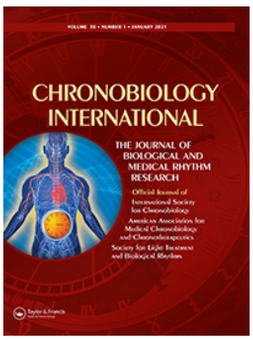

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REPORT

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Associations between diurnal preference, impulsivity and substance use in a young-adult student sample

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ABSTRACT

A diurnal preference for eveningness is common in young adulthood and previous research has associated eveningness with anxiety symptoms as well as increased smoking and alcohol use behaviors. There is some evidence that impulsivity might be an important explanatory variable in these associations, but this has not been comprehensively researched. Here we used both subjective and objective measures of impulsivity to characterize impulsive tendencies in young adults and investigated whether trait impulsivity or trait anxiety could mediate the link between eveningness and substance use. A total of 191 university students (169 females), age range 18–25 y, completed the study. Diurnal preference, sleep quality, anxiety, impulsivity, and substance use were assessed by questionnaire. Impulsivity was also measured using a delay discounting task. Eveningness correlated with trait anxiety and trait impulsivity, and these associations were still significant after controlling for sleep quality. On the delayed discounting task, eveningness correlated with a tendency to prefer smaller immediate rewards over delayed, larger ones. Evening types also reported higher levels of alcohol and cigarette use even after controlling for sleep quality. These associations were found to be completely mediated by self-reported impulsivity; anxiety did not contribute. The current results could help inform interventions aiming to reduce substance use in young adult populations.

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Impulsivity; trait anxiety; chronotype; diurnal preference; eveningness; alcohol; tobacco; delay discounting

Introduction

Diurnal preference refers to an individual's preferred timing of daily activity, wake-up and bed times. The distribution of diurnal preference follows a continuum between two extremes: morning types who prefer to sleep and wake up early, and evening types who prefer to sleep and wake up later (Horne and Ostberg 1976; Kerkhof 1985). Age is an important contributing factor to an individual's diurnal preference. Eveningness peaks at the end of adolescence with a subsequent shift toward morningness becoming apparent with increasing age (Adan et al. 2012). The peak of eveningness in young adulthood coincides with the transition to university. In university student samples, up to 40% identify as evening types, with eveningness more pronounced in males (Adan and Natale 2002; Schneider et al. 2011). Social and familial factors clearly play a role at this age point, such as a reduction of parental control on sleep schedules and increased social and educational demands (Adan et al. 2012). Reconciling one's diurnal preference with these demands has consequences for mental health in student-age populations. Insufficient sleep and irregular sleep-wake patterns are present in up to 60% of students (Lund et al. 2010). A large proportion of students seem to be chronically sleep deprived, particularly in the first year of university; this has been linked to heightened anxiety levels (Norbury and Evans 2019). This is of note given the high prevalence and consequences of anxiety problems in student-age populations (Evans et al. 2018). Students who are evening types report poorer sleep quality, increased tobacco use, and a higher prevalence of minor psychiatric disorders (Schneider et al. 2011). Thus, sleep/wake timing might be a crucial factor influencing mental health and lifestyle behaviors in student-age populations.

Eveningness has been associated with poorer mental health and greater substance use across the lifespan. Large cohort studies have associated greater eveningness with a range of comorbidities, and psychological disorders in particular (Knutson and von Schantz 2018). Eveningness has been associated with higher anxiety symptomology in adolescent, young adult, and older adult samples (Kivela et al. 2018). Although evening types are more likely to report poor sleep quality (in

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Supplemental data for this article can be accessed on the publisher's website.

itself linked to higher anxiety levels), there is some evidence that the association between eveningness and anxiety is independent of sleep factors, although studies are lacking. In a healthy sample of predominantly younger adults, Cox and Olatunji (2019) found an association between eveningness and anxiety that persisted even after controlling for sleep disturbances. In that study, diurnal preference was assessed using the self-report Morningness-Eveningness Questionnaire (MEQ) that aims to characterize timing of peak alertness; findings were corroborated with actigraph-based measures. The current study aimed to confirm whether eveningness contributes to anxiety symptomology independent of sleep quality, while also considering other important factors linked to eveningness, specifically, substance use and impulsivity (Fabbian et al. 2016).

Increased smoking and alcohol use behaviors have been consistently linked to eveningness in adolescent (Hasler et al. 2017; Urban et al. 2011), university (Kabrita et al. 2014; Whittier et al. 2014) and older adult samples (Adan 1994), as assessed using the MEQ. Importantly, one study showed that smoking and alcohol use mediated the relationship between eveningness and poorer psychological wellbeing, in healthy adults across the age range (Wittmann et al. 2010). This suggests that substance use behavior might be related to the heightened risk of anxiety associated with eveningness; we explore this in the current study.

Impulsivity might also be an important factor that contributes to higher levels of substance use in evening types, but this has not been investigated. Novelty-seeking traits have been shown to be higher in young-adult evening types (Adan et al. 2010; Hsu et al. 2012). Other studies have shown that eveningness is associated with higher levels of subjective trait impulsivity, as measured by the Barratt Impulsivity Scale (BIS-11; Patton et al. 1995). This has been shown in healthy young adults (Kang et al. 2015) and in a sample aged 20–70 y, with impulsivity mediating an observed relationship between eveningness (from MEQ) and anger (Hwang et al. 2016). A relationship between eveningness (from MEQ) and self-reported risk propensity has also been shown in young adults (Gowen et al. 2019); Wang and Chartrand (2015) linked eveningness to greater self-reported financial risk-taking in an adult sample aged 18 to 69 y. Thus, links between eveningness and subjective impulsivity appear to be robust. Another questionnaire-based study by Stolarski et al. (2013) found that young-adult evening types (from MEQ) reported a greater present-hedonistic time perspective, suggesting a preference for immediate over delayed rewards.

Behavioral paradigms are useful in probing these relationships in terms of the underlying cognitive mechanisms, but studies are lacking. Computer-based delay discounting tasks can be used to empirically test how impulsivity in evening types impacts reward preferences, by asking participants to choose between smaller immediate rewards over larger, delayed rewards. One study, found no difference between young adults with a morning/intermediate diurnal preference and evening types using such a task. However, the modest sample size (n = 86) and the collapsing of early and intermediate chronotypes into a single group limits the interpretation these results (Berdynaj et al. 2016).

In sum, although links between eveningness, anxiety, impulsivity, and substance use could be inferred, detail is lacking in the literature. Young adult evening types show increased smoking and alcohol use behaviors, as well as higher anxiety symptomology and higher trait impulsivity. The relationships with anxiety and impulsivity could potentially serve to explain the higher substance use, but this has not been investigated. Coping motives for use of alcohol and other substances in young people with high trait anxiety has been well demonstrated (Comeau et al. 2001; Kuntsche et al. 2006). Likewise, trait impulsivity is a robust predictor of substance use, and specific impulsivity-related personality traits (including sensation seeking and negative urgency) have been shown to directly predict, for example, problematic drinking in university students (Adams et al. 2012). At present, it is uncertain how trait anxiety and/or impulsivity contribute to the observed links between eveningness and substance use. Given the individual relationships previously identified, it is mechanistically plausible that trait anxiety and/or impulsivity are causally involved in the relationship between eveningness and substance use. The implications of substance use behavior for young people's physical and mental health are profound, so identifying potential causal pathways merits careful study. This could inform treatment approaches, but investigations are lacking. To address this, we collected subjective data regarding diurnal preference (using the MEQ), sleep quality, trait anxiety, impulsivity (using the BIS), and substance use, in a student-age sample. Decisional impulsivity was objectively measured in the lab using a delay discounting task (which assesses preference for small, immediate rewards versus larger but delayed rewards). First, we hypothesized (H1) a link between eveningness and anxiety symptoms that exists independent of lower sleep quality (in line with previous findings). Second (H2), we predicted that evening types would report higher levels of substance use (caffeine, cigarettes, and alcohol, assessed separately). Also we predicted that evening types would show higher levels of self-reported impulsivity (H3), and this

would be reflected in an experimental setting (delayed discounting task), manifesting as a preference for immediate rewards (H4). Finally (H5) we hypothesized that trait impulsivity and/or trait anxiety might play a causal role in the relationship between diurnal preference and substance use in this young adult population. As such, parallel mediation models (with trait impulsivity and trait anxiety as mediator variables) were conducted.

Methods

All procedures were approved by the University of Surrey Ethics Committee (reference: FT-1819-23). Informed consent was given by all study participants; appropriate ethical standards were followed throughout.

Participants

Participants consisted of undergraduate students from two university sites (Surrey and Roehampton) in the UK. The study was advertised to students online via a SONA systems (https://www.sona-systems.com/) participant recruitment portal. Inclusion criteria were age: 18–28 y. Exclusion criterion were: current or previous clinical diagnosis of substance abuse, Attention Deficit Hyperactivity Disorder (ADHD), or Gambling disorder (determined through self-report). Participants received course credit for taking part, and this was not related to task performance.

Procedure

The study took approximately 45 min to complete and consisted of a lab task and questionnaires; all participants completed these in the same order. Since time of testing could act as a potential confound, all data collection took place within a narrow time window (between 11:00 and 14:00 h). Using a Windows PC, questionnaires and demographic information were collected using Qualtrics (www.qualtrics.com) and the delayed discounting task was administered using E-Prime 2.0.

Self-report measures

Substance Use was assessed using the following questions:

For cigarette use: "Approximately how many cigarettes do you smoke per week (including weekends)?"

For caffeine use: "Approximately how many cups of coffee do you drink per week (including weekends)?" "Approximately how many cans of caffeinated drinks to do you consume per week (including weekends)?"

For alcohol use: "Approximately how many units of alcohol (a unit is approximately equivalent to a small glass of wine or half a pint of beer/lager) do you drink per week (including weekends)?"

Diurnal Preference was measured using the 5-item Reduced Morningness-Eveningness Questionnaire (rMEQ) (Adan and Almirall 1991). This measure instructs participants to rate their responses on a 4-point scale (e.g., "During the first half hour after you wake up in the morning, how do you feel?" "Very tired", "fairly tired", "fairly refreshed", and "very refreshed"). Acceptable internal consistency was observed ($\alpha = 0.70$). Previous work has shown good test-retest reliability ($r = 0.76–0.79$) and high correlation with the original Morningness-Eveningness Questionnaire ($r = 0.87–0.90$) (Di Milia et al. 2013).

Sleep quality was assessed with the Pittsburgh Sleep Quality Index (PSQI), a 19-item measure which considers seven components of sleep: quality, latency, duration, efficiency, disturbance, sleeping medication, and daytime dysfunction. Scores can range from 0 to 21 with higher scores indicating worse sleep quality. Acceptable internal consistency was observed ($\alpha = 0.72$) for the total score. Test-retest reliability has previously been reported as $r = .87$ (Backhaus et al. 2002). A score >5 reflects poor quality sleep (Buysse et al. 1989), and this criterion has a sensitivity of 98.7 and specificity of 84.4 for differentiating insomnia patients from controls (Backhaus et al. 2002).

Trait Anxiety was measured using the 20-item State-Trait Anxiety Index (STAI). Trait anxiety items include: "I worry too much over something that really doesn't matter" and "I am content; I am a steady person". Items are rated on a 4-point scale. Satisfactory internal consistency ($\alpha = 0.85$) was observed. Reasonable test–retest reliability ($r = 0.31–0.86$) has previously been reported in young adult groups (Spielberger et al. 1983).

Impulsivity was measured using the 30-item 'Barratt Impulsiveness Scale' (BIS-11; Patton et al. 1995) which includes 3 subscales (attention, motor, nonplanning). Participants indicate their responses on a four-point scale. Satisfactory internal consistency was observed ($\alpha = 0.81$) for the total score. Good test-retest reliability has previously been reported ($r = 0.83$) (Stanford et al. 2009).

Laboratory task – Delayed Discounting Task (DDT; Norbury (2017)) which assessed temporal discounting. Participants were required to indicate, by button press, their preferences for receiving a hypothetical reward (e.g., £100) after some delay or a smaller randomly selected amount (e.g., £45) to be received immediately (e.g., "Would you prefer £45 now, or £100 in 1 month"). The experiment included three amounts (£100, £1000,

and £10000), each presented with the following delays (1 week, 1 month, 12 months, 5 ys, and 10 y). If the participant rejected the immediate reward, its value was increased until the participant accepted. This process was then repeated and the indifference point computed as the average of the two accepted values. Participants completed all three conditions of the experiment (£100, £1000, and £10000), which were presented in random order. For each participant, a delayed discounting metric was calculated by the area under the curve (AUC) method. This well-used method involves plotting indifference point values obtained at each of the delays, and total area under the value/delay curve calculated. Both value and delay axes were normalized, meaning that AUC falls in the range of 0 to 1. Steeper discounting by that participant (i.e., a lower subjective value of delayed rewards) leads to a smaller AUC value (Myerson et al. 2001).

Statistical analysis

All analyses were conducted using IBM SPSS Statistics 25. Raw Pearson's correlations between all variables of interest can be found in Supplementary Material (Table S1). Age and gender were entered as covariates for all analyses and statistics reported in Results. There was no missing data. Data were checked for outliers, and no data points were found to be more than 3.29 standard deviations from the mean. All measures were seen to be approximately normally distributed and scatterplots indicated approximately linear relationships. Partial correlations assessed relationships between diurnal preference and sleep quality (as independent variables, IVs), and trait anxiety, subjective impulsivity, delayed discounting, and substance use (cigarettes, alcohol, and caffeine, assessed separately) (as dependent variables, DVs). Correlations were assessed separately with diurnal preference and sleep quality as IVs, and then sleep quality was entered as a covariate (alongside age and gender) to investigate whether correlations with diurnal preference were still present after controlling for sleep quality.

Parallel mediation was used to investigate whether the associations between rMEQ and substance use were mediated by trait impulsivity (BIS – total) and trait anxiety (STAI). The PROCESS SPSS Macro version 3.5, model four (Preacher and Hayes 2008) was used. The IV was rMEQ score, and the DV was alcohol/cigarette/caffeine consumption (three separate models). BIS (total) and STAI and were entered as mediating variables, with PSQI, age, and gender as covariates. See Figure 1 for a graphical depiction of the models. Unstandardized coefficients are presented from the mediation models.

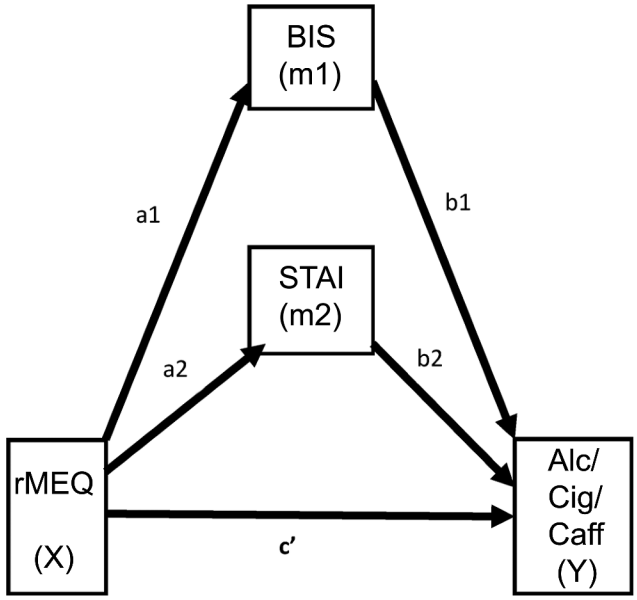

Figure 1. Parallel Mediation Models were run for each of the dependent variables: Alc (Alcohol), Cig (Cigarettes), and Caff (Caffeinated drinks) consumption.

Results

Sample characteristics

Twenty-two males and 169 females completed the study (mean age 19.56, s.d. 1.39 y) (Table 1). Sleep quality as assessed by the PSQI was poor overall (mean = 7.25). Using the generally-adopted criterion of PSQI >5 to differentiate good and poor sleep (Buysse et al. 1989), only 22% of the sample qualified as 'good' sleepers.

Relationships between diurnal preference, sleep quality, and anxiety

A significant correlation was observed between diurnal preference (from rMEQ) and sleep quality (r = −.156, p = .031), indicating that greater eveningness was associated with reduced sleep quality. rMEQ correlated with trait anxiety (r = −.232, p = .002), indicating that

Table 1. Descriptive statistics.

	Minimum	Maximum	Mean	Std. Deviation
Age (y)	18	25	19.56	1.39
PSQI	2	15	7.25	2.33
MEQ	4	21	11.73	3.50
Trait anxiety	24	72	46.42	10.60
BIS Total	44	89	64.03	8.80
BIS- Attentional	8	29	17.15	3.68
BIS- Motor	12	34	21.64	4.16
BIS- Nonplanning	17	35	25.24	4.00
Delayed Discounting (AUC)	0.12	0.90	0.49	0.20
Alcohol (units/wk)	0	30	4.22	5.63
Cigarettes (/wk)	0	30	1.80	5.59
Caffeinated drinks (/wk)	0	48	5.80	7.41

eveningness was associated with higher trait anxiety. PSQI also correlated with trait anxiety (r = .575, $p < .001$), indicating that lower quality sleep was associated with higher trait anxiety (Table 2). To test H1, we controlled for sleep quality (by adding PSQI score alongside age and gender as a covariate); partial correlations showed that the correlation between rMEQ and trait anxiety was still significant (r = −.181, $p = .013$).

Relationships between diurnal preference, sleep quality, and substance use

Significant negative correlations were observed between rMEQ score and weekly consumption of cigarettes and alcohol (Table 2), indicating that eveningness was associated with higher consumption of cigarettes and alcohol, supporting H2. A correlation was observed with caffeinated drinks, but only at trend-level. No relationships were seen with PSQI score. With PSQI included as a covariate in the partial correlations, significant relationships between diurnal preference and alcohol use (r = −0.17, $p = .020$) and between diurnal preference and cigarette use (r = −0.160, $p = .028$) were maintained, while for caffeinated drinks a trend was no longer seen (r = −0.123, $p = .092$).

Relationships between diurnal preference, sleep quality, and subjective impulsivity

Significant correlations were observed between PSQI and rMEQ scores and the subjective impulsivity measure (BIS). Both lower quality sleep and greater eveningness were associated with greater impulsivity. On the BIS subscales, only the attentional subscale correlated with sleep quality, whereas all three subscales correlated with diurnal preference (Table 3), supporting H3.

Since eveningness was, itself, associated with lower sleep quality, it is possible that poorer sleep in evening types could explain the relationship between eveningness and impulsivity. Controlling for sleep quality in the partial correlations, significant associations were still found between rMEQ and total BIS scores (r = −.350, $p < .001$) as well as the attentional (r = −.261, $p < .001$), motor (r = −.210, $p = .004$), and non-planning (r = −.319, $p < .001$) subscales. To further confirm this, correlations were re-assessed excluding participants who reported poor quality sleep (PSQI >5). In this subsample (N = 42), the significant correlation between rMEQ and total BIS scores (r = −.437, $p = .005$) was still observed, as were significant correlations with the attentional (r = −.490, $p = .001$) and non-planning (r = −.381, $p = .015$) subscales. Thus, the relationship between diurnal preference and impulsivity appears to be independent of sleep quality.

Table 2. Pearson correlation coefficients and associated *p* values (in brackets), for associations between sleep quality, diurnal preference, anxiety, and substance use, controlling for age and gender.

	Anxiety	Substance Use		
	STAI	Smoking	Alcohol	Caffeinated Drinks
PSQI	.575 (<0.001)	.060(0.409)	0.029(0.693)	0.094(0.200)
rMEQ	−.232(0.001)	−.167(0.021)	−.172(0.018)	−.135(0.063)

Table 3. Pearson correlation coefficients and associated *p* values (in brackets), for associations between sleep quality, diurnal preference, and impulsivity (BIS-total and subscales, Delayed Discounting task AUC (Area Under the Curve)), controlling for age and gender.

	BIS	BIS Subscales			Delayed Discounting Task
	Total	Attentional	Motor	Nonplanning	AUC
PSQI	.208 (0.004)	.411 (<0.001)	−0.003 (0.935)	0.081(0.268)	−0.095(0.195)
rMEQ	−.370 −.326	(<0.001) (<0.001)	−.297 0.165 (0.024)	(<0.001)	−.207(0.004)

Relationships between diurnal preference, sleep quality, and delayed discounting

Correlations were assessed for PSQI and rMEQ scores against impulsivity measured by the delayed discounting task. Delayed discounting was analyzed as Area Under the Curve (AUC), with smaller values indicating steeper discounting (Table 3). A significant positive association was observed between rMEQ and delayed discounting (r = 0.165, $p = .024$), indicating that greater eveningness was associated with a preference for smaller immediate rewards over larger later ones, supporting H4.

Investigating the mediating role of trait anxiety and trait impulsivity in the relationships between diurnal preference and substance use

To investigate H5, three parallel mediation models were run (IV: rMEQ score, DVs: alcohol/cigarette/caffeine consumption, Mediators: BIS (total) and STAI), see Figure 1. Sleep quality (PSQI) was controlled for by adding it as a covariate; age and gender were also included as covariates.

For alcohol

Results indicated that eveningness is indirectly related to alcohol use through its relationship with trait impulsivity. Eveningness was associated with higher impulsivity (a1 = −0.871; $p < .001$), and higher impulsivity was subsequently related to higher

alcohol use (b1 = 0.148, p = .0038). A 95% bias-corrected confidence interval based on 10,000 bootstrap samples indicated that the indirect effect through impulsivity (a1b1 = −0.129), holding anxiety constant, was entirely below zero (−0.236 to −0.034). In contrast, although eveningness was associated with higher anxiety (a2 = −0.453; p = .013), anxiety score was not related to higher alcohol use (b2 = −0.049, p = .303), and the confidence intervals for the indirect effects through anxiety (a2b2 = 0.022) overlapped with zero (−0.022 to 0.088). After accounting for anxiety and impulsivity, there was no significant association between rMEQ and alcohol use (c' = −0.168, p = .175).

For cigarettes

Results indicated that eveningness is indirectly related to cigarette use through its relationship with trait impulsivity. Higher impulsivity was related to higher cigarette use (b1 = 0.174, p = .0004). A 95% bias-corrected confidence interval based on 10,000 bootstrap samples indicated that the indirect effect through impulsivity (a1b1 = −0.152), holding anxiety constant, was entirely below zero (−0.297 to −0.045). In contrast, although anxiety score was related to higher cigarette use (b2 = 0.097, p = .037), the confidence intervals for the indirect effects through anxiety (a2b2 = −0.044) overlapped with zero (−0.130 to 0.009). After accounting for anxiety and impulsivity, there was no significant association between rMEQ and cigarette use (c' = −0.062, p = .601).

For caffeinated drink consumption

Results indicated that eveningness is indirectly related (at trend level) to caffeinated drink consumption through its relationship with trait impulsivity. Higher impulsivity was related to higher caffeinated drink consumption (b1 = 0.154, p = .022). A 95% bias-corrected confidence interval based on 10,000 bootstrap samples indicated that the indirect effect through impulsivity (a1b1 = −0.134), holding anxiety constant, was entirely below zero (−0.297 to −0.009). In contrast, anxiety score was not related to higher caffeinated drink consumption (b2 = −0.021, p = .745), and the confidence intervals for the indirect effects through anxiety (a2b2 = 0.009) overlapped with zero (−0.044 to 0.065). After accounting for anxiety and impulsivity, there was no significant association between rMEQ and caffeinated drink consumption (c' = −0.135, p = .409).

Discussion

We set out to investigate links between eveningness, anxiety, impulsivity, and substance use in a young adult sample. Consistent with previous findings in similar age ranges (Norbury and Evans 2019), sleep quality was found to be poor overall with only 22% of individuals meeting criteria for 'good' sleep on the PSQI. We found that MEQ correlated with sleep quality, such that greater eveningness was associated with worse quality sleep. A strong correlation was identified between eveningness and trait anxiety. Sleep quality also correlated strongly with trait anxiety, but after controlling for sleep quality, we found that eveningness was still independently associated with anxiety. This corresponds with the findings of a previous study (Cox and Olatunji 2019). Thus, it appears that there exists an association between eveningness and trait anxiety that cannot be explained by poorer sleep quality. This points to eveningness as potentially having a unique contributing role to anxiety symptoms in young adults. Circadian-related interventions might, therefore, be beneficial for reducing anxiety symptoms in student-age populations, the prevalence of which is increasing. Further work using longitudinal designs should seek to establish the direction of causality in this relationship as this cannot be inferred from the current study.

We predicted that evening types would show higher levels of subjective and objective impulsivity. For subjective impulsivity, both lower quality sleep and greater eveningness were associated with greater self-reported impulsivity. On the BIS subscales, only the attentional subscale correlated with sleep quality, whereas all three subscales correlated with eveningness. These associations held when sleep quality was controlled for, indicating that poorer sleep in evening types was not responsible for these effects. To further confirm this, we excluded poor quality sleepers (PSQI >5) and still found strong correlations between eveningness and total BIS scores as well as with the attentional and non-planning subscales, indicating that even amongst good sleepers eveningness associates significantly with self-reported impulsivity. This accords with and builds on previous work showing that eveningness is linked to higher subjective trait impulsivity, both in young adults (Kang et al. 2015) and across a wider adult age range (Hwang et al. 2016).

A strength of the current study was the inclusion of an objective impulsivity measure (Delayed Discounting); previous studies have often relied solely on self-report measures. No correlation was seen with sleep quality, but greater eveningness correlated with a tendency to prefer smaller immediate rewards over

delayed, larger ones. A previous study in a similar student-age sample found that eveningness was associated with a present-hedonistic time perspective (judged subjectively) (Stolarski et al. 2013). The present finding, based on a more rigorous measure of preference for immediate versus delayed rewards, suggests that higher trait impulsivity in young adult evening types manifests behaviorally as a bias toward immediate rewards. Replication of this finding in an expanded sample size would be recommended to confirm the association. Previous studies that have investigated risky decision-making found that young adult evening types have a greater propensity for risk-taking, as measured using self-report scales (such as the DOSPERT that questions likelihood to engage in risky activities across various domains) (Killgore 2007; Wang and Chartrand 2015). However, associations are less robust when risk-taking tasks (specifically the Balloon Analog Risk Task, BART) are employed; one study found an effect (Gowen et al. 2019), whereas others have not (Ingram et al. 2016; Killgore 2007). The effects seen here with the temporal discounting task are interesting in this context. Although it is a lab-based task that provides a quantitative behavioral measure of impulsivity, it is not as purely objective as the BART, for example, since it presents participants with a series of hypothetical choices regarding reward preferences. It is, therefore, closer to subjective scales, such as the BIS and DOSPERT, and suggests that effects of diurnal preference on impulsivity and risky behavior are most apparent when linked to real-world responding. Likewise, in a study on motor response inhibition using a lab-based task (GO/NOGO), Kang et al. (2015) found young adult evening types to have a lower rate of successful inhibition, but only at the trend-level.

Substance use is an example of risky real-world behavior that has important consequences for health (e.g., Hingson et al. 2005). We explored the relationships between sleep quality, diurnal preference, and substance use. Sleep quality did not associate with self-reported substance use (consumption of alcohol, cigarettes, or caffeinated drinks). However, significant relationships were seen with eveningness for alcohol and cigarette use, and for caffeinated drink consumption at the trend level. This accords with previous work suggesting that diurnal preference has a greater impact than sleep quality on substance use profiles (Hasler et al. 2017). Mediation analyses investigated the role of trait impulsivity and trait anxiety in these relationships. It was found that impulsivity (but not anxiety) mediated the associations between eveningness and cigarette, alcohol, and caffeine use, such that after accounting for trait impulsivity and trait anxiety there was no direct relationship between diurnal preference and substance use for all three substance classes. The indirect path via impulsivity was significant in all three cases; thus, trait impulsivity completely mediated the relationships. Previous work has linked eveningness to increased smoking and alcohol use in both young adult (Hasler et al. 2017; Kabrita et al. 2014; Schneider et al. 2011; Urban et al. 2011; Whittier et al. 2014) and older adult samples (Adan 1994). The current study points to trait impulsivity as a key mediating variable in these relationships, is an important novel finding. Impulsivity alone has been reliably linked to substance use. For example, BIS scores correlate with self-reported alcohol consumption (Henges and Marczinski 2012) and BIS scores differentiate smokers from nonsmokers (Balevich et al. 2013) in young adult samples. Other studies have explored this relationship in more detail and particular impulsivity-related personality traits are implicated. Self-reported lack of premeditation and sensation seeking is significantly related to drinking and cigarette use in university students (Adams et al. 2012; Spillane et al. 2010). Negative urgency (a tendency to act impulsively during negative affective states) is also an important contributor to alcohol (Adams et al. 2012) and cigarette use (Doran et al. 2013) in university-age samples; negative reinforcement expectancies might be an important mediating factor (Doran et al. 2013; Pang et al. 2014). Future studies could explore the current findings in more depth by considering the role of specific impulsivity-related personality factors such as these; more detailed explorations of which facets of impulsivity (preferably measured using objective methods) contribute to the mediation effects identified here would also be beneficial.

Further, interventions to reduce impulsivity might have efficacy in reducing substance use behaviors in this age group. Individuals whose impulsivity levels decline across ages 18 to 25 y show corresponding decreases in alcohol use (Littlefield et al. 2010). Although diurnal preference is often regarded as a trait-like characteristic, eveningness is somewhat modifiable by behavioral and pharmacological interventions (Hasler et al. 2016), and chronotherapeutic approaches involving bright light and melatonin (Emens and Burgess 2015). It has been suggested these might have positive effects in reducing substance use (Hasler et al. 2016). This is an intriguing possibility. The current work confirms an important association between eveningness and substance use levels in young adults, but also suggests that intervention approaches will only show efficacy if they result in reduced impulsivity amongst evening types. The current work points to impulsivity as a crucial mediator between diurnal preference and

substance use behaviors; impulsivity could therefore, represent a more effective therapeutic target in evening types. In contrast, we could not identify a role for anxiety in mediating the link between eveningness and substance use, reinforcing the notion that impulsivity might be the more efficacious focus for any such intervention. In terms of neural underpinnings, imaging studies point to differences in brain regions implicated in impulsivity and reward. Young adult male evening types show altered reward activity in prefrontal and striatal areas, and these associate with higher alcohol use (Hasler et al. 2013). Volumetric differences in reward-related areas have also been identified in evening types (Norbury 2020).

Limitations of the present study should be noted. We used the rMEQ to assess diurnal preference. The rMEQ has been shown to have good external validity in relation to actigraphy (Natale et al. 2006), and the MEQ has been used more than any other scale for assessing diurnal preference (Levandovski et al. 2013). Indeed, the majority of studies discussed herein used the MEQ or rMEQ. An alternative would have been to use the Munich Chronotype Questionnaire (MCTQ) (Roenneberg et al. 2003). Interindividual differences in morningness-eveningness (chronotype) are measured by the MCTQ based on the timing of sleep and wakefulness, separately for free and work days. However, while morningness-eveningness (as measured by the MEQ) strongly correlates with chronotype (based on time of mid-sleep on free days, as measured by the MCTQ) (Zavada et al. 2005), the MCTQ collects additional detailed information on actual sleep-wake behavior. Evening types often suffer a mismatch between their chronotype and social demands on work days, accumulating sleep debt during the work week, which is compensated for on free days by extending sleep duration. This has been termed 'social jetlag' and could contribute to higher substance use in evening types, particularly with regard to cigarette use in the elderly (Wittmann et al. 2006). The MCTQ allows 'social jetlag' to be quantified and future studies should explore this. In the current study, the focus was on trait-level characteristics and the MEQ (that measures preferences for activity and rest and which can be regarded as a personality trait) was chosen over the MCTQ (that is based on actual sleep-wake times and is, therefore, more state-level). Time constraints prevented both measures being included here. Ideally, future work should seek to confirm findings using circadian measures that do not rely on self-report (e.g., by wrist actigraphy or measurements of melatonin or core body temperature). Indeed, all the measures included here relied on self-report and are thus subject to reporting biases; future work would benefit from inclusion of objective measures where possible (e.g., of substance use). Another limitation is that the sample was predominantly female and although gender was controlled for in all analyses, potential gender effects require further exploration. Females are at higher risk of anxiety disorders (Blanco et al. 2014); gender effects on impulsivity are also known to be significant. For example, Gowen et al. (2019) showed that young adult males display higher risk-taking than females. Interestingly, however, Gowen et al. (2019) found that chronotype effects on risk-taking were only present in females, not males. The fact that the current study used a sample comprised of predominantly female university students impacts the generalizability of its findings. This underlines the importance of replicating the current study in an expanded sample with a more representative gender balance, especially since there are a greater proportion of evening types amongst young adult males than females (Schneider et al. 2011), replication in a non-university sample would also be beneficial. Finally, the study design was cross-sectional, and, as such, inferences regarding the directionality and causality of the associations and mediation effects identified here cannot be made based on the current study. It would be beneficial to consider in future work how the associations identified here evolve longitudinally to examine the effects of eveningness in young adulthood on mental health and substance use patterns longer-term. Further, assessment of other forms of substance use (such as illicit substances) would also be beneficial, since the present study only considered alcohol, caffeine, and cigarette use. Also, the current study excluded individuals with substance abuse and gambling disorder; future work could investigate whether the relationships identified here might be generalizable to and be of importance in clinically addicted groups such as these.

In conclusion, the present study provides important information regarding the impact of diurnal preference in young adulthood. After controlling for reduced sleep quality, eveningness was associated with higher trait anxiety and higher levels of subjective impulsivity; evening types also showed a higher preference for immediate rewards on the temporal discounting task. In accordance with previous work, eveningness was also associated with higher consumption of alcohol and cigarettes (and perhaps caffeine). These relationships were found to be completely mediated by levels of trait impulsivity, while no role was found for trait anxiety. This

could be useful for informing possible interventions that aim to reduce substance use in young adults.

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The authors have no conflicts of interest to report.

Data availability statement

The dataset associated with the paper can be downloaded from https://osf.io/h95np/

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