Original article

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The effects of sleep quality, sleepiness, fatigue, and psychological resilience on attention performance

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Abstract

Introduction: The aim of the study was to examine the relationships between sleep quality, sleepiness, fatigue, resilience, and attention parameters in a sample consisting of university students.
Material and methods: The study involved 123 university students aged between 18 and 33 years. A sociodemographic data form, the Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS), Fatigue Severity Scale (FSS), Depression, Anxiety, and Stress Scale (DASS 21), and the Brief Resilience Scale (BRS) were administered to the participants. Attention assessment was conducted using the Cognitrone (COG), Signal Detection (SIGNAL), Inhibition (INHIB), and Perception and Attention Functions Battery, part of the computer-based Vienna Test System (VTS).
Results: Out of all the participants, 77.2% were female, and 22.8% were male, with an average age of 21.53 (SD = 2.54) years. A positive correlation was found between COG-Corrects and PSQI scores, and COG-Incorrects and DASS-Stress. There was a negative correlation between SIGNAL-Corrects and FSS. No correlation was revealed among sleep quality, sleepiness, fatigue, resilience variables, and reaction inhibition or divided attention. Furthermore, multiple regression analysis indicated that attention scores were predicted only by sleep quality and fatigue severity.
Conclusions: Based on the study's findings, it is conceivable that situational factors such as sleep quality, sleepiness, and fatigue have a more significant impact on attention compared with constant variables such as depression, anxiety, stress, and resilience.

Key words: Vienna Test System, attention, fatigue, sleepiness, resilience.

Introduction

Attention is a primary and complex cognitive function that refers to the frontage and focus of mental resources on a stimulus. Simultaneously, it represents turning towards a stimulus while disregarding others (Posner *et al*. 2016). Attention is separated into four types: selective, sustained, executive, and divided. Selective attention refers to the capacity to focus on a particular stimulus while disregarding other distracting stimuli. Divided attention is the ability to deal with multiple stimuli simultaneously, and executive attention ensures that attention is maintained (Rueda *et al*. 2023). Sustained attention requires long-term focus on a stimulus and is regarded as a concept associated with alertness (Cohen 2013). According to contemporary theories, attention is a system that consists of multiple brain networks with interrelated but distinct functions (Fisher 2019). Spikman and van Zomeren (2010) stated that attention has two general dimensions, selectivity and intensity; they also refer in their articles to the Vienna Test System (VTS), which is a computer-based application used in the assessment of sustained attention, focused/selective attention, and divided attention (Spikman and van Zomeren 2010).

Although attention is a parameter that multiple psychological factors can impact, there has been more focus on how specific psychological processes such as sleep, fatigue, and psychopathological processes (e.g., depression, anxiety) affect attention. Sleep has a restitutive function in human life and is essential for physiologic and circadian rhythms. Quantitative and qualitative shifts in sleep influence multiple systems (Bryant *et al*. 2020). Daytime sleepiness is a condition typically seen as a result of delaying sleep and inability to sleep, disrupting the person's daily activities (Selvi *et al*. 2016). Sleep is a crucial cycle for our attentional capacity to maintain precisely timed communication between multiple circuits in the brain to select and suppress stimuli. Compared with more superficial forms of learning, such as classic conditioning or habituation, learning processes that require selective attention are also expected to be regulated by sleep (Kirszenblat and van Swinderen 2015). Although it is obvious that sleep regulates attention, the reverse may also be valid; attention triggers the need for sleep. Attention is critical for numerous forms of learning, and the more a person learns during the day, the more sleep-related flexibility may be required to regulate and respond to the synaptic changes that occur during awakening. Sleep and attention regulate each other reciprocatively (Hanlon *et al*. 2009). Recent studies show that sleep deprivation can directly disrupt high-level cognitive processes (Stepan *et al*. 2020) and that attention components such as inhibition, selective attention, and attention maintenance are more sensitive to sleep deprivation (García *et al*. 2021).

Fatigue is anything that causes wear and tear on the physical or mental resources of the body. Fatigue is considered to be an indicator of an individual's response to physical and psychological demands. It is also a protective action when it reduces the individual's capacity to maintain function (Lasseter 2009). The effects of fatigue include cognitive disorders such as attention deficit, memory and decision-making disorders, long-term reaction times, and psychological problems such as decreased motivation, decreased alertness, anger, anxiety, hostility, and depression (Rosenthal *et al*. 2008).

Although the effect of depressive symptoms provides mixed results, specifically because the focus is on different aspects of attention and diverse measurements of attention are used, some studies have found a significant relationship between depression and impaired attention performance (Rohling *et al*. 2002; Ross *et al*. 2003; Watari *et al*. 2006). Compared with depression, the relationship between anxiety and cognitive impairment has been studied somewhat less, and some evidence suggests that comorbid depressive and anxiety symptoms may have a synergistic effect (Kizilbash *et al*. 2002).

Psychological resilience consists of social resources and protective factors against adverse effects and can affect the metacognitive process of individuals in response to their feelings (Yi *et al*. 2020). When the literature is inspected, no difference is found in the level of receiving emotional information between individuals with high and low resilience; however, there is a distinction in their ability to eliminate emotional information. It is observed that individuals with high resilience recover from the influence of both positive and negative emotional information much faster, and it is claimed that it explains the negative relationship between resilience and depression and anxiety (Joormann and Gotlib 2007; Wells 2008; Yi *et al*. 2020).

This study aims to measure how university students' attention levels, which significantly impact their academic success, are affected by some psychological factors. We hypothesized that there would be a relationship between sleep quality, sleepiness, fatigue, depression, anxiety, stress, resilience, and components of attention. In addition, low sleep quality, poor resilience, high sleepiness, fatigue, and high depression, anxiety, and stress would result in worse attention performance.

Material and methods

Procedures

In the study conducted with the Psychology Department of the University of Health Sciences, students first made an appointment to participate in the study through an appointment schedule created using Google Forms. At the specified time, the student was first informed about the procedure and then the Vienna Test was administered. The test was administered by psychologists who were authorized and certified to use the Vienna Test System (VTS) by making the students complete the necessary sample applications. After taking the VTS, the student was asked to complete the other scales in the study in the form of a paper and pencil test. Students had to be present in the study environment for a total of 50-60 minutes for these applications. For participation in the study, students were asked to sign an informed consent form and their voluntary participation was ensured in this way. Participants who specified current or previous general medical, neurologic, or psychiatric disorders on the sociodemographic data form were excluded from the study. Participants were told that participation in the study was voluntary and that they could withdraw from the study at any time without any excuse. In exchange for their participation, subjects were given extra credits regardless of completing the survey. The study was approved by the Ethics Committee of the University of Health Sciences (2023-23/264).

Participants

A total of 123 university students, aged 18-33 (mean: 21.53 ±2.54) years, 95 (77.2%) women and 28 (22.8%) men, participated in the study. Of the participants, all of whom were single, 17 (13.8%) had low, 98 (79.7%) had medium, and eight (6.5%) had high-income levels. The data were collected using the convenience sampling method. To calculate the sample size, the G*Power version 3.1.9.6 program was used. This program, written by Franz Foul (1992-2020), is open to general use. When determining the number of samples for multiple linear regression analysis, the "multiple linear regression fixed model R^2 increased" model was chosen. With the effect size index f^2 medium (0.15), α err probe value 0.05, power (1-β err probe) 0.95, and number of tested predictors as 13, the total number of samples was determined as 107.

Instruments

Sociodemographic data form: The researchers created the form to document some sociodemographic and clinical characteristics of the participants, such as age, sex, place of residence, sleeping habits, and whether they had a physical or mental illness.

Pittsburgh Sleep Quality Index (PSQI): The PSQI, developed by Buysse *et al.*, is used to assess sleep quality (Buysse *et al.* 1989). It has seven parameters: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. There are a total of 24 questions comprising 19 self-rated questions and five questions rated by the bed partner. At the end of the evaluation, individuals obtain a sleep quality score between 0 and 21 points. Scores of 5 and higher indicate poor sleep quality. The Turkish validity and reliability study of the scale was performed by Ağargün *et al.* (1996).

Epworth Sleepiness Scale (ESS): The scale is used to assess daytime sleepiness in sleep disorder studies. In the scale consisting of eight questions in total, each question is evaluated in a score range of 0-3. At the end of the evaluation, a daytime sleepiness score between 0 and 24 points is obtained for each individual. Scores of 11 and higher indicate excessive daytime sleepiness. The ESS was developed by Johns (1991), and its Turkish validity and reliability study was conducted by Ağargün *et al.* (1999).

The Fatigue Severity Scale (FSS): The scale, which consists of nine questions in total, evaluates the severity of fatigue. The questions are Likert-type and range from 1 to 7 points. The total score ranges from 0 to 63, and the average of the nine questions is recorded as the score. Scores of 4 and higher indicate severe fatigue. The Turkish adaptation study of the scale developed by Krupp *et al.* (1988) was performed by Armutlu *et al.* (2007).

Depression, Anxiety and Stress Scale (DASS-21): DASS-21 was developed by Lovibond and Lovibond (1995) to assess the symptoms of depression, anxiety and stress as a 21-item short form. The scale consists of three seven-item sub-scales covering the three symptoms that are rated on a four-point Likert scale ranging from *never* (0) to *almost always* (3). The Cronbach α internal consistency reliability coefficient of the scale, whose Turkish adaptation study was carried out by Akın and Çetin (2007), was determined as 0.89 for the entire scale.

The Brief Resilience Scale (BRS): The BRS was developed by Smith *et al.* (2008) to measure the resilience of individuals and was adapted into Turkish by Doğan (2015). The scale consists of six items and is a 5-point Likert-type scale. A high score on the scale indicates high psychological resilience. Doğan (2015) found the Cronbach α reliability of the scale to be 0.81 in his study.

Neuropsychological Attention Tasks: The VTS was used for computer-assisted neuropsychological tests. The VTS is a clinical and research test system developed by the Austrian-based company Schuhfried, for clinical and applied psychology use (Schuhfried 2012). Visual stimuli were presented on the screen, and auditory stimuli were given through headphones. The tests used are described below.

Cognitrone (COG): The test provides an assessment of attention and concentration via a comparison of figures regarding their coherence and measures the storage capacity of spatial working memory. Participants compare a geometric figure with other geometric figures. They then determine whether the comparison figure is identical to one of the other four geometric figures. S4-S5 forms work with a fixed working time of 1.8 seconds per item. The duration of the test is 8 minutes. The S5 (a parallel form with a fixed presentation time per item) form was used in the study. The reliabilities of forms are very high, most of them being over $r = 0.95$. In the S4-S5 forms, scoring is calculated by adding the total correct and total incorrect points.

INHIB: The test measures the various aspects of response inhibition. Response inhibition is a fundamental requirement for flexible and appropriate behavior, and constitutes part of the executive functions. The different test forms of INHIB implement four paradigms of response inhibition. Go/no-go parallel forms were used in the S3/S4 forms. The respondent may be asked to react only to the presentation of a particular stimulus (go/no-go). INHIB takes 7 minutes to complete. The split-half reliability coefficient of the test was 0.82.

SIGNAL (signal detection): SIGNAL measures long-term focused attention and the visual differentiation of a relevant signal when distractor signals are present. It is formed from the perception of weak signals against a constantly changing background. The S1 form was used in the study; it consists of white signals on a black background. In the S1 format, which takes about 15 minutes, the person taking the test is asked to notice and react by pressing the button in the situations where four dots come together and form a square shape from points randomly appearing on the screen during the test. Before the test, the person is given a trial, and the test is started after the person understands the test. Split-half reliability coefficients are $r = 0.74$ and $r = 0.85$.

WAF: WAF consists of a combination of perception and attention functions. It measures fundamental subfunctions of attention. These subfunctions can be exemplified as alertness, vigilance, and divided attention. The standard test-short form (WAF-SF) was used in the study. WAF-SF consists of intrinsic alertness (visual) and cross-modal divided attention (visual-auditory). The participants respond to an intensity change in the color of a black square or the frequency change of a sound. The task of the participants is to react to changes in the relevant stimuli while ignoring irrelevant ones. The duration of the test is 8 minutes. Cronbach's α for intrinsic alertness (visual) was determined as 0.947 and for cross-modal divided attention (visual-auditory) it was 0.887.

Statistical analysis

First, normality tests were performed on the data obtained and kurtosis and skewness values were calculated. All scales except INHIB/S4-Omission Errors, and SIGNAL/S1-Corrects tests had values in the range of +1.5-1.5 (Tabachnick and Fidell 2013) (Table 1). Therefore, Spearman correlation coefficients were conducted to evaluate the relationships between neuropsychological test results and other scale scores. Furthermore, two-way multivariate analysis of variance (MANOVA), the *t*-test, and the Mann-Whitney *U* test were used to compare the groups formed on sleep scales, and multiple linear regression analysis was used to determine the variables predicting attention parameters. Statistical analyses were performed using the SPSS v.25 software package.

Results

Correlations between attention tests, sleep quality, sleepiness, fatigue, depression, anxiety, stress, and psychological resilience scales were calculated using Spearman correlation coefficients for INHIB/S4-Omission Errors, and SIGNAL/S1-Corrects tests did not show normal distribution. The results of the correlation analysis are presented in Table 1. When the correlations were analyzed, it was found that the attention tests were more correlated within themselves, and the other variables were more correlated within themselves. Significant positive correlations were determined between COG-Corrects and PSQI ($r = 25$), COG-Incorrects and DASS-Stress ($r = 0.19$), and a significant negative correlation was found between SIGNAL-Corrects and FSS ($r = –0.22$).

The number of participants with bad sleep quality was 76 (61.8%), and the number of those with good sleep quality was 47 (38.2%). The number of participants with excessive sleepiness was 100 (81.3%), and the number of those without excessive sleepiness was 23 (18.7%). The number of participants expressing severe fatigue was 73 (59.3%), and the number of those who did not express severe fatigue was 50 (40.7%). Comparisons between groups were made using the Mann-Whitney *U* test according to these two continuous variables, INHIB/S4-Omission Errors, and SIGNAL/S1-Corrects, and analyses were made using the *t*-test for other continuous variables (Table 2). In the comparison made according to sleep quality groups, it was found that the group with bad sleep quality had better attention and concentration skills. In addition, the group with bad sleep quality had poorer sleep quality and higher levels of depression, stress, sleepiness, and fatigue severity. In the groups formed according to sleepiness, it was found that the depression, anxiety, stress, excessive sleepiness, and fatigue levels of the sleepiness group were significantly higher than in the group without sleepiness. No significant

Table 1. Mean, standard deviation, skewness, kurtosis values of variables and Spearman correlation coefficients for the relationships among variables

	M ±SD	SK/KU	2	3	4	5	6	7	8	9	10	11	12	13	14
1	51.54 ±8.06	–0.40/–0.08	0.17	0.09	–0.19*	0.30**	–0.26**	–0.14	–0.12	0.25**	0.09	0.05	0.07	–0.01	0.03
2	27.28 ±9.81	0.47/–0.13	1	0.12	0.21*	–0.07	0.02	0.05	–0.11	–0.07	0.03	0.19*	0.06	–0.09	0.01
3	11.00 ±6.14	0.61/0.13		1	0.31**	–0.15	–0.11	0.02	0.05	0.02	0.10	0.09	0.00	0.03	–0.03
4	7.66 ±8.45	2.13/4.45			1	–0.44**	0.28**	0.22*	0.01	–0.05	0.18	0.06	0.10	0.06	0.12
5	48.19 ±5.79	–1.60/6.57				1	–0.27**	–0.18*	0.08	–0.01	–0.08	–0.14	–0.10	–0.05	–0.22*
6	240.93 ±39.98	1.54/1.34					1	0.36**	–0.06	0.02	0.12	0.09	0.03	0.09	0.12
7	445.79 ±102.50	0.81/1.15						1	0.06	–0.02	0.05	0.01	0.05	0.02	0.01
8	18.81 ±4.36	–0.18/0.04							1	–0.12	–0.42**	–0.36**	–0.35**	–0.19*	–0.29**
9	5.59 ±2.63	1.11/1.41								1	0.40**	0.37**	0.34**	0.28**	0.28**
10	5.50 ±4.00	0.85/0.00									1	0.36**	0.62**	0.37**	0.32**
11	5.33 ±4.88	1.19/0.90										1	0.54**	0.34**	0.36**
12	7.29 ±4.91	0.50/–0.38											1	0.38**	0.29**
13	15.02 ±4.39	0.55/0.42												1	0.29**
14	4.30 ±1.34	–0.01/–0.40													1

1. COG/S5-Corrects, 2. COG/S5-Incorrects, 3. INHIB/S4-Commission Errors, 4. INHIB/S4-Omission Errors, 5. SIGNAL/S1-Corrects, 6. WAFS/SF-Intrinsic Alertness, 7. WAFS/SF-Cross-Modal Divided Attention, 8. Brief Resilience Scale-Total, 9. Pittsburgh Sleep Quality Index-Total, 10. DASS 21-Depression, 11. DASS 21-Stress, 12. DASS 21.Anxiety, 13. Epworth Sleepiness Scale-Total, 14. Fatigue Severity Scale

$^{*}p < 0.05$, $^{**}p < 0.01$

Table 2. Comparison of sleep quality, excessive sleepiness, and fatigue severity

	1* *N* = 76 M ±SD	2* *N* = 47 M ±SD	*t*	3* *N* = 100 M ±SD	4* *N* = 23 M ±SD	*t*	5* *N* = 73 M ±SD	6* *N* = 50 M ±SD	*t*
1	53.08 ±7.93	49.06 ±7.69	–2.76**	51.41 ±7.95	52.13 ±8.64	0.39	51.96 ±8.46	50.94 ±7.46	–0.68
2	26.59 ±9.86	28.38 ±9.72	0.98	27.27 ±9.69	27.30 ±10.55	0.02	26.75 ±9.66	28.04 ±10.07	0.71
3	11.26 ±6.57	10.57 ±5.41	–0.60	11.03 ±5.87	10.87 ±7.31	–0.11	10.99 ±5.97	11.02 ±6.43	0.03
4	240.93 ±39.98	239.79 ±45.31	–0.25	243.22 ±41.68	230.96 ±30.35	–1.33	237.37 ±34.90	246.12 ±46.30	1.19
5	445.63 ±103.55	446.04 ±101.90	0.02	448.29 ±100.81	434.91 ±111.27	–0.56	439.74 ±95.11	454.62 ±112.85	0.79
6	18.49 ±4.51	19.34 ±4.10	1.06	18.47 ±4.11	20.30 ±5.16	1.84	17.96 ±4.40	20.06 ±4.02	2.70**
7	7.07 ±2.22	3.19 ±0.88	–11.40**	5.77 ±2.70	4.78 ±2.17	–1.64	5.92 ±2.33	5.10 ±2.97	–1.71
8	6.55 ±4.29	3.81 ±2.77	–3.90**	6.00 ±3.92	3.35 ±3.72	–2.96**	6.19 ±4.28	4.50 ±3.36	–2.34*
9	6.13 ±4.88	4.04 ±4.66	–2.34*	5.78 ±4.88	3.39 ±4.52	–2.15*	6.40 ±5.30	3.78 ±3.74	–3.02**
10	7.89 ±4.98	6.32 ±4.67	–1.75	7.96 ±4.66	4.39 ±4.99	–3.27**	8.12 ±4.98	6.08 ±4.58	–2.31*
11	15.64 ±4.5	14.00 ±3.95	–2.05*	16.30 ±3.83	9.43 ±0.79	–8.52**	15.89 ±4.50	13.74 ±3.92	–2.74**
12	4.60 ±1.29	3.81 ±1.29	–3.30**	4.42 ±1.29	3.78 ±1.45	–2.09*	5.19 ±0.86	3.00 ±0.71	–14.85**
	1* *N* = 76 Mean rank	**2* *N* = 47 Mean rank**	***Z***	**3* *N* = 100 Mean rank**	**4* *N* = 23 Mean rank**	***Z***	**5* *N* = 73 Mean rank**	**6* *N* = 50 Mean rank**	***Z***
13	62.93	61.53	–0.12	63.90	53.74	–1.24	63.23	60.21	–0.46
14	62.13	61.79	–0.05	60.96	66.52	–0.68	57.70	68.28	–1.62

1. COG/S5-Corrects, 2. COG/S5-Incorrects, 3. INHIB/S4-Commission Errors, 4. WAFS/SF-Intrinsic Alertness, 5. WAFS/SF-Cross-Modal Divided Attention, 6. Brief Resilience Scale-Total, 7. Pittsburgh Sleep Quality Index-Total, 8. DASS 21-Depression, 9. DASS 21-Stress, 10. DASS 21-Anxiety, 11. Epworth Sleepiness Scale-Total, 12. Fatigue Severity Scale, 13. INHIB/S4-Omission Errors, 14. SIGNAL/S1-Corrects,
1 Bad sleep quality group, 2* Good sleep quality group, 3* Group with excessive sleepiness, 4* Group without excessive sleepiness, 5* Group with severe fatigue, 6* Group without severe fatigue*

$^{*}p < 0.05$, $^{**}p < 0.01$

difference was found between the two groups in terms of attention parameters. In the groups formed according to fatigue severity, it was found that the group with low fatigue severity had higher psychological resilience, and the group with high fatigue severity had higher levels of depression, anxiety, stress, excessive sleepiness, and fatigue. There was no significant difference between the two groups in terms of attention parameters and sleep quality.

MANOVA was also conducted to determine whether the three groups had a common effect on the dependent variables in comparisons between groups. INHIB/S4-Omission Errors and SIGNAL/S1-Corrects were not included in the MANOVA because they did not show normal distribution; MANOVA was performed on other continuous variables because they showed normal distribution and their variances were distributed homogeneously. As a result of the MANOVA analysis, it was determined that the effects of the three main effects of all three groups, sleep quality (Wilks' lambda (λ) = 0.561, $F(12,104) = 6.77, p < 0.001$), sleepiness (Wilks' lambda (λ) = 0.623, $F(12,104) = 5.25$, $p < 0.001$), and fatigue severity (Wilks' lambda (λ) = 0.411, $F(12,104) = 12.41, p < 0.001$), on the dependent variables were significant because Wilk's lambda test p values were less than 0.05. Because Wilk's lambda test p-values of sleep quality*sleepiness (Wilks' lambda (λ) = 0.854, $F(12,104) = 1.48, p = 0.145, p > 0.05$), sleep quality*fatigue severity (Wilks' lambda (λ) = 0.897, $F(12,104) = 0.10$, $p = 0.458$, $p > 0.05$), and sleepiness*fatigue severity (Wilks' lambda (λ) = 0.916, $F(12,104) = 0.08$, $p = 0.650$, $p > 0.05$) common effects were greater than 0.05, their effects on the dependent variables were nonsignificant. Only on the INHIB/S4-Comission Errors from dependent variables were the sleep quality*sleepiness*fatigue severity (Wilks' lambda (λ) = 0.818, $F(12,104) = 1.93$, $p = 0.039$, $p < 0.001$) common effects found significant because the Wilk's lambda test p-values were less than 0.05. The significant results are included in Table 3.

Multiple linear regression analysis was conducted using the stepwise method to determine the predictive effect of other variables except attention parameters on a total of seven attention parameters used in the study. It was found that the attention parameters were predicted by two models. The predictive effect of sleep quality was found only in the model created for COG/S5-Corrects and the predictive effect of fatigue severity was found only in the model created for SIGNAL/S1-Corrects. In the first model created for COG/S5-Corrects, the model was predicted only by sleep quality at 5% and the model was found to be significant ($F(1,121) = 7.71, p < 0.001$). The second model created by SIGNAL/S1-Corrects was predicted only by fatigue severity of 8% and the second model was determined to be significant ($F(1,121) = 11.59$, $p < 0.001$). The results are shown in Table 4.

Discussion

The current study aimed to investigate the effects of health-related factors such as depression, anxiety, stress, resilience, sleep quality, sleepiness, and fatigue on attention components in university students. The impact of some of these factors on attention has been investigated previously. This study aspired to expand the scope of previous research by using a cross-sectional design and objective measurements that were

Table 3. MANOVA results applied to the main variables of the study according to sleep quality, sleepiness and fatigue severity groups

Groups	Dependent variables	Sum of squares	*df*	Mean square	*F*	*p*	η^2
Sleep quality	COG/S5-Corrects	554.32	1	554.32	8.78	0.004	0.071
	Pittsburgh Sleep Quality-Total	240.39	1	240.39	70.96	0.000	0.382
	DASS 21-Anxiety	108.92	1	108.92	7.79	0.006	0.063
	DASS 21-Depression	92.57	1	92.57	4.21	0.042	0.035
Sleepiness	DASS 21-Anxiety	90.06	1	90.06	6.44	0.012	0.053
	DASS 21-Stress	235.23	1	235.23	10.89	0.001	0.087
	Epworth Sleepiness-Total	728.43	1	728.43	62.19	0.000	0.351
Fatigue severity	Brief Resilience-Total	123.93	1	123.93	7.085	0.009	0.058
	Fatigue Severity Scale	6763.83	1	6763.83	131.89	0.000	0.534
Sleep quality * Sleepiness * Fatigue severity	INHIB/S4-Commission Error	552.04	1	552.04	16.20	0.000	0.123

Table 4. Regression analysis results of the effect of sleep quality, sleepiness, fatigue severity, psychological resilience, depression, anxiety and stress on attention parameters

	Predictive variables	*B*	*SE*	β	*t*	R^2	*F*	ΔR^2
COG/S5 Corrects	Constant	47.35	1.67		28.40**		7.71**	0.052
	PSQI	0.75	0.27	0.25	2.78**	0.052		
	Predictive variables	***B***	***SE***	**β**	***t***	R^2	***F***	ΔR^2
SIGNAL/S1 Corrects	Constant	53.67	1.68		31.84**		11.59**	0.080
	FSS	–0.14	0.04	–0.30	–3.41**	0.080		

**p < 0.05, **p < 0.01*
PSQI – Pittsburgh Sleep Quality Index, FSS – Fatigue Severity Scale

supposed to be measured reliably and validly in a computer environment using the VTS. The current study revealed several striking findings. First, attention, concentration, and spatial working memory capacity performances were better in students with poor sleep quality. This finding was also confirmed in the correlation analysis. Secondly, as fatigue scores increase, selective attention and performance of maintaining attention decrease. Finally, the above-mentioned health-related variables did not affect response inhibition and divided attention tasks.

A positive correlation was detected between COG-correct reactions and the PSQI. The COG-correct responses subtest provides an assessment of attention and concentration, measuring the storage capacity of spatial working memory. Individuals scoring high in this variable can pay attention to related issues and work properly. According to our findings, poor sleep quality increases attention and concentration. In the comparison between the groups, it was noted that the attention and concentration skills of the group with poor sleep quality were better than the group with good sleep quality. In a study conducted by Alvaro with university students in 2014, a result similar to ours was obtained. Participants with poor sleep quality had better attention performance (Alvaro 2014). Alvaro suggested that students developed precautions against sleep loss and adapted to insomnia. However, unlike our findings, other studies found that poor sleep quality was associated with worse attention performance (Benitez and Gunstad 2012; Gobin *et al*. 2015). There are also studies in which there is no significant relationship between sleep quality and attention levels (Abdolalizadeh and Nabavi 2022; Kurniawan and Meiyanti 2021). Although the relationship between sleep quality and working memory has been well studied, there are conflicting results. It is suggested that there is a strong relationship between poor sleep quality and spatial working memory and that poor quality sleep has a negative impact on phonologic and spatial working memory (del Angel *et al*. 2015; Güneş *et al*. 2023; Richards *et al*. 2017; Tsirimokos *et al*. 2022; Xie *et al*. 2019). Unlike the mentioned studies, no significant relationship was found between sleep duration and working memory scores (Mehta *et al*. 2020). Even in the conditions of partial sleep deprivation and total sleep deprivation, visual working memory capacity was not affected (Drummond *et al*. 2012). A recent study found that sleep quality did not affect visual short-term memory function (Li 2022). Studies revealed that the sleep habits of university students are quite weak (Alvaro 2014; Gilbert and Weaver 2010). Therefore, students may adapt to insomnia, as suggested by Alvaro (2014). Additionally, because the participants in our study were well educated and young, they may have been less affected by poor sleep quality.

A negative correlation was found between fatigue and SIGNAL-Corrects. The SIGNAL-Corrects subtest assesses selective attention and long-term attention capacity. The scores obtained from these variables determine the level of attention the person directs to a task or problem during an activity. According to our findings, as the level of fatigue increases, the performance of focusing and sustaining attention worsens. These findings support previous studies showing that fatigue is associated with cognitive impairments (Neu *et al*. 2011). The results of this study revealed no relationship between daytime sleepiness, depression, anxiety, and stress levels and selective and sustained attention. These findings contradict previous studies showing the negative effect of daytime sleepiness on attention. Studies in both clinical and non-clinical samples have shown that daytime sleepiness impairs attention (van Schie *et al*. 2012; Yun *et al*. 2015). In adolescents with attention-deficit/hyperactivity disorder (ADHD), it has been reported that shortening of sleep duration and daytime sleepiness increase attention deficit, and there is a potential causal link between sleep duration and symptoms (Becker *et al*. 2019). A study conducted with a sample of university students revealed that ADHD symptoms are significantly related to insomnia and feeling sleepy during the day (Kass *et al*. 2003). Another recent study with a sample of university students found that ADHD symptoms were observed at higher rates in students with sleep disorders, and ADHD symptoms increased as sleep quality decreased (Eroğlu *et al*. 2022). However, similar to our findings, there are also studies showing that daytime sleepiness is not related to attention (Clare 2019; Orihuela *et al*. 2023). Again, unlike our findings, as depression and anxiety levels increased in young adults, impairments in attention and executive functions were observed (Castaneda *et al*. 2008). It will be important for future studies to examine the effects of fatigue, sleepiness, depression, anxiety and stress levels on focusing and sustaining attention with comprehensive attention tasks.

The variables we examined were not associated with divided attention and inhibitory control. A meta-analysis concluded that divided attention was less affected by sleep loss than other types of attention (Lim and Dinges 2010). It may not be affected even in old age (Stenuit and Kerkhofs 2008). The inhibitory function investigated with the Stroop Test was not associated with sleep quality (Nebes *et al*. 2009; Rana *et al*. 2018). Relatively constant factors such as resilience, depression, anxiety, and stress were not found to predict attention. The predictive effect of sleep quality was found only in the model for COG/S5-corrections, and the predictive effect of fatigue severity was found solely in the model for SIGNAL/S1-corrections. Only sleep quality had a predictive effect on Cog-correct and sleepiness on SIGNAL. Although there are conflicting results regarding the prediction of attention by these variables in the literature, it has been found that sleepiness and insomnia are predictors of attention (Kass *et al*. 2003). On the other hand, it was observed that the total score of the PSQI was not a significant predictor of long-term attention (Gobin *et al*. 2015). It can be suggested that attention parameters are not affected because it does not take long for university students to experience negative situations such as poor sleep, fatigue, anxiety, depression, and stress. Therefore, it would be possible that the duration of exposure to these health-related situations (such as how many years a person has been sleepless or depressed) is a determining factor in attention.

The current study has several limitations. First, all participants were aged between 18 and 33 years. All participants were university students (undergraduate, graduate, and doctorate), which may implement a ceiling effect on the study and reduce the influence of factors such as sleep quality, sleepiness, and fatigue on attention components. Therefore, the scope of this study is limited to young adults and educated persons. This study used self-report scales completed by the participants to evaluate sleep quality and related factors, which is the second limitation of the study. The self-report approach has limitations compared with more objective sleep measurements such as polysomnography. The next limitation of the study is that all participants were students or graduates of the Department of Psychology, so the findings did not include a comparison of students from other majors. Furthermore, most of the participants were women, which has the potential to limit the generalizability of the findings. Despite all these limitations, attention was evaluated using an objective method and we conducted the study with a relatively large sample, constituting the study's strength. In the future, replicating and expanding this study with a heterogeneous group, a clinical sample with sleep disorders, and an objective method such as polysomnography will benefit further investigations in this field.

Conclusions

This study extends the perspective on the relationship between attention and health-related factors such as sleep quality, sleepiness, fatigue, and resilience. Moreover, the results will contribute to the emergent literature. Contrary to our hypothesis, poor sleep quality increased concentration and spatial working memory performance. Our hypothesis was not confirmed because we found that concentration and spatial working memory were not significantly impacted by variables other than sleep quality. Likewise, our hypothesis that there was a relationship between resilience and components of attention was not supported. Our hypothesis that higher fatigue scores would lead to worse attention performance was supported. However, our hypothesis that high sleepiness would have a negative effect on attention performance was not supported. Attention is required to encode and process information as part of the learning process (Alvaro 2014). The effects of sleep loss are mainly evident in higher cognitive functions such as attention, memory, and problemsolving, and consequently, it can severely affect learning capacity and academic performance (Curcio *et al*. 2006). Considerable studies confirm the association of late sleep onset, irregular sleep, insufficient sleep, and poor sleep quality with worse academic performance in university students (Gilbert and Weaver 2010; Medeiros *et al*. 2001; Okano *et al*. 2019). In this context, it will be essential to question sleep and related factors in students with low academic performance.

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Disclosure

The authors declare conflict of interest.

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