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Circadian functioning, student wellbeing, and academic achievement: associations with use of electronic devices at night

Richard Carciofo

School of Psychology and Clinical Language Sciences, University of Reading, Reading, UK

ABSTRACT

Eveningness preference is associated with measures of poor well-being. However, recent research has found that Morning Affect (sleep inertia) and Distinctness (amplitude of diurnal variations in functioning) may be more strongly related to wellbeing indices. The current study investigated associations between Eveningness, Morning Affect, Distinctness, academic achievement, and student wellbeing (assessed with the College Student Subjective Wellbeing Questionnaire). Data was obtained from an online survey of 232 Chinese university students aged 19–27 (mean = 20.65; SD = 1.365); additional measures included conscientiousness, mind wandering, sleep quality, life satisfaction, substance use, and use of electronic devices at night. Morning Affect (MA) was positively correlated with academic achievement, Academic Satisfaction and Academic Efficacy; Eveningness was positively correlated with School Connectedness and School Gratitude; Distinctness was negatively correlated with Academic Efficacy. The negative correlation between Eveningness and academic achievement was mediated by lower MA. The negative correlation between Eveningness and MA was mediated by more use of electronic devices at night, and also the negative correlation between use of electronic devices at night and MA was mediated by Eveningness. These results suggest potentially important relationships between use of electronic devices at night, circadian functioning, student wellbeing, and academic achievement.

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Morningness-eveningness; sleep inertia; electronic screen time; academic achievement; student wellbeing

Introduction

Individual differences in the phase of the sleep-wake cycle reveal a person's chronotype: evening-types have a later phase (waking and sleeping later in the day), and morning-types an earlier phase, and these differences closely relate to individual morningness-eveningness preferences for earlier or later rising and activity schedules (Adan et al. 2012).

CONTACT Richard Carciofo r.g.carciofo@reading.ac.uk School of Psychology and Clinical Language Sciences, University of Reading, Reading RG6 6AH, UK

This research was undertaken while at the Department of Health and Environmental Sciences, Xi'an Jiaotong-Liverpool University, Suzhou, Jiangsu, China.

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Chronotype and morningness-eveningness preferences are linked with various measures of wellbeing. Greater orientation towards morningness has been associated with more reported positive affect, and emotional and social wellbeing (Howell et al. 2008; Biss and Hasher 2012; Hasan et al. 2022), more life satisfaction (Randler 2008), more physical activity (Suh et al. 2017), and more balanced time perspective (Stolarski et al. 2013).

In contrast, eveningness has been consistently associated with depression (e.g. Antypa et al. 2017; Au and Reece 2017), poor sleep quality (Bakotic et al. 2017), and poor physical health, including hypertension (Partonen 2015). Mechanisms that may explain the associations between eveningness and poor psychological wellbeing include genetics, brain structure and functioning (such as neural reward sensitivity), social jetlag (misalignment of social and biological clocks; Wittmann et al. 2006), poor sleep, and night-time light exposure (for a review of possible mechanisms see Taylor and Hasler 2018). For instance, poor sleep quality may mediate the relationship between eveningness and depression (Bakotic et al. 2017; Van den Berg et al. 2018). Furthermore, evening-types report more substance use, including alcohol, caffeine, nicotine, and energy drinks, and are more likely to consume coffee and alcohol later in the day (Wittmann et al. 2006; Bakotic et al. 2017; Suh et al. 2017; Arrona-Palacios et al. 2020; Siudej and Malinowska-Borowska 2021). Poor sleep quality, sleep debt, and weekend bedtime delay may mediate the relationship between eveningness and substance use (Bakotic et al. 2017), and substance use may influence sleep architecture (Zhang et al. 2006; Chan et al. 2013).

Eveningness is also associated with more electronic screen time soon before bedtime (Shimura et al. 2018), and with more video-game playing (Krejci et al. 2011; Vollmer et al. 2014), and problematic internet use (Przepiorka et al. 2021). Exposure to artificial light at night can disrupt the circadian system (Touitou and Point 2020). Green et al. (2017) found that short wavelength light from electronic devices was associated with changes in sleep (e.g. longer sleep latency), changes in sleep architecture (e.g. a reduction in slow wave sleep), more daytime sleepiness, and suppressed melatonin levels; performance on an attention task the following morning was also adversely affected.

Poor quality sleep and sleep deprivation are associated with negative affect, anxiety, stress, and depression (Augner 2011; Carciofo et al. 2014; Horne et al. 2019; Lund et al. 2010), and with impaired cognitive functioning (Alapin et al. 2000; Åkerstedt 2007). Negative mood, reduced motivation, and impaired cognitive functioning may also impact self-control mechanisms. Morningness has been associated with more self-control (Digdon and Howell 2008) and with having more Future Time Perspective, which may be related to effortful impulse control such that morning-types have greater ability to control/inhibit impulses and delay gratification (Stolarski et al. 2013). In contrast, eveningness has been associated with impulsivity (Caci et al. 2005) and with lower conscientiousness, while morningness is positively correlated with more conscientiousness (Lipnevich et al. 2017). Furthermore, sleep-related impairment of executive control mechanisms may provide a basis for the observed association between eveningness and more frequent mind wandering (Carciofo et al. 2014; Carciofo 2022a).

Sleep-related impairments to cognitive functioning, motivation, and self-control may also impact academic achievement. Academic achievement is positively associated with conscientiousness, intrinsic motivation, and self-regulation, and negatively associated with stress, depression, and test anxiety (Richardson et al. 2012). Morningness has been associated with better academic achievement, and eveningness with poorer academic achievement (Randler and Frech 2006; Preckel et al. 2011; Önder et al. 2014; Scherrer and Preckel 2021), even when accounting for intelligence and conscientiousness (Zajenkowski et al. 2024). Eveningness is related to experiencing more negative affect early in the school day, while morningness is associated with more positive mood and relaxation (Randler et al. 2014). The relationships between morningness-eveningness and academic achievement have several possible mediators including sleep quality, mind wandering, and conscientiousness (Eberspach et al. 2016; Carciofo 2021). Social jetlag is also related to poorer academic achievement, and its effect may be mediated through reduced conscientiousness (Borgio and Louzada 2021).

Thus, eveningness may be associated with negative impacts on wellbeing and achievement in the educational context. The College Student Subjective Wellbeing Questionnaire (CSSWQ; Renshaw and Bolognino 2016; Renshaw 2018) assesses four aspects of wellbeing in students: Academic Satisfaction, Academic Efficacy, School Connectedness, and College Gratitude. All components have shown moderate to strong positive correlations with life satisfaction, conscientiousness, and positive affect, and also (particularly Academic satisfaction and Academic efficacy) positively correlate with academic achievement (such as grade point average/GPA); small to strong negative correlations have also been found with negative affect, anxiety, and depression (Renshaw 2018; Zhang and Carciofo 2021).

Further research on potential mechanisms of association between morningness-eveningness, wellbeing, and academic achievement may contribute to theoretical understanding and inform potential interventions. However, much research on these associations has utilised self-report scales such as the Morningness-Eveningness Questionnaire (MEQ; Horne and Östberg 1976) or Composite Scale of Morningness (CSM; Smith et al. 1989), in which scores are totalled to produce a unidimensional assessment of morningness-eveningness, even, while the scales may be comprised of multiple factors reflecting a heterogeneity of item content. An alternative approach is available in the Morningness-Eveningness-Stability-Scale improved (MESSi; Randler et al. 2016) which has separate subscales for Eveningness and Morning Affect, with the latter being comprised of items related to alertness in the morning/time required to achieve full wakefulness, comparable to a measure of sleep inertia duration (Carciofo 2023). In addition, the MESSi assesses Distinctness, i.e. diurnal variations in the amplitude of cognitive functioning, affect, and motivation (Ogińska 2011; Dosseville et al. 2013; Randler et al. 2016). Higher morning affect (less sleep inertia) has been associated with more morningness, positive affect, wellbeing, life satisfaction, conscientiousness, better sleep quality, and more Future Time Perspective, while more Distinctness is associated with more negative emotionality, poor sleep quality, spontaneous mind wandering, neuroticism, and Past Negative Time Perspective (Randler et al. 2016; Díaz-Morales et al. 2017; Díaz-Morales and Randler 2017; Rodrigues et al. 2018; Carciofo and Song 2019; Demirhan et al. 2019; Carciofo 2020, 2022a, 2024; Hasan et al. 2022).

Thus, the primary aims of the current study were, firstly, to test associations between Morning Affect (MA), Eveningness (EV), Distinctness (DI), and wellbeing (measured with the CSSWQ) and academic achievement in university students. Given that indices of wellbeing have been positively associated with morningness and MA, and negatively with DI, and that academic achievement has been positively associated with morningness and indices of wellbeing, it was expected that student wellbeing and academic achievement would be positively associated with MA and negatively associated with DI. Also, although eveningness has been reliably associated with poor wellbeing when measured with composite measures of morningness-eveningness, when measured with the MESSi indices of poor wellbeing, such as depression, have been more strongly associated with low MA and more DI than with EV (Díaz-Morales et al. 2017; Carciofo 2020). So, it was investigated whether student wellbeing and academic achievement may also be more strongly associated with MA and DI than with EV. Also, given that evening-types are more likely to experience sleep inertia (Carciofo 2023), and as sleep inertia may have substantial negative impacts on cognitive functioning (Jewett et al. 1999; Lundholm et al. 2021; Occhionero et al. 2021) it was tested whether Morning Affect (i.e. sleep inertia duration) may mediate the association between EV and academic achievement, as it has been found to mediate between EV and conscientiousness (Carciofo 2022b) and EV and negative emotionality (Carciofo 2020). Associations with attendance were also explored.

Secondly, the current study aimed to extend exploration of factors that may be involved in the relationship between EV and MA. Research utilising the MESSi has consistently found a negative correlation between EV and MA (e.g. Díaz-Morales et al. 2017; Díaz-Morales and Randler 2017; Rodrigues et al. 2018; Carciofo and Song 2019; Demirhan et al. 2019). Although sleep-related factors (e.g. sleep duration and sleep quality) seem plausible mechanisms for the EV-MA association, research utilising the MESSi has shown consistent negative correlations between poor sleep and having less MA (i.e. more sleep inertia) but weak/small/inconsistent correlations with EV (Demirhan et al. 2019; Carciofo 2020, 2022a). So, to help elucidate factors possibly involved in the relationship between EV and MA, associations between MA, EV, substance use (alcohol, nicotine, and caffeine) and electronic screen time were explored, as were associations with DI. Assuming that the delayed bedtime associated with more eveningness may increase the likelihood of late night use of substances and electronic devices, it was investigated whether substance use (alcohol, nicotine, and caffeine) and/or electronic screen time may mediate the EV-MA relationship. Alternative models with use of substances and electronic devices as the predictors were also tested.

Method

Sample

An email invitation including the link to the survey was sent to approximately 8700 students at an English-medium university in Suzhou, China. The briefing stated that participation was voluntary, unpaid, anonymous, with the right to withdrawn at any time; inclusion criteria were being a Chinese student at the university aged at least 18 years. After clicking an icon to give informed consent, the survey was presented. Of 425 participants who began the survey, 232 meeting the inclusion criteria provided complete responses which were used for the analysis. The participants' mean age = 20.65 (SD = 1.365; range = 19–27); 96 males (mean age = 20.82, SD = 1.635) and 136 females (mean age = 20.53, SD = 1.128), t = 1.618, df = 230, p = .107. Approval of the research protocol was provided by the Research Ethics Committee at Xi'an Jiaotong-Liverpool University, Suzhou, China (research proposal number: 20-04-03).

Materials

The Morningness-Eveningness-Stability-Scale improved (MESSi; Randler et al. 2016; Chinese version:; Carciofo and Song 2019). This has subscales for Morning Affect (MA), assessing alertness/sleep inertia upon awakening (e.g. *I feel drowsy for a long time after awakening*), with higher scores indicating shorter lasting sleep inertia; Eveningness (EV; circadian preference for activity/time of optimal functioning, e.g. *I am more an evening than a morning active person*); Distinctness (DI; amplitude of diurnal variation in functioning, e.g. *There are moments during the day when it is harder for me to think*). Each subscale has five items, scored 1–5, so higher scores show more MA/EV/DI. The MESSi has shown a consistent factorial structure across translations and good internal consistency (e.g. Díaz-Morales and Randler 2017; Carciofo and Song 2019; Demirhan et al. 2019).

The College Student Subjective Wellbeing Questionnaire(CSSWQ; Renshaw and Bolognino 2016; Renshaw 2018; Chinese version: Zhang and Carciofo 2021). The CSSWQ has 16 items, with four items for each of the four subscales: Academic Satisfaction (e.g. *I am happy with how I've done in my classes*), Academic Efficacy (e.g. *I am a diligent student*), School Connectedness (e.g. *I can really be myself at this school*), and College Gratitude (e.g. *I feel thankful for the opportunity to learn so many new things*). Items are scored on a 1 (strongly disagree) to 7 (strongly agree) scale. The CSSWQ has shown good construct validity, internal consistency, and test–retest reliability (Renshaw 2018; Zhang and Carciofo 2021).

The Big Five Inventory, 44-item (BFI-44; John and Srivastava 1999; Chinese version: John and Srivastava 2003; Carciofo et al. 2016). Only the conscientiousness subscale was used in the current study. This has nine items, each scored on a 1–5 Likert scale; higher scores show more conscientiousness. The BFI-44 has shown good construct validity and reliability (Soto and John 2009).

The Mind Wandering-Deliberate and Mind Wandering-Spontaneous scales (Carriere et al. 2013; Chinese versions: Carciofo and Jiang 2021) assess intentional/deliberate mind wandering (e.g. *I allow my thoughts to wander on purpose*) and unintended/spontaneous mind wandering (e.g. *I find my thoughts wandering spontaneously*). Each scale has four items each utilising a 7-point Likert scale; higher scores show more trait-level mind wandering. Good internal consistency and consistent associations with measures of attentional control have been reported for the scales (Carriere et al. 2013).

The Students' Life Satisfaction Scale (SLSS; Huebner 1991). The 5-item Chinese version validated by Jiang et al. (2018) scores each item on a 1–6 scale, so higher scores show more general life satisfaction. A reference to "kids" in one item was replaced with "people". The SLSS has shown acceptable internal consistency and consistent correlations with other measures of wellbeing.

Lifestyle questions:

How often do you have problems with your sleeping, for example, insomnia or frequently waking during the night? Options were (1) never, (2) occasionally, (3) at least once a month, (4) at least once a week, (5) every day.

How many hours do you usually sleep every night? Options were 4 or less, 5, 6, 7, 8, 9 or more.

Your class attendance during this academic year. Options and scoring were (1) Less than 20%, (2) 20%-50%, (3) 50%-80%, (4) 80%-100%.

Your Grade Point Average (GPA) during this academic year. Options and scoring were (1) Very bad, (2) Below average, (3) Average, (4) Good, (5) Excellent.

How often do you smoke? Options and scoring were (1) never, (2) rarely, (3) on average 1–2 per day, (4) on average 3–10 per day, (5) on average >10 per day.

For the following three items options and scoring were (1) never, (2) rarely, (3) several times a month, (4) at least once a week, (5) daily/almost daily: *How often do you drink alcohol? How often do you drink coffee or caffeinated drinks? How often do you stay up late because you are using your phone, computer, or playing video games?*

Data analysis

The mean, standard deviation, range, skewness, kurtosis, and Cronbach's alpha (internal consistency) were calculated as descriptive statistics for each scale/subscale. In addition, for more comparison with previous studies, a composite measure of morningness-eveningness was calculated by reversing the scores for Eveningness then adding them to the scores for Morning Affect (for this procedure see also Vagos et al. 2019).

Pearson's product-moment correlation was used for correlational analysis, for which coefficients of .10, .30, and .50 may be taken to indicate small, medium, and large effect sizes, respectively (Cohen 1992). $N = 194$ is adequate to establish a corelation of $r = .2$ with 80% power at $p = .05$ (https://sample-size.net/correlation-sample-size/); while much analysis on the current study was exploratory, previous research on correlates of MA/EV/DI (such as sleep quality, conscientiousness, and life satisfaction) has shown coefficients of around this magnitude or stronger (e.g. Díaz-Morales and Randler 2017; Demirhan et al. 2019; Carciofo 2020, 2022a). Following previous research (e.g. Jankowski 2016, Seli et al. 2019; Carciofo 2020; Carciofo and Jiang 2021), partial correlations were calculated for EV while controlling for MA and for deliberate mind wandering when controlling for spontaneous mind wandering and vice versa. Mediation effects were tested with PROCESS (Hayes 2022); indirect effects were calculated from 5000 bootstrap samples, with statistical significance indicated when the 95% percentile bootstrap confidence intervals exclude zero.

Results

Descriptive statistics are shown in Table 1. For most measures the scores covered the range of possible values. Internal consistency was good, with values of Cronbach's alpha all > .7. Distributions generally approximated normality, with absolute values of skewness and kurtosis mostly <1, however smoking had strong positive skewness, with 196/232 (84.5%) reporting that they never smoke. Also, 182/232 (78.4%) reported consuming alcohol never or rarely.

Age was not significantly correlated with any of the variables except CSSWQ School connectedness, $r = .174$ ($p = 0.008$). Gender differences were found for Distinctness: male mean = 18.47 ($SD = 4.245$), female mean = 20.40 ($SD = 3.409$), $t = -3.690$, df = 175.563, $p < .001$; Attendance: male mean = 2.81 ($SD = .874$), female mean = 3.12 ($SD = .817$), $t = -2.721$, df = 230, $p = .007$; and Alcohol consumption, male mean = 2.10 (SD = .989), female mean = 1.82 ($SD = .851$), $t = 2.312$, df = 230, $p = .022$.

Table 1. Descriptive statistics.

	Range (possible)	Mean	Standard deviation	Skewness	Kurtosis	Cronbach's Alpha
CSSWQ Academic satisfaction	*4–26 (4–28)*	*16.39*	*4.934*	*-.211*	*-.542*	*.857*
CSSWQ Academic efficacy	*4–28 (4–28)*	*16.11*	*5.827*	*-.239*	*-.481*	*.922*
CSSWQ School connectedness	*5–28 (4–28)*	*19.78*	*4.679*	*-.469*	*.185*	*.821*
CSSWQ School gratitude	*6–28 (4–28)*	*23.44*	*4.174*	*-1.346*	*2.433*	*.866*
CSSWQ total	23–105 (16–112)	75.72	15.147	−.535	.395	.910
Morningness-eveningness	13–46 (10–50)	27.89	6.689	.161	−.377	.811
Morning Affect	5–25 (5–25)	15.84	3.895	−.148	−.241	.787
Eveningness	6–25 (5–25)	17.94	4.321	−.251	−.555	.817
Distinctness	5–25 (5–25)	19.60	3.887	−.890	.857	.730
Conscientiousness	13–44 (9–45)	29.41	5.860	−.233	−.219	.821
Mind wandering-deliberate	4–28 (4–28)	17.40	6.305	−.168	−.835	.804
Mind wandering-spontaneous	4–28 (4–28)	18.04	6.209	−.280	−.536	.870
Life satisfaction	5–30 (5–30)	19.97	5.800	−.600	−.178	.906
Grade Point Average (GPA)	1–5 (1–5)	3.36	.915	−.223	.049	-
Attendance	1–4 (1–4)	2.99	.853	−.533	−.340	-
Poor sleep quality	1–5 (1–5)	2.63	1.163	.635	−.562	-
Sleep duration	1–6 (1–6)	4.03	1.085	−.359	−.249	-
Late night screen time	1–5 (1–5)	3.82	1.239	−.754	−.581	-
Alcohol	1–5 (1–5)	1.94	.919	.964	.727	-
Caffeine	1–5 (1–5)	3.43	1.372	−.287	−1.284	-
Smoking	1–5 (1–5)	1.36	.943	2.620	5.716	-

N = 232; standard error of skewness = .160; standard error of kurtosis = .318. CSSWQ = College Student Subjective Wellbeing Questionnaire.

Table 2. Correlations with the CSSWQ.

	Academic satisfaction	Academic efficacy	School connectedness	School gratitude	CSSWQ total
Morningness-eveningness	.061	.219***	−.062	−.056	.070
Morning Affect	.172**	.246***	.079	.057	.191**
Eveningness	.060	−.118	.167*	.139*	.064
Eveningness, controlling for Morning Affect	*.124*	*-.041*	*.205***	*.167**	*.136**
Distinctness	−.095	−.153*	−.022	.039	−.086
Conscientiousness	.438***	.708***	.337***	.230***	.582***
Mind wandering-deliberate	−.101	−.315***	−.072	−.054	−.191**
Mind wandering-deliberate, controlling for MW-spontaneous	*.037*	*-.156**	*.003*	*-.060*	*-.062*
Mind wandering-spontaneous	−.296***	−.422***	−.167*	−.002	−.311***
Mind wandering-spontaneous, controlling for MW- deliberate	*-.282****	*-.331****	*-.151**	*.025*	*-.257****
Life satisfaction	.572***	.296***	.527***	.340***	.557***
Grade Point Average (GPA)	.475***	.658***	.308***	.171**	.550***
Attendance	.327***	.339***	.181**	.191**	.345***
Poor sleep quality	−.048	−.116	−.059	.044	−.066
Sleep duration	.023	.037	.051	−.085	.014
Late night screen time	−.106	−.368***	−.055	−.027	−.200**
Alcohol	.085	.063	.041	.107	.094
Caffeine	.101	.056	.047	.151*	.110
Smoking	.022	−.001	−.030	.070	.017

N = 232. $^{*}p \le .05$; $^{**}p \le .01$; $^{***}p \le .001$. MW = mind wandering. CSSWQ = College Student Subjective Wellbeing Questionnaire.

Table 2 shows correlations between CSSWQ and the other study variables. Academic Satisfaction had small to strong significant positive correlations with MA, conscientiousness, life satisfaction, GPA, and attendance, and negatively correlated with spontaneous mind wandering (MW). Academic efficacy showed the same significant correlates, and also a significant small/medium positive correlation with morningness-eveningness (ME), and significant medium negative correlations with Distinctness, deliberate MW, and late night use of electronics. School connectedness had significant small to large positive correlations with conscientiousness, life satisfaction, GPA and attendance, and with Eveningness (which was slightly stronger after controlling for MA). Also, a significant small negative correlation was shown with spontaneous MW. School gratitude showed the same pattern of correlations, except that with MW was not significant, and there was a significant small correlation with consumption of caffeine. Sleep quality and duration, alcohol use, and smoking did not show any significant correlations with CSSWQ. Correlations between CSSWQ components (see Supplementary materials, Table S1) ranged from .262 (Academic efficacy and School gratitude) to .588 (Academic satisfaction and Academic efficacy).

ME had a small/medium positive correlation with academic achievement (GPA), $r = .237$, as did MA, $r = .273$ ($ps < .001$). Distinctness had a small negative correlation with GPA, $r = -.140$ ($p = .033$). Eveningness was also negatively correlated with GPA, although this did not reach statistical significance, $r = -.121$ ($p = .066$) and, furthermore, when controlling for MA this correlation was attenuated to $r = -.036$ ($p = .590$). Correlations between ME/MA/EV/DI and attendance were small/weak and not significant: .095 (ME), .103 (MA), −.055 (EV), and −.049 (DI).

Correlations related to the second aim of the current study are shown in Table 3. Late night screen time had significant small/medium correlations with morningness-eveningness and MA (negative), and EV (positive). When controlling for MA, the correlation with EV was slightly attenuated. Use of caffeine, alcohol, and nicotine did not have any significant correlations with the components of circadian functioning.

Other correlations between study variables replicated previously reported associations (see Supplementary materials, Table S2). For all study correlations, when controlling for age and gender in partial correlations, the largest absolute difference compared to the zero-order correlation coefficients was .046.

Mediation analysis

There was a significant indirect effect of EV on GPA through MA (Table 4, model 1). Regarding the inter-relationships between EV, MA, substance use and electronic screen time, indirect effects from EV to MA through alcohol, caffeine, and nicotine were all non-significant (confidence intervals included zero), but there was a significant indirect effect from EV to MA through electronic screen time (Table 4, model 2). Alternative models with substance use/electronic screen time as the predictor, EV as the mediator, and MA as the outcome were also tested. Again, the models with alcohol, caffeine, and nicotine use were all non-significant,

Table 3. Correlations between circadian functioning, substance use, and electronic screen time.

	Late night screen time	Alcohol	Caffeine	Smoking
Morningness-eveningness	−.356***	−.038	.006	.023
Morning Affect	−.253***	.020	.005	.008
Eveningness	.322***	.078	−.004	−.028
Eveningness, controlling for Morning Affect	*.263****	*.089*	*-.002*	*-.027*
Distinctness	.068	.014	.013	.015

N = 232. ***$p \leq .001$.

Table 4. Mediation analysis.

Regression model 1: Criterion = Grade Point Average	Predictor: Eveningness β	Mediator: Morning Affect β	-	Unstandardised indirect effect (95% CI) [standardised indirect effect (95% CI)]
R = .275, R^2 = .076, F(2, 229) = 9.371***	−.036	.261***	-	−.0179 (−.0331/-.0062) [−.0847 (−.1546/-.0304)]
Regression model 2: Criterion = Morning Affect	**Predictor: Eveningness β**	**Mediator: Electronic screen time β**	-	**Unstandardised indirect effect (95% CI) [standardised indirect effect (95% CI)]**
R = .360, R^2 = .130, F(2, 229) = 17.061***	−.271***	−.166*	-	−.0481 (−.0951/-.0085) [−.0534 (−.1045/-.0095)]
Regression model 3: Criterion = Morning Affect	**Predictor: Electronic screen time β**	**Mediator: Eveningness β**	-	**Unstandardised indirect effect (95% CI) [standardised indirect effect (95% CI)]**
R = .360, R^2 = .130, F(2, 229) = 17.061***	−.166*	−.271***	-	−.2745 (−.4511/-.1285) [−.0873 (−.1413/-.0411)]
Regression model 4: Criterion = Grade Point Average	**Predictor: Eveningness β**	**Mediator 1: Electronic screen time β**	**Mediator 2: Morning Affect β**	**Unstandardised indirect effect (95% CI) [standardised indirect effect (95% CI)]**
R = .332, R^2 = .111, F(3, 228) = 9.443***	.018	−.200**	.228***	−.0026 (−.0065/-.0003) [−.0122 (−.0300/-.0015)]
Regression model 5: Criterion = Grade Point Average	**Predictor: Electronic screen time β**	**Mediator 1: Eveningness β**	**Mediator 2: Morning Affect β**	**Unstandardised indirect effect (95% CI) [standardised indirect effect (95% CI)]**
R = .332, R^2 = .111, F(3, 228) = 9.443***	−.200**	.018	.228***	−.0147 (−.0300/-.0040) [−.0199 (−.0401/-.0056)]

N = 232. *$p \le .05$; **$p \le .01$; ***$p \le .001$.

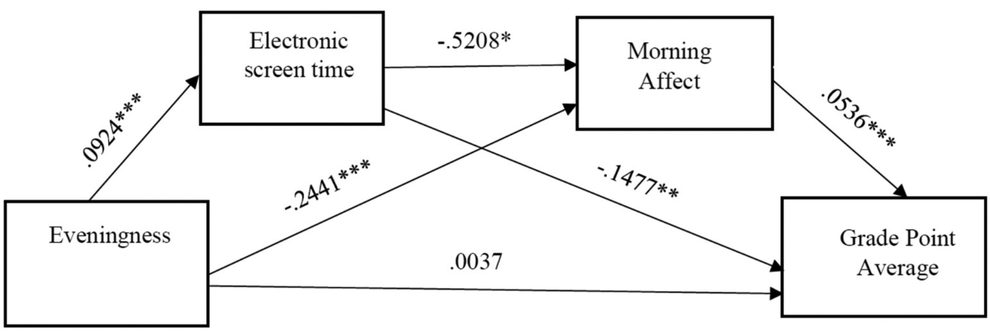

Figure 1. Serial mediation model: indirect effect of eveningness on grade point average, through electronic screen time and morning affect. Values are unstandardized regression coefficients. Indirect effect = −.0026 (95% CI = −.0065/−.0003). *$p \le .05$; **$p \le .01$; ***$p \le .001$.

but there was a significant indirect effect from electronic screen time through EV to MA (Table 4, model 3). Building on these results, a fourth model tested the indirect effect from EV through electronic screen time and MA to GPA, and a fifth model tested the indirect effect from electronic screen time through EV and MA to GPA. Both models had significant indirect effects (see Table 4, models 4 and 5, and Figures 1 and 2). All models in Table 4 remained significant when age and gender were included as covariates (see Supplementary materials, Table S3).

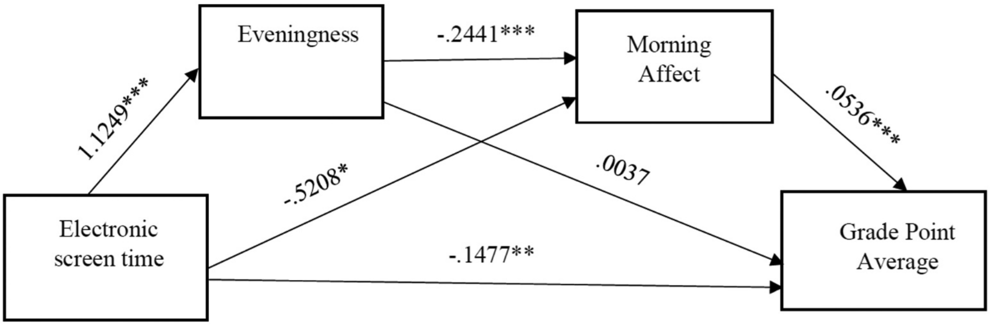

Figure 2. Serial mediation model: indirect effect of electronic screen time on grade point average, through eveningness and morning affect. Values are unstandardized regression coefficients. Indirect effect = −.0147 (95% CI = −.0300/−.0040). **p* ≤ .05; ***p* ≤ .01; ****p* ≤ .001.

Discussion

The current study aimed to: (1) investigate associations between Morning Affect (MA), Eveningness (EV), Distinctness (DI), and wellbeing, academic achievement, and attendance in university students, including whether MA mediates the association between EV and academic achievement. (2) Investigate associations between MA, EV, DI, and substance use (alcohol, nicotine, and caffeine), and electronic screen use at night. It was also tested whether substance or screen use mediates the EV-MA relationship and/or whether EV mediates the relationship between substance use/screen use and MA.

Correlational analysis showed that Morning Affect (MA) had small/medium significant positive correlations with Academic Satisfaction (AS) and Academic Efficacy (AE), while morningness-eveningness (composite of MA + reversed Eveningness) only correlated with AE. In contrast, Eveningness had small significant positive correlations with School Connectedness (SC) and School Gratitude (SG), which were (slightly) stronger after controlling for Morning Affect, as was the correlation with AS. Distinctness had a small significant negative correlation with AE.

These findings are consistent with other evidence showing positive associations between higher Morning Affect (less sleep inertia) and measures of wellbeing, such as positive affect, life satisfaction, and less negative emotionality, and negative associations between Distinctness and wellbeing (e.g. Carciofo and Song 2019; Carciofo 2020, 2022a, 2024; Demirhan et al. 2019; Díaz-Morales et al. 2017; Díaz-Morales and Randler 2017; Hasan et al. 2022; see also the Supplementary materials, Table S2). Also, while MA may be more associated with aspects of wellbeing related to academic achievement, the current findings indicate that Eveningness may be more associated with wellbeing related to having a sense of connection with the learning institution, which may perhaps be related to more involvement in the evening social activities. The current results for Eveningness as assessed by the MESSi contrast with findings from studies utilising composite measures of morningness-eveningness (such as the MEQ and CSM) which have found that eveningness tends to be associated with indices of poor wellbeing (for a review, see Taylor and Hasler 2018). Other research utilising the MESSi has likewise shown, for example, stronger associations between negative emotionality and low MA (and more DI) than with EV (Díaz-Morales et al. 2017; Carciofo 2020). This suggests the possibility that some previously reported associations between eveningness and poor wellbeing may have been driven by items on composite scales which assess Morning Affect.

Academic achievement (GPA) had a moderate positive correlation with MA and small negative correlations with Eveningness and Distinctness. Díaz-Morales and Puig-Navarro (2022) also found that EV had a small negative correlation with academic performance ($r = -.14$, compared to $r = -.121$ in the current study) in a sample of 725 adolescents aged 12–17, although correlations with MA and DI were weak (.07 and = .01, respectively, compared to .273 and −.140 in the current study). However, although not the focus of the study, Carciofo (2024; see the supplementary materials) found GPA correlations of .123 (MA), −.085 (EV), and −.211 (DI). There were also small/moderate correlations with attendance of .213 (MA), −.161 (EV), and −.194 (DI), while those in the current study were weak/small (the strongest being with MA, $r = .103$).

Despite some variation in strength, perhaps related to sample differences, the positive association between GPA and MA, and negative association with EV, have been consistent. However, while the negative correlation between EV and academic achievement replicates that found with composite morningness-eveningness measures, the current study found that when controlling for MA the correlation became very weak. Furthermore, there was a significant indirect effect of Eveningness on GPA through Morning Affect. This adds to previous findings showing that MA mediates between Eveningness and: negative emotionality (Carciofo 2020), spontaneous mind wandering (Carciofo 2022a), and conscientiousness (Carciofo 2022b). Sleep inertia (low MA) adversely impacts energy, mood, motivation, and cognitive functioning (Jewett et al. 1999; Lundholm et al. 2021; Occhionero et al. 2021). So, this may include less effective conscientious self-regulation for undertaking study, and more mind wandering (poorer control of attention), which may adversely impact academic achievement.

Also, consistent with previous research (Renshaw 2018; Zhang and Carciofo 2021) CSSWQ components had small to strong positive correlations with conscientiousness, life satisfaction, and GPA, and also with attendance. Caffeine consumption had a small positive correlation with Student Gratitude; the reliability and possible basis for this association require further research. In addition, spontaneous mind wandering had small/moderate negative correlations with Academic Satisfaction, Academic Efficacy, and School Connectedness; Academic Efficacy had a small negative correlation with deliberate mind wandering, and a medium negative correlation with late night screen time. CSSWQ components did not show any significant correlations with sleep quality or duration, alcohol use, or smoking. Zhang and Carciofo (2021) also found no correlations between CSSWQ and alcohol use, but found a small positive correlation between School Connectedness and smoking.

Morning Affect, Eveningness, and Distinctness did not show any significant correlations with smoking, caffeine use, or alcohol use. The lack of correlations for Eveningness contrasts with previous research showing associations between eveningness and more use of alcohol, nicotine, and caffeine (e.g. Wittmann et al. 2006; Bakotic et al. 2017; Suh et al. 2017). Although most previous research has utilised composite measures of morningness-eveningness, Arrona-Palacios et al. (2020) found more use of alcohol and nicotine in evening-types as assessed with the MESSi. The discrepant results in the current study may reflect sample differences: Arrona-Palacios et al. (2020) included adults aged 18–77 (mean = 27.79), while the current study had a younger sample; also, the rates of alcohol and nicotine use were relatively low in the current sample, possibly reflecting cultural or subcultural differences. Further research may explore this.

However, Eveningness was associated with more late night screen time: a moderate positive correlation with the Eveningness subscale and a moderate negative correlation with the composite measure of morningness-eveningness. These results are consistent with previous research findings of eveningness being associated with more electronic screen time (Krejci et al. 2011; Shimura et al. 2018), including related to more video-game playing and problematic internet use (Krejci et al. 2011; Vollmer et al. 2014; Przepiorka et al. 2021). In addition, Morning Affect had a small/moderate negative correlation with late night screen time, while DI only showed a weak positive correlation. These findings for EV, MA, and DI are consistent with those from an unpublished study of associations with problematic video-game playing (Jiang 2020).

Furthermore, there was a significant indirect effect from EV to MA through electronic screen time, supporting a path from being more evening-type to more likelihood of late night use of electronic devices, consequently leading to more sleep inertia. However, there was also a significant indirect effect from electronic screen time to MA through EV, supporting a path from late night use of electronic devices leading to more eveningness, consistent with light exposure from devices contributing to a phase delay, leading to more eveningness (Krejci et al. 2011). The circadian system can be disrupted by artificial light (Touitou and Point 2020), and short wavelength light emitted by electronic devices may increase sleep latency and reduce the amount of slow wave sleep (Green et al. 2017). Thus, influences on sleep patterns and sleep architecture may be a mechanism for the association between more eveningness and less MA (more sleep inertia).

Furthermore, exploratory analysis showed a significant indirect effect of Eveningness on academic achievement (GPA) sequentially through late night screen time and MA. Also, there was a significant indirect effect of late night screen time on GPA sequentially through Eveningness and MA, consistent with the finding that chronotype and emotional/behavioural problems serially mediated between electronic screen time and academic achievement in a sample of 9–12 year olds (Matsui et al. 2024). Evening-types are more likely to experience social jetlag due to having to rise for early classes, and sleep inertia is more likely when rising closer to the nadir of the circadian core body temperature rhythm (Scheer et al. 2008). The impact of late night use of electronic devices on sleep may exacerbate the effects of social jetlag/sleep inertia. Impaired cognitive functioning and task performance are associated with poor sleep (Alapin et al. 2000; Åkerstedt 2007) and sleep inertia (Jewett et al. 1999; Lundholm et al. 2021; Occhionero et al. 2021). Related to this, self-regulation/self-control may be adversely impacted: the relationship between morningness and self-control may be mediated by social jetlag (Wang and Hu 2016), and social jetlag may have an indirect effect on poorer academic achievement through reduced conscientiousness (Borgio and Louzada 2021). Tasks that require more self-regulatory effort induce "self-regulatory fatigue" leading to a weaker relationship between conscientiousness and task engagement/persistence (Nes et al. 2011). Also, reduced cognitive stability (Marcusson-Clavertz et al. 2020) and impaired executive functioning (McVay and Kane 2010) may increase the frequency of spontaneous mind wandering. Together, these sleep-related influences may adversely impact academic achievement and aspects of student wellbeing.

Limitations and future research

The current study involved a limited student sample from a single university; further studies may include samples from multiple universities, and compare countries, and obtain more detailed information such as year of study, socio-economic status, and mental health status. Also, the current study only utilised self-report measures, including a subjective measure of GPA, which may be less valid than actual grades (Morris and Fritz 2015). So, further research on this topic would benefit from using objective measures of academic achievement. In addition, more fine-grained measures of some variables may be informative, such as assessing the time of day of caffeine consumption (Siudej and Malinowska-Borowska 2021), the type of electronic screen use involved (phone, TV, computer, etc), and usual bed and wake times on school and free days to allow for calculation of social jetlag. Also, facets and behavioural indicators of conscientiousness may be assessed (Carciofo 2022b), to more fully investigate associations with academic achievement. The cross-sectional design of the current study precludes any conclusions about causality; these may be tested in longitudinal research.

Further research may also extend the network of variables. For example, Future Time Perspective is associated with better academic achievement, conscientiousness, and more MA (Carciofo 2024), while Present Hedonistic and Present Fatalistic Time Perspectives are associated with experiencing social jetlag (Borisenkov et al. 2019). Maladaptive metacognitive beliefs, such as in the uncontrollability and consequences of thoughts, are associated with less MA and more negative emotionality (Carciofo 2020) and with poorer academic achievement (Carciofo 2021). Also, late night electronic screen exposure from playing online games is associated with depression, with this relationship partially mediated by daytime sleepiness (Lemola et al. 2011), and daytime sleepiness is negatively related with learning motivation (Roeser et al. 2013). Longitudinal research may investigate the possible bidirectional relationship between chronotype and late night use of electronic devices, and how this may be associated with other bidirectional relationships such as those between sleep and emotion/affect (Kahn et al. 2013), and morningness-eveningness and academic achievement (Scherrer and Preckel 2021).

Further research on the relationship between EV and MA may consider types of sleep disturbances, such as coughing/snoring (Carciofo 2022a), and social jetlag. Also, while not significant in the current study, alcohol and nicotine use may be further investigated in other samples, given that they may influence sleep architecture (Zhang et al. 2006; Chan et al. 2013). Eating habits may also be a factor: eveningness is associated with late night meals (Suh et al. 2017).

However, while the relationships between circadian functioning, student wellbeing, and academic achievement may be complex, identification of possible mechanisms of association may provide the basis for the development of interventions which may benefit student wellbeing and achievement, such as through improved sleep hygiene, including in relation to restricting late night screen time. The role of sleep inertia in the relationship between eveningness and poorer academic achievement may be related to evidence showing delayed school times may improve attendance, punctuality, and GPA, and reduce behavioural problems in high school students (James et al. 2023).

Conclusion

Components of circadian functioning were related to student wellbeing and academic achievement: more Morning Affect (MA; i.e. less sleep inertia) was associated with better academic achievement, Academic Satisfaction and Academic Efficacy; Eveningness was positively correlated with School Connectedness and School Gratitude, and Distinctness was negatively correlated with Academic Efficacy. Eveningness had an indirect effect on academic achievement through its association with lower MA; Eveningness had an indirect effect on MA through its association with more late night electronic screen time; and electronic screen time had an indirect effect on MA through Eveningness. Interventions to reduce the likelihood or duration of sleep inertia may benefit student wellbeing and academic achievement.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Richard Carciofo http://orcid.org/0000-0003-2069-7047

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