluency Test (VFT): The VFT is used to evaluate complex attention functions (fluency, mental retrieval, and sustaining attention). In the test, the participant is first asked to say animal names for 1 minute and recorded. This section evaluates semantic fluency. The participant is then asked to produce as many words as possible starting with the given letters (K, A, S) for 1 minute. This also measures phonetic fluency. The norms of the Turkish form of the test were collected in a psychology master's study.[38]

Trail Making Test (TMT): The TMT assesses visual-motor conceptual scanning, abstract thinking, the ability to change settings among stimulus sets, inhibition of response tendency, the ability to follow sequences, and attention.[39] It consists of two parts, forms A and B. In form A, the participant is asked to combine the circles containing numbers from 1 to 25 in the correct order and one after the other. In form B, numbers and letters are in circles and the participant is asked to connect the circles to form one number and one letter (such as 1-A, 2-B, 3-C). In the evaluation of the test, the time taken to complete both sections and the number of errors made are used. The interference period is determined by subtracting the duration of form A from the duration of form B. The validity and reliability study of the Turkish version of the test has been conducted.[40]

Tower of London (TOL): The TOL test evaluates executive function skills such as planning and problem-solving. There are several versions of the test, but this study used the Drexel University TOL test version.[41] The test consists of ten problems of increasing difficulty. The validity and reliability study of the Turkish version of the test has been conducted.[42]

Statistical Analysis

The G*Power 3.1.9.4 program was used to determine the number of participants in the study. For one-way analysis of variance (ANOVA), it was found that the smallest sample size should be 180 with an effect size of 0.25, a margin of error of 0.05 and a statistical power of 85%. Cohen[43] states that 80% effect size is sufficient. For statistical analysis, first the minimum and maximum values, and the mean and standard deviation scores of the scores obtained from the scales were calculated, then the skewness and kurtosis values were calculated to determine whether the data set showed normal distribution. Normal distribution calculations were made by taking into account George and Mallery's[44] view that the data set showed normal distribution if the skewness and kurtosis values were between +2 and -2. The differences between the three groups created in the data set were examined using One-Way ANOVA for variables showing normal distribution and the Kruskal-Wallis H test for variables not showing normal distribution. The correlations between the scale scores of the entire group were calculated using Spearman correlation analysis because the data set included scales that did not show normal distribution. The SPSS v.25 program was used for all analyses. The statistical significance level was determined as $p<0.05$.

Results

Demographic Characteristics and Scale Findings

The minimum, maximum, mean, standard deviation, skewness, and kurtosis values of the continuous variables are presented in Table 1. The chronotypes of the participants were determined using the score ranges they received on the MEQ. According to the cut-off scores in the MEQ, 42 (23.33%) participants were found to be evening-type, 90 (50%) were intermediate-type, and 48 (26.67%) were morning-type. One-Way ANOVA was performed to determine whether these groups differed in terms of age, education level, and chronobiologic type. No difference was observed between the groups in terms of education level ($p=0.179$), but it was found that the groups differed in terms of age and chronobiologic type ($p<0.008$ and $p<0.001$, respectively).

In the ANOVA analysis applied to variables showing normal distribution from groups formed according to chronobiologic types, the determination of the homogeneity of the groups was calculated using Levene's test. Because the Levene's test values of the variables other than ESS were $p>0.05$, post hoc analysis was performed using Tamhane correction for ESS and Bonferroni correction for the other variables. As a result of the ANOVA analysis, statistically significant differences were found between the groups in sleepiness, fatigue, depression, and anxiety variables ($p<0.013$, $p<0.001$, $p<0.013$, and $p<0.047$, respectively). As a result of the post hoc analysis performed using Bonferroni correction to determine which groups differed for the variables with significant differences, it was found that there was a significant difference in the depression variable only between the evening and morning types in favor of the evening type, but there was no significant difference between the groups in the fatigue and anxiety variables ($p>0.018$). In the post hoc analysis performed using Tamhane correction for the sleepiness variable, there was no significant difference between the groups ($p>0.018$) (Table 2).

Neuropsychological Test Findings

As a result of the analyses performed to determine whether the study data set showed normal distribution, it was determined that the ST-interference time, ST-number of incorrect answers, ST-number of corrections, TMT-A time, TMT-B time, TMT-B-A, TMT-number of errors, and TOL-total initiation time variables did not show normal distribution; the other variables were found to be in accordance with the normal distribution. According to the Kruskal-Wallis H test performed for variables that did not show normal distribution, a significant difference was found between the groups only in the TMT-A-time ($p<0.034$); no significant difference was found between the groups in other variables. The difference between the groups for the TMT-A-time variable was examined using the Mann-Whitney U test. As a result of the

Table 1. Minimum, maximum, mean, standard deviation, skewness and kurtosis values of the study variables						
	Min.	**Max.**	**Mean**	**SD**	**Skewness**	**Kurtosis**
MEQ	22.00	69.00	49.87	9.50	-0.29	-0.319
ESS	0.00	20.00	7.68	3.95	0.69	0.047
FSS	0.00	63.00	38.59	12.96	-0.36	-0.32
BDI	0.00	33.00	12.38	6.74	0.09	-0.62
BAI	0.00	24.00	12.10	7.17	0.04	-1.15
DST-forward	4.00	8.00	6.67	1.068	-0.36	-0.89
DST-backward	3.00	7.00	4.79	0.93	0.38	-0.19
ST-interference time (sec)	8.00	83.00	33.64	12.47	1.19	2.37
ST-number of incorrect	0.00	6.00	0.52	1.033	2.55	7.34
ST-number of corrections	0.00	10.00	2.10	2.01	1.39	2.19
VFT-semantic fluency	11.00	42.00	25.17	5.57	0.49	0.26
VFT-semantic fluency, perseveration	0.00	2.00	0.42	0.69	1.35	0.41
VFT-phonetic fluency: K-A-S	16.00	86.00	46.63	12.17	0.33	0.34
VFT-phonetic fluency, perseveration	0.00	4.00	0.62	0.85	1.25	0.96
TMT-a time (sec)	12.00	76.00	29.47	11.11	1.46	2.60
TMT-b time (sec)	18.00	201.00	68.58	30.48	2.09	5.73
TMT-b-a (interference time)	3.00	184.00	39.67	27.89	2.45	8.29
TMT-number of errors	0.00	4.00	0.45	0.69	1.85	4.69
TOL-total correct score	0.00	8.00	2.69	1.90	0.38	-0.38
TOL-total move score	8.00	96.00	43.59	17.49	0.42	0.16
TOL-total initiation time	10.00	86.00	29.13	15.80	1.54	2.72
TOL-total application time	83.00	374.00	181.68	54.65	0.87	0.71
TOL-total complete time	94.00	411.00	210.28	59.10	0.79	0.68

BAI: Beck anxiety inventory, BDI: Beck depression inventory, DST: Digit span test, ESS: Epworth Sleepiness Scale, FSS: Fatigue Severity Scale, MEQ: Morningness-eeveningness questionnaire, ST: Stroop test, TMT: Trail Making test, TOL: Tower of London, VFT: Verbal Fluency test, SD: Standard deviation

Table 2. Comparison of sociodemographic data and scale scores of chronotypes						
Variables	**Evening types (n=42)**	**Intermediate types (n=90)**	**Morning types (n=48)**	**F**	**p**	**η^2**
Age (yr)	21.50±3.73	22.64±6.84	25.88±9.30	4.95	0.008	
Education (yr)	14.05±1.86	13.26±2.72	13.00±3.51	1.74	0.179	
MEQ	36.62±4.49	49.89±3.50	61.44±3.09	516.83	**0.001**	
ESS	9.09±4.80	7.54±3.74	6.69±3.18	**4.42**	**0.013**	0.048
FSS	45.05±11.98	36.38±12.72	37.08±12.63	**7.33**	**0.001**	0.076
BDI	14.76±6.12	12.22±6.48	10.60±7.24	**4.48**	**0.013**	0.048
BAI	12.93±6.95	12.88±7.08	9.92±7.22	**3.12**	**0.047**	0.034

BAI: Beck anxiety inventory, BDI: Beck depression inventory, ESS: Epworth Sleepiness Scale, FSS: Fatigue Severity Scale, MEQ: Morningness-eeveningness questionnaire

binary analyses, it was determined that there was a significant difference in favor of the evening type (Table 3 and Table 4).

Correlation Analysis

Relationships between morningness-eveningness, sleepiness, fatigue, depression, anxiety and neuropsychological variables were examined using Spearman correlation analysis because some variables in the data set did not show normal distribution. According to the results, negative significant relationships were found between MEQ and ESS (r=-0.16, p<0.01), FSS (r=-0.21, p<0.05), BDI (r=-0.25, p<0.05), and between VFT-animals (r=-0.18, p<0.01) and VFT-KAS (r=-0.16, p<0.01) among neuropsychological variables. Sleepiness was positively correlated with fatigue, depression, and anxiety neuropsychological tests, DST-backward (r=0.18, r=0.16, r=0.19, and r=0.16, respectively; p<0.01). Fatigue was positively and significantly correlated with depression, anxiety, and neuropsychological variables such as TMT-A time and TOL-total initiation time (r=0.39, p<0.05, r=0.32, p<0.05, r=0.15, p<0.01, and r=0.16, p<0.01, respectively). Depression was found to be significantly positively correlated with anxiety and only with the number of ST-number of incorrect answers among neuropsychological variables (r=0.56, p<0.05 and r=0.15, p<0.01, respectively). Anxiety was found to be positively correlated with the neuropsychological variables TMT-A time, TMT-B time, and TMT-interference (r=0.15, p<0.05, r=0.24, p<0.05, and r=0.22, p<0.05, respectively), and negatively correlated with DST-forward, VFT-animals, and VFT-KAS (r=-0.18, p<0.01 and r=-0.16, p<0.01, respectively). Additionally, significant relationships were found between neuropsychological variables (Table 5).

Table 3. ANOVA results of neuropsychological variables

	Evening types (n=42)	Intermediate types (n=90)	Morning types (n=48)	F	p	η^2
DST-forward	6.71±1.11	6.71±1.04	6.54±1.09	0.45	0.0541	0.005
DST-backward	4.93±0.95	4.80±0.96	4.67±0.86	0.89	0.414	0.010
VFT-semantic fluency	25.67±6.04	25.79±5.61	23.58±4.84	2.72	0.69	0.030
VFT-semantic fluency, perseveration	0.41±0.70	0.47±0.74	0.35±0.60	0.43	0.653	0.005
VFT-phonetic fluency: K-A-S	49.07±12.05	46.28±12.18	45.17±12.20	1.23	0.294	0.014
VFT-phonetic fluency, perseveration	0.79±0.89	0.52±0.74	0.67±0.99	1.46	0.235	0.016
TOL-total correct score	2.79±1.87	2.56±1.97	2.88±1.81	0.50	0.606	0.006
TOL-total move score	41.05±18.00	46.40±18.49	40.56±14.32	2.36	0.098	0.026
TOL-total application time	177.46±48.37	185.27±57.10	178.65±55.77	0.39	0.677	0.004
TOL-total complete time	208.62±57.08	212.74±60.18	207.13±59.83	0.16	0.851	0.002

DST: Digit Span test, TOL: Tower of London, VFT: Verbal Fluency test

Table 4. Kruskal-Wallis results for neuropsychological parameters

	Evening types (n=42)	Intermediate types (n=90)	Morning types (n=48)	Kruskal-Wallis H	p
ST-Interference time (sec)	92.63	89.26	90.97	0.126	0.939
ST-Number of incorrect	92.98	86.24	96.32	2.065	0.356
ST-Number of corrections	90.19	87.15	97.05	1.179	0.555
TMT-a time (sec)	91.11	81.92	106.06	**6.741**	**0.034**
TMT-b time (sec)	97.69	83.20	97.90	3.535	0.171
TMT-b-a (interference time)	97.70	86.12	92.41	1.503	0.472
TMT-number of errors	98.21	85.91	92.36	2.344	0.310
TOL-total initiation time	93.92	88.01	92.18	0.436	0.804

ST: Stroop test, TMT: Trail Making Test, TOL: Tower of London

Table 5. Correlations between morningness-eveningness, sleepiness, fatigue, depression, anxiety and neuropsychological variables

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	**-0.16***	**-0.21****	**-0.25****	-0.08	-0.11	-0.12	0.04	0.08	0.08	**-0.18***	-0.05	**-0.16***	-0.06	0.14	0.08	0.03	-0.04	0.03	-0.01	0.01	0.00	-0.01
2	1	**0.018***	**0.16***	**0.19***	-0.00	**0.16***	-0.11	-0.13	0.04	-0.01	0.05	0.09	0.03	0.10	0.02	-0.01	0.03	0.05	0.05	0.06	0.06	0.07
3		**1**	**0.39****	**0.32****	-0.01	0.00	0.13	0.10	0.09	-0.04	-0.10	0.059	-0.02	**0.15***	0.01	-0.04	0.09	0.04	-0.05	**0.16***	0.04	0.09
4			1	**0.56****	-0.09	-0.06	0.03	**0.15***	0.03	-0.14	-0.05	-0.095	-0.01	-0.00	0.14	0.12	0.06	0.00	-0.05	0.02	0.06	0.08
5				1	**-0.18***	-0.09	0.091	0.11	0.06	**-0.16***	-0.01	**-0.16***	-0.00	**0.15***	**0.24****	**0.22****	0.06	-0.07	0.02	0.13	0.04	0.07
6					1	**0.33****	-0.12	-0.06	-0.02	0.10	-0.02	**0.23****	-0.06	-0.08	**-0.16***	**-0.16***	0.04	0.08	-0.03	-0.07	**-0.17***	**-0.20****
7						1	-0.11	-0.05	-0.05	0.09	-0.07	**0.23****	0.05	-0.12	-0.08	-0.06	0.07	0.04	-0.07	0.05	**-0.15***	**-0.15***
8							1	**0.23****	**0.25****	**-0.19***	-0.03	-0.02	0.08	**0.23****	**0.16***	0.11	-0.02	0.03	-0.01	0.11	0.11	0.12
9								1	0.07	-0.02	0.00	**-0.20****	-0.07	**0.21****	0.08	0.00	-0.00	0.02	-0.04	-0.00	0.01	-0.01
10									1	**-0.18***	-0.02	-0.10	0.03	**0.16***	0.03	-0.03	0.03	-0.03	0.08	0.05	0.05	0.06
11										1	**0.15***	**0.30****	0.05	**-0.18***	**-0.20****	-0.11	-0.02	-0.10	0.06	**-0.20****	**-0.15***	**-0.18***
12											1	-0.02	0.04	-0.03	0.00	0.08	0.12	-0.06	-0.00	-0.06	-0.09	-0.09
13												1	**0.25****	**-0.15***	**-0.22****	**-0.15***	-0.03	0.01	-0.06	0.02	**-0.17***	**-0.17***
14													1	0.01	0.04	0.08	0.12	-0.03	-0.00	0.03	-0.09	-0.08
15														1	0.32**	-0.04	-0.07	0.07	0.03	**0.24****	**0.24****	**0.28****
16															1	**0.86****	**0.43****	-0.01	0.09	**0.25****	**0.24****	**0.29****
17																**1**	**0.50****	-0.04	0.12	0.13	**0.15***	**0.18***
18																	1	0.03	0.06	0.00	0.05	0.06
19																		1	**-0.73****	**0.37****	**-0.38****	**-0.25****
20																			1	**-0.26****	**0.63****	**0.49****
21																				1	**0.21****	**0.44****
22																					1	**0.96****
23																						1

*p<0.01, **p<0.05. 1. Morningness-Eveningness Questionnaire, 2. Epworth Sleepiness Scale, 3. Fatigue Severity Scale, 4. Beck Depression Inventory, 5. Beck Anxiety Inventory, 6. Digit Span Test - Forward, 7. Digit Span Test - Backward, 8. Stroop Test - Interference Time, 9. Stroop Test - Number of Incorrect Responses, 10. Stroop Test - Number of Corrections, 11. Verbal Fluency Test - Semantic Fluency, 12. Verbal Fluency Test - Semantic Fluency Perseverations, 13. Verbal Fluency Test - Phonetic Fluency - K-A-S, 14. Verbal Fluency Test - Phonetic Fluency Perseverations, 15. Trail Making Test - Part A Completion Time, 16. Trail Making Test - Part B Completion Time, 17. Trail Making Test - Difference Between Part B and Part A, 18. Trail Making Test - Number of Errors, 19. Tower of London Test - Total Correct Score, 20. Tower of London Test - Total Move Score, 21. Tower of London Test - Total Initiation Time, 22. Tower of London Test - Total Application Time, 23. Tower of London Test - Total Completion Time

Discussion

The aim of this study was to compare executive function performances such as attention, working memory, verbal fluency, mental flexibility, resistance to interference, planning, and problem-solving, and the levels of sleepiness, fatigue, depression, and anxiety of individuals according to chronotype groups classified as morning, evening, and intermediate-types. Also, to examine the relationships between chronotype, executive functions, sleepiness, fatigue, depression, and anxiety. In the study, measurements were made using neuropsychological tasks consisting of objective and standardized tests that are frequently used in clinical settings. However, while collecting data, neuropsychological tests were applied without determining the chronotypes of the individuals. Therefore, the optimal time according to the chronotype of the individuals was not taken into account, and the synchronicity effect was not taken into account, especially for executive functions. This type of application was preferred considering that individuals could not use their executive functions in accordance with their chronotype in daily life conditions (e.g., work, school).

It is seen in the literature that studies examining executive functions and chronotypes together differ from each other in terms of application. In this context, while examining the relationship between chronotype and cognitive performance, it is observed that various procedures have been developed, sometimes taking into account the synchrony and sometimes asynchrony effects, but it is evident from these studies that there is no clarity on this issue. There are studies suggesting that the strength of the relationship between the circadian clock and cognitive performance increases with age, with morning hours being the most optimal for cognitive performance in older adults and evening hours being more optimal for younger individuals,[45] there is also evidence that the time of day when testing takes place is of little importance for young college-aged individuals.[46]

The findings of the study revealed that there was a significant difference between the groups only in the TMT-A time in terms of executive functions. Part A of the TMT assesses processing speed based on visual scanning ability. This finding shows that evening-types have better processing speed than morning-types and intermediate-types. Chronotypes performed similarly in other areas of executive function, including attention, working memory, verbal fluency, mental flexibility, resistance to interference, planning, and problem-solving. In a study examining the effect of chronotype on cognition under asynchrony conditions, it was found that evening-types performed better than morning types on working memory and information processing speed tasks.[19] In their study conducted with a young sample of 77 people in 2008, Bennet et al.[14] found a synchrony effect in the area of mental flexibility from executive functions, but no effect of circadian typology or synchrony was found in the areas of simple attention, sustained attention, and verbal fluency. In a recent study, Evansová et al.[22] examined the relationship between the time of application of cognitive tests and cognitive performance of morning, intermediate-types, and evening-types in a sample of 42 people. It was found that morning people scored high in the ST-color naming section, but no effect of chronotype and synchrony was found on TMT-A and TMT-B, DST, working memory, attention, and alertness. In another study conducted with university students, morning students performed better in spatial skills when measured in the evening, and evening students performed better in spatial skills when measured in the morning. No effect of synchrony or chronotype was found on other cognitive abilities such as simple attention and picture completion.[17] In attention-related tasks, synchrony also had an effect on evening-types, and morning-types showed increased attention at suboptimal times of the day.[21] These studies, using synchrony and asynchrony designs, show that chronotype has an effect on a specific area of cognitive functions. The results of the present study, conducted at various times throughout the day under consistent conditions, align with the findings in existing literature and support these studies, while considering the limited impact of chronotype.

Another aim of the current study was to evaluate whether there was a relationship between chronotype and executive functions. In the correlation analysis, negative significant relationships were found between MEQ and VFT-animals and VFT-KAS, which are neuropsychological tests that assess verbal fluency. The VFT assesses executive control skills as well as sustaining attention because participants are required to access and retrieve words from their vocabulary stores, focus on the task while doing so, avoid perseveration, and select words with certain restrictions.[47] This finding suggests that evening chronotype is associated with better sustained attention, verbal fluency, and executive control skills. There are different findings in the literature regarding chronotype and sustained attention. For example, in a recent study where synchrony was not required, no relationship was found between chronotype and executive functions such as set shifting, sustained attention, and response inhibition.[48] In another study conducted with an adolescent sample and where synchrony was not required, no relationship was found between chronotype and different attention measures.[49] It has been found that not all components of attention are affected by chronotype and show different fluctuations at different times of the day. In this study, alertness was affected by synchrony and chronotype, and the attentional component was not affected by time of day and chronotype. Executive control was found to be lower in the middle of the day for both chronotypes.[24] It is known that evening types have difficulty adapting to external conditions that require an early start to the day. It has been claimed that evening types protect themselves from distracting elements by doing their work in the evening or at night to overcome this difficulty, and that the need to overcome these difficulties can lead to the development of some cognitive abilities of evening-types, such as problem-solving.[50] The reason why the evening-type is associated with better verbal fluency, sustained attention, and executive control may be a result of better coping with this difficulty, as suggested by Preckel et al.[50]

According to the ANOVA findings, statistically significant differences were found between the groups in terms of sleepiness, fatigue, depression, and anxiety scores among other variables examined in the current study. However, as a result of post hoc analyses, it was determined that there was a significant difference between evening and morning types only in the depression variable, in favor of the evening-type. In the present study, the evening-type's high depression scores are consistent with the findings in the literature.[51] Being an evening person is considered a risk for developing depression.[52] The evening-type has also been associated with depressive, cyclothymic, irritable, and anxious temperaments that may predispose to mental disorders.[53] On the other hand, being a morning person is considered a protective factor against depression, and it is suggested that the depressive period is milder in morning people than in evening people.[54] Although the average fatigue and sleepiness scores of the evening type were higher than the other two types, it was seen that there was no significant difference between the groups in the post hoc analysis with Bonferroni and Tamhane correction. In the correlation analysis, negative significant relationships were found between morningness-eveningness and sleepiness and fatigue. Data on sleepiness are consistent with literature findings that evening chronotypes have higher daytime sleepiness than morning people.[48,55] The higher fatigue score with evening chronotype is also consistent with the findings of a recent study.[56]

An interesting finding of our study was that sleepiness was positively correlated with fatigue, depression, anxiety variables, and DST-backward from neuropsychological tests in the correlation field. DST-backward is sensitive to working memory. Working memory capacity increases as participants' sleepiness, fatigue, depression, and anxiety levels increase. Similar to this result, a study found that university students with poor sleep quality had better attention, concentration, and spatial working memory capacity.[57,58] This may be because the younger population has developed precautions against sleep loss and has adapted to sleeplessness.[58] At the same time, an increase in cerebral activation associated with inhibition may be observed as a compensatory response after sleep deprivation.[25] It can be argued that our participants are young, have a high level of education, and, are students or working individuals, so they have developed a tolerance to sleep loss, and their executive functions are less affected in this situation.

The current study has several limitations that should be addressed in future research. First, all participants were aged 18-45 years. The majority of the participants were university students, which limits the generalizability of this study to the general population. At the same time, the higher average educational attainment may have exerted a ceiling effect on the participants' study, reducing the effect of chronotype on executive functions. This therefore limits the scope of this study and limits it to be interpretable only to young adults and educated individuals. Finally, this study was designed from a circadian typology perspective rather than a synchrony/asynchrony effect. It is known that measurements made with the simultaneity effect result in better performance in some areas of cognitive functions. In this context, some of the participants may have been tested under the influence of synchrony and some under the influence of asynchrony. Therefore, whether the neuropsychological assessment time corresponded to the participants' chronotype preference time may have affected their performance. However, the strengths of the study are that executive functions were evaluated using an objective method and the study comprised a relatively large sample.

Conclusion

The present study examined the effect of chronotype on executive functions by applying detailed executive function tests to a large sample group where individuals with different chronotype preferences, such as students and employees, could not directly choose their own sleep-wake times and were obliged to start the day early due to social demands. When executive functions were evaluated as a whole, evening chronotypes performed better than intermediate and morning types in terms of information processing speed. Morning chronotypes were associated with difficulty sustaining attention, low verbal fluency, and poor executive control skills. No significant effect or relationship was found in other areas of executive functions. It is thought that this study design, in which we also included intermediate-types, will contribute to the growing literature on the effect of chronotype on cognitive processes.

Ethics

Ethics Committee Approval: This study was approved by the University of Health Sciences Turkey Hamidiye Scientific Research Ethics Committee (decision number: 14/38, date: 21.07.2023).

Informed Consent: Participants were informed about the purpose of the study and written informed consent was obtained from participants who volunteered to participate in the study. The study was conducted in accordance with the Principles of the Declaration of Helsinki.

Footnotes

Authorship Contributions

Concept: H.D., Design: H.D., Y.B., Data Collection or Processing: H.D., M.Ş., A.F.S., S.İ., Analysis or Interpretation: H.D., Y.B., Literature Search: H.D., M.Ş., A.F.S., S.İ., Writing: H.D., Y.B.

Conflict of Interest: The authors declare that they have no conflict of interest.

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