Emotional states in adolescents: Time of day X chronotype effects while controlling for psychopathological symptoms and sleep variables

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The present study primarily aimed to investigate the interactive effect of chronotype and time of day on adolescent's emotional states. Chronotype influences behaviour throughout the day, with variables such as mood exhibiting circadian rhythmicity. We also considered the influence of potential covariates, such as sleep variables and psychopathological symptoms. A total of 190 8th-grade students (53.7% males; mean age 13.47±.70) completed a two-part protocol: part one probing sleep (BaSIQS), chronotype (CSM), and psychopathological symptoms (SDQ); part two targeting emotional states (FS; STAIC-S; EAPNC), while manipulating time of day (first and last hours of the school day). The hypothesized interaction failed to reach significance, despite correlational analyses and visual inspection of mean values suggesting some interactive effects. Time of day independently impacted positive emotional states, rising from morning to afternoon, and anxiety-state, which dropped. Chronotype independently influenced momentary mood (non-significant when sleep and psychopathological symptoms were controlled for), positive affect (non-significant when controlling for psychopathological symptoms), and anxiety (non-significant when sleep quality and psychopathological symptoms were controlled for). There were consistent effects of time of day, but its interaction with chronotype did not reach significance. Some associations between chronotype and emotional states seemed to be influenced by sleep and/or psychopathological symptoms.

Keywords: Chronotype; time of day; sleep; emotional states; adolescence.

Introduction

Morningness-eveningness, also known as chronotype, is a continuum in sleep-wake behaviour (preferred bedtimes and wake times) and in preference for earlier or later hours to engage in cognitively/physically demanding tasks (Schmidt et al. 2007; Randler et al. 2017). Most of the population – 60% to 70% – isn't placed at either end of the spectrum, thus manifesting an intermediate-type (Tonetti, Natale et al. 2015; Cuesta et al. 2017). Besides intermediate-types, although some authors suggest the possibility of four distinct chronotypes (Putilov 2017; Putilov et al. 2019), the general consensus in chronobiological literature is the classification of morning- and evening-types. Compared to evening-types, morning-types prefer earlier sleep schedules and exhibit an acrophase advance regarding physiological circadian markers, such as endogenous core body temperature and melatonin secretion, meaning these phenomena reach their zenith (*i.e.,* peak) earlier in relation to the external clock time (Mongrain et al. 2004; Schmidt et al. 2007; Cuesta et al. 2017). In fact, most biological phenomena manifest circadian oscillations along the 24-hour cycle (Foster and Kreitzman 2014; Ospri et al. 2017), including psychological variables such as subjective well-being (Birchler-Pedross et al. 2009), alertness (Vollmer et al. 2013), attention (Escribano and Díaz-Morales 2014), mood (Díaz-Morales et al. 2015), and positive affect (Murray et al. 2002). Chronotype can be determined through actigraphy or biomarkers, such as cortisol and melatonin secretion levels (Adan et al. 2012; Randler and Engelke 2019). These methods, although very reliable, are not the most time- nor cost-effective. Therefore, self-report questionnaires can be employed as inexpensive alternatives to efficiently determine circadian preferences in large samples (Costa et al. 2013; Tonetti, Adan, et al. 2015), showing reliable correlations to biomarkers (*e.g.,* Kantermann et al. 2015), as well as to actigraphy measures (*e.g.,* Faßl et al. 2019).

The expression of morningness-eveningness varies significantly throughout the lifespan (Randler et al. 2017). During adolescence, there is a delay in the circadian

system's phase motivated by puberty, resulting in a steadier progression towards an eveningness orientation (Costa et al. 2013; Randler et al. 2017), with a peak occurring at 17-19 years old in males and 15-18 years old in females (Fischer et al. 2017; Randler et al. 2017). Although chronotype is partially determined by genetic factors, up to 50% (Kalmbach et al. 2017), behaviours often associated with adolescence, such as late-night technology, may further contribute to the progression towards later sleep-wake patterns by delaying melatonin onset and extending the circadian cycle (Roenneberg et al. 2007; Malone, Zemel, Compher, Souders, Chittams, Thompson, Lipman, 2016; Vollmer et al. 2017). This progression towards eveningness in adolescence motivates a misalliance between adolescents' circadian rhythm and societal demands, such as early school start times (Roenneberg et al. 2012; Vollmer et al. 2017), amplifying the so-called 'social jetlag', characterized by a significantly shorter sleep duration on school days and subsequent overcompensation during free days (Malone, Zemel, Compher, Souders, Chittams, Thompson, Pack, et al. 2016; Vollmer et al. 2017).

In a review on the consequences of adolescent's evening preferences, Díaz-Morales and Escribano (2014) describe the eveningness' effects on several important factors in adolescent's development, such as a poorer academic achievement (Preckel et al. 2011; Díaz-Morales and Escribano 2014;). Díaz-Morales and Escribano (2014) report that eveningness in adolescence relates to sleep problems (e.g., excessive daytime somnolence, recurrent sleep debt), personality traits traditionally less valued in the school system (e.g., nonconforming and withdrawn behaviours, higher sensation seeking, lower conscientiousness), health issues and unhealthy habits (e.g., poorer physical health, higher alcohol and caffeine consumption), and emotional and psychological difficulties (e.g., higher prevalence of depression symptoms and suicidal ideation). In fact, recent literature suggests that eveningness is associated with increased levels of

psychopathological symptoms (Hsu et al. 2012), such as higher risk for anxiety disorders, with heightened symptoms' severity (Antypa et al. 2016; Cox and Olatunji 2019). In a study conducted with adolescents (N=1046; 12-16 years old) on the relationship between sleep habits, chronotype, and anxiety, Díaz-Morales (2016) found that eveningness was positively correlated with anxiety. Besides anxiety, evening-types amongst adolescents are more likely to report poor mental health and experience emotional and behavioural issues (Li et al. 2018; Gariépy et al. 2019), including depressive symptoms (Alvaro et al. 2014), aggression and anti-social behaviours (Schlarb et al. 2014), conduct problems (Merikanto et al. 2017), and higher predisposition to develop insomnia (Li et al. 2018). The recurring disruption of the circadian rhythm in evening-types motivated by social jetlag can, in turn, exacerbate mood-related problems and play a role in the development of mood disorders, since it dysregulates hormonal and neurobiological processes involved in mental health, such as monoamine transmission, hypothalamic–pituitary–adrenal axis function, and neurogenesis (McClung 2013). Conversely, evidence indicates that morning-types tend to report improved subjective well-being and life satisfaction (Jankowski 2015), as well as better subjective health (Biss and Hasher 2012).

Regarding the understanding of how morningness-eveningness and time of day can influence the diurnal oscillations in adolescent's emotional states, the major research focus has been on the separate impact of both factors rather than the interactive effect, which remains marginally explored. Concerning the relationship between chronotype and emotional states in adolescence, in a field study with 97 adolescents (37 females) aged 10-17 (M=13.14) where mood was assessed during school's first lesson (about 8.00 a.m.), Randler et al. (2014) reported that a tendency towards eveningness was correlated with worse mood and higher negative affect, while morningness was positively correlated with activation, relaxation, and positive mood. Likewise, Dagys et al. (2012) found less

positive affect in evening chronotypes. Their goal was to investigate the effects of chronotypes and sleep deprivation on affect in adolescence (10-16 years-old). Adolescents' affect was measured in two sleep conditions: full rest (8.5 hours of sleep on two consecutive nights) and sleep deprivation (maximum of 6.5 hours on the first night and 2 hours on the next). Results showed that evening-types reported less positive affect and lower positivity ratios than morning-types in both rested and sleep-deprived conditions.

Regarding the relationship between time of day and emotional states in adolescence, Barber et al., (1998) examined the daily fluctuations in mood, conceptualized as positive affect, arousal, and stress, from 7.30 a.m. to 9.30 p.m. amongst 162 7th-grade students (85 females, aged around 12-13). Results showed an increment in arousal and positive affect during the early morning (between rising time and 11.30 a.m.), reaching a peak in the late morning-early afternoon (11:30 a.m.–3.30 p.m.) and in the late afternoon-early evening (3:30 p.m.–7.30 p.m.), before dropping to the lowest level in the evening period, between 7.30 p.m. and bedtime. Barber et al. (1998) also found that stress levels were the highest during early morning and decreased steadily throughout the day, registering the lowest levels in the evening (7.30 p.m.-bedtime).

In one of the few studies considering both chronotype and time of day effect on adolescent's emotional states, Díaz-Morales et al. (2015) assessed mood throughout the school day in morning- (n = 179), intermediate- (n = 326), and evening-types (n = 150) adolescents (aged 12-16) at three moments (8.10-8.30 a.m.; 10.20–11.40 a.m.; 1.50–2.10 p.m.). Mood was assessed with the Faces Scale (FS; Andrews and Withey 1976), administered twice with a one-week interval. Separate effects of chronotype and time of day were found, with the former explaining 3.7% of the variance in mood and the latter explaining 5.2%. More specifically, morning-types experienced the best mood while

evening-types reported the worst mood. Moreover, all adolescents regardless of chronotype reported the lowest mood at the beginning of the school day, which got progressively better as the end of the school day approached. However, the interaction chronotype x time of day was found to be non-significant. Díaz-Morales et al. (2015) repeated the analyses controlling for time in bed, to verify whether the influence of chronotype on mood was due to evening-types' shorter time spent in bed. The same pattern of results was found, suggesting that a shortened time in bed is not responsible for the decreased mood in evening-types. In a similar study but with young adults, Jankowski and Ciarkowska (2008) examined mood's diurnal oscillations in 31 male college students (18-30 years old) exhibiting extreme morning (n = 16; M = 23.4, SD = 2.48 years old) and evening orientations (n = 15; M = 22.3, SD = 1.89 years old). Mood was measured with the UWIST Mood Adjective Check List (Matthews et al. 1990), a scale with 29 items divided into three subscales pertaining to the levels of energetic arousal (EA; tired–energetic), tense arousal (TA; relaxed–nervous), and hedonic tone (HT; unpleasant–pleasant). There were nine assessment moments during the day, with each participant being assessed every 1.5 hours between 8 a.m. and 8 p.m. Results showed that all three mood dimensions were influenced by both chronotype and time of day separately, although an interactive effect was only found on EA. For evening-types EA increased during the day reaching its peak at 8 p.m., while for morning-types EA was maximum between 11 a.m. and 12.30 p.m. and then decreased reaching its minimum level at 8 p.m.. For all participants, the peak in tense arousal was observed at 8 a.m., dropping promptly afterwards to the lowest point at around 11 a.m., rising slowly again until 8 p.m.. Evening-types consistently exhibited higher tense arousal than morning-types. Similarly, regardless the participant's chronotype, the lowest level of hedonic tone occurred at 8 a.m. and increased until 2 p.m. Afterwards, it decreased again until 5 p.m., rising

afterwards to peak at 8 p.m.. Morning-types consistently displayed higher hedonic tone levels.

As mentioned, the interaction time of day x chronotype on emotional states in adolescence has been less studied than the separate impact of each factor. Hence, it seems of critical importance to examine how adolescents' chronotype and time of day influence their emotional states, since psychobehavioural variables such as mood and emotional states exhibit circadian rhythmicity (Díaz-Morales et al. 2015), along with the fact that interindividual differences in circadian preference can exert further influence. Therefore, the current study aimed to examine two possible ways that can lead to circadian fluctuations of emotional states in adolescence, as well as the interaction between both: a) time of day – emotional states can fluctuate along the 24h-cycle; b) chronotype – emotional states can be influenced by morningness-eveningness; c) interaction time of day x chronotype - emotional states' fluctuations throughout the day can manifest differently for morning-, intermediate-, and evening-types, depending on the combination with time of day. We hypothesized that morning-types should reveal a better mood in the early hours, whereas evening-types should experience a better mood later in the day.

We also aimed to further probe these effects while controlling for certain confounding variables that might explain emotional states, namely, psychopathological symptoms and multiple sleep's dimensions (sleep length on weekdays, perceived sufficient sleep, and sleep quality). Sleep is essential for adolescents' normative development and functioning, with insufficient sleep and irregular sleep–wake patterns being associated with worst well-being and physical and psychological health (Malone, Zemel, Compher, Souders, Chittams, Thompson, Lipman 2016). Moreover, sleep-related variables (e.g., sleep quality or sleep duration on weekdays) are known to be linked to emotional state, subjective well-being, and positive and negative affect (Kahn et al. 2013;

Kalak et al. 2014; van Zundert et al. 2015; Marques et al. 2017; Ong et al. 2017), hence, it seems germane to examine whether sleep variables relating to length and quality constitute confounding variables that might influence emotional states. Psychopathological symptoms were also controlled for since correlations have been established between psychopathological symptoms, such as depression or anxiety symptoms, and emotional state, well-being, and positive and negative affect in adolescents both in clinical and non-clinical samples (cf., previously cited studies and also Verstraeten et al. 2009; Gilbert 2012; Bartels et al. 2013; Fernandez et al. 2018).

Methods

Participants

Data was collected from two School Clusters from Portugal's Centre Region (NUTS II), comprising an initial sample of 203 8th-grade students. 13 pupils from the initial pool were excluded due to incomplete information. The final sample (N=190) was comprised of 88 females (46.3%) and 102 males (53.7%). Over 90% of participants had 13 or 14 years old, with the sample's mean age being 13.47 ± .70 years old (range 12-16 years). Regarding age, there were no significant differences between male (M = 13.53; DP = .79) and female adolescents (M = 13.40; DP = .58) [$t_{(183,994)}$ = -1.33, p = .184].

Measures

In order to answer the study's target questions and evaluate the emotional states' oscillations, we administered the Portuguese versions of Face Scale (FS), Anxiety-State Scale from State-Trait Anxiety Inventory for Children (STAIC-S) and Positive and Negative Affect Scale for Children (EAPNC). Chronotype was assessed through the Composite Scale of Morningness (CSM). Covariates were assessed with Strengths and Difficulties Questionnaire (SDQ), to screen for psychopathological symptoms, and with

Basic Scale on Insomnia and Quality of Sleep (BaSIQS), used to obtain a measure of overall sleep quality, as well as to estimate sleep length and a subjective perception on sufficiency of sleep through an additional set of questions.

Faces Scale (FS)

To capture oscillations in the emotional states throughout the day, FS (Andrews and Withey 1976) was used as a measure of momentary mood and subjective well-being. Seven simple drawings of faces are displayed horizontally across a happiness-sadness continuum. Participants were asked to rate their mood in that exact moment by ticking the face that better seems to translate it. Scores ranged from 1 to 7, with higher scores translating a better momentary mood.

Anxiety-State Scale from State-Trait Anxiety Inventory for Children (STAIC-S)

STAIC (Spilberger 1973) is a self-report measure of anxiety symptoms in 8 to 18-year-olds. This instrument encompasses two independent scales: The Trait Scale, a measure of a more stable and long-lasting tendency to experience anxiety, and the State Scale (STAIC-S), that assesses current levels of anxiety. In this study, the Portuguese version (Matias 2004) of only the STAIC-S was used since it would detect potential fluctuations in emotional states throughout the day. STAIC-S includes 20 items on a three-point Likert scale, from 1 to 3, with higher scores suggesting more pronounced levels of anxiety. STAIC-S' internal consistency was excellent ($\alpha = .90$) as per George's and Mallery's (2003) criteria.

Positive and Negative Affect Scale for Children (EAPNC)

The Positive and Negative Affect Scale for Children is an original Portuguese instrument (*Escala de Afeto Positivo e Negativo em Crianças)* adapted from Giacomoni's (2002) work by Ameixa (2013). EAPNC is similar to the well-known Positive and Negative

Affect Schedule (PANAS; Watson et al. 1988), although developed specifically for younger participants (8 to 14 years old). EAPNC is a self-report measure of positive and negative affect that lists 30 adjectives describing various emotions (*e.g.,* satisfied, scared), each to be classified within a 5-point Likert scale. This measure was employed for its potential to capture emotional states' oscillations throughout the day. EAPNC is comprised of two subscales: Positive Affect (items 1, 2, 4, 6, 8, 9, 10, 12, 13, 16, 18, 19, 20, 24, 29) and Negative Affect (items 3, 5, 7, 11, 14, 15, 17, 21, 22, 23, 25, 26, 27, 28, 30). According to George's and Mallery's (2003) criteria, both subscales revealed excellent internal consistency's values (Positive Affect: $\alpha = .92$; Negative Affect: $\alpha = .90$).

Composite Scale of Morningness (CSM)

CSM is a pen-and-paper self-report measure of chronotype developed by Smith et al. (1989). CSM encompasses the items with the best psychometric properties of both Morningness-Eveningness Questionnaire (MEQ; Horne and Östberg 1976) and Diurnal Type Scale (DTS; Torsvall and Åkerstedt 1980). In the current study, we used the European Portuguese version - *Questionário Compósito de Matutinidade* (Silva et al. 1995). CSM consists of 13 Likert-type questions scaled from 1–4 (10 items) or 1–5 (3 items), adding up to a score ranging from 13 (extreme eveningness) to 55 (extreme morningness) (Smith et al. 1989; Tonetti, Adan, et al. 2015). The items inquire about the usual rise time and bedtime, as well as preferred times for physical activity and cognitive performance. CSM has proven to be a reliable and valid tool to assess chronotype with robust psychometric properties (Díaz-Morales and Sánchez-López 2004; Caci et al. 2005; Díaz-Morales 2007). The Portuguese version has also positive indicators of reliability and validity, both in adolescents and young adults (Gomes et al. 2016). In the present study,

Cronbach's alpha was α = .81 which is considered a good indicator of internal consistency (George and Mallery 2003).

Basic Scale on Insomnia and Quality of Sleep (BaSIQS)

BaSIQS (Gomes et al. 2015) is a Portuguese paper-and-pencil self-report instrument to assess overall sleep quality and difficulties with sleep onset and maintenance in the month prior. It was developed using large samples of higher education students. All seven Likert-type items are scaled from 0 to 4 with the final two being reversed. Ranging from 0 to 28, higher scores correspond to an overall poorer sleep. In addition to the seven items of the BaSIQS, we also inquired students about their sleep-wake schedules and durations in an additional set of questions. BaSIQS internal consistency value in the present sample was considered below the acceptable, so the last item (perceived sleep depth) was disregarded, rising the Cronbach's alpha to a minimum acceptable value for research purposes of α = .60 (George and Mallery 2003).

Strengths and Difficulties Questionnaire (SDQ)

SDQ (Goodman 1997; Goodman et al. 1998) is a brief behavioural questionnaire for screening psychopathological symptoms in children and adolescents. SDQ includes versions for parents or teachers of 4 to 16-year-olds, as well as parallel self-report versions that can be completed autonomously by 11- to 16-year olds. In the current study, we used the Portuguese self-report version, *Questionário de Capacidades e Dificuldades* (Fleitlich et al. 2005). The 25 Likert-type items can be summed to obtain a total score. An α = .65 was found for internal consistency, which is considered acceptable (George and Mallery 2003).

Procedures

Following the approval from the Portuguese Ministry of Education's monitorization

system of investigations in schools (MIME DGE – registrations number: 0665200001), two School Clusters were contacted. Prior to proper data collection, a brief summary of the study was presented to the adolescents and the informed consent forms were handed out to be given to parents/guardians. After proper consent, data collection took place during regular classes. Firstly, adolescents responded to SDQ, CSM, and BaSIQS, being instructed to answer autonomously and honestly to several questions probing potential psychopathological symptoms, as well as regarding sleep schedules, overall sleep quality, and preference for certain hours of the day to develop their activities. After a week, adolescents responded to FS, STAIC-S, and EAPNC in two moments, that is, at the first (8.30 a.m.) and last hours (4.30 p.m.) of the school day, during their regular classes. These two moments were selected considering the Portuguese school schedule for 8th-grade, since classes usually begin at 8.30 a.m. and finish at 5.30 p.m. Adolescents were instructed to respond to several questions probing their emotional states. At the first hour (8.30 a.m.), adolescents were informed that they would respond twice to the same questions but that they should answer these questions in accordance to how they felt in that exact moment, regardless of how they might have felt previously. The day of the week in which adolescents responded to the questionnaires was adjusted to each class to best fit their school schedule. Considering the potential influence of the weekend effect in the questionnaires' responses, Mondays and Fridays were excluded.

Statistical analysis

All analyses were performed using version 22.0 of IBM SPSS Statistics for Windows (IBM Corp., Armonk, NY). An alpha level of .05 was used for all statistical tests. Missing values were replaced with the mean of all responses given by the participant on the scale. For each scale, the internal consistency, measured by Cronbach's alpha, was analyzed and interpreted according to George' and Mallery's (2003) criteria, which considers $\alpha \geq$

.6 to be acceptable although $\alpha \geq .8$ is preferable as it is an indicator of stronger reliability. As a general rule, Nunnally (1978) recommends a minimum level of $\alpha \geq .7$, although depending on the nature and purpose of the scale. Descriptive statistics were conducted to characterize the sample regarding sleep, chronotype, psychopathological symptoms, and emotional states. In order to conduct the multivariate analyses of variance, Skewness (Sk) and Kurtosis (Ku) were analyzed ($|Sk| < 3$; $|Ku| < 8$), revealing a non-violation of the normality assumption (Kline 2015). Pearson product-moment correlation coefficients were computed to assess the correlations between scores obtained on each scale/variable. Correlations were conducted as a first approach to explore the associations between chronotype and emotional states in distinct times of the day, thus providing preliminary data on how chronotype relates to emotional states depending on time of day. Correlational analyses were also conducted to examine the associations between potential confounders/covariates and emotional states, as well as the presence and strength of associations between confounders and chronotype, so as to prepare subsequent ANCOVA analyses, assuring non-multicollinearity between covariates and morningness-eveningness. Pearson's r was interpreted according to Cohen's (1988, p .79-81) classification: $.10 \leq r \leq .29$ for small correlations; $.30 \leq r \leq .49$ for medium correlations; $.50 \leq r \leq 1.0$ for large correlations. Four mixed-model 3 x 2 ANOVAs, one for each dependent variable (measures of emotional states: FS; STAIC-S; EAPNC-positive affect; and EAPNC-negative affect), were conducted with chronotype group (intermediate-, morning-, and evening-type as between-subjects factor) and time of day (morning/afternoon as within-subjects factor) as independent variables. Afterwards, sixteen mixed-model 3 x 2 ANCOVAs were conducted entering the same factors while controlling for psychopathological symptoms (SDQ's total score), sleep quality (sum of BaSIQS' first 6 items), sleep length on weekdays - the difference between rise time and

bedtime on weekdays, and perceived sufficient sleep – a score from 0 (getting insufficient sleep all weeknights) to 4 (getting sufficient sleep all weeknights), in order to clarify chronotype's effect and its interaction with time of day. To evaluate magnitude, the classification of partial eta squared (η_p^2) for each effect followed Cohen's (1988, p. 284-287) criteria for Eta square, where $\eta^2 = .01$ is a small effect size, $\eta^2 = .06$ is a medium effect size and $\eta^2 = .14$ is a large effect size.

Results

Descriptive and exploratory correlational analyses

CSM's score mean exhibited no significant differences between genders [$t_{(188)} = .35$, $p = .730$]. Table 1 displays descriptive statistics for all scales considered in the analyses.

[INSERT TABLE 1]

Chronotype group (considered in later mixed-model ANOVAs and ANCOVAs) was further classified through percentiles, as shown in Table 2.

[INSERT TABLE 2]

Correlations between chronotype, emotional states, psychopathological symptoms, and sleep variables

Pearson-product moment correlation coefficients between chronotype and emotional states' measures in two distinct moments of the day are displayed in Table 3, as well as the correlations' coefficients between these measures and other variables that may theoretically affect emotional states, to be considered as potential covariates to control for.

[INSERT TABLE 3]

Regarding correlations between chronotype (CSM's score) and emotional states' measures, results show that correlations were stronger in the morning, lessening or losing significance altogether in the afternoon. Correlations between emotional states' measures and potential covariates revealed mostly small correlations for FS, while STAIC-S and EAPNC (positive affect scale and negative affect scale) exhibited small to moderate correlations. Correlations between chronotype (CSM's score) and potential covariates were small (SDQ, sleep quality, and sleep length) to moderate (perceived sufficient sleep), allowing for the execution of mixed-model ANCOVAS, since covariates aren't strongly associated with the factor chronotype.

To precis our results, correlational analyses suggest that higher morningness associates with an overall better momentary mood, more positive affect, and less negative affect and anxiety in the morning. Conversely, according to the same coefficients, a stronger tendency towards eveningness was associated with lower momentary mood, less positive affect, and higher levels of negative affect and anxiety in the morning. Nonetheless, this pattern of associations between chronotype and emotional states' measures was not observed in the afternoon.

Emotional states variables by chronotype and time of day – multifactorial analyses

Means and standard deviations for each emotional states' measure by time of day (morning; afternoon – repeated measures/within-subjects factor) and chronotype (evening-, intermediate-, or morning-type – between-subjects factor) are displayed on Table 4. Results from all four mixed-model 3 x 2 ANOVAs are summarized in Table 5.

[INSERT TABLE 4]

[INSERT TABLE 5]

The analysis with FS' score revealed that the interaction between time of day and chronotype failed to reach significance. However, a main effect of time of day on FS' score was found, $F(1, 187) = 26.79$, $p < .001$, with FS' scores being higher in the afternoon than in the morning, registering a close to large size effect, $\eta_p^2 = .125$. A small main effect of chronotype was also detected, $F(2, 187) = 3.20$, $p = .043$, $\eta_p^2 = .033$, with morning-types scoring significantly higher than evening-types. Intermediate-types' scores did not differ from evening-types and morning-types' scores.

The analysis of variance of EAPNC-positive affect revealed a non-significant interaction effect of time of day x chronotype. However, it yielded a medium main effect for time of day, $F(1, 187) = 13.69$, $p < .001$, $\eta_p^2 = .068$, such that the positive affect was significantly higher in the afternoon than in the morning. The main effect of chronotype was also significant, $F(2, 187) = 5.01$, $p = .008$, with morning-types experiencing significantly more positive affect than both intermediate- and evening-types, registering a close to medium size effect, $\eta_p^2 = .051$. There were no significant differences between scores obtained by intermediate- and evening-types.

Regarding EAPNC-negative affect, all effects were statistically non-significant (interaction of time of day x chronotype; time of day; chronotype). These findings underline the lack of association between these factors/their interaction and negative affect.

Regarding STAIC-S, the interaction effect of time of day x chronotype was non-significant. Nonetheless, a medium main effect of time of day was detected, $F(1, 187) = 11.59$, $p = .001$, $\eta_p^2 = .058$, such that anxiety-state symptoms were higher in the morning than in the afternoon. A small to medium main effect of chronotype was also found, $F(2, 187) = 4.68$, $p = .010$, $\eta_p^2 = .048$, with morning-types reporting significantly less

symptoms of anxiety-state than intermediate-types and evening-types. There were no significant differences between scores obtained by intermediate- and evening-types.

Effects of chronotype x time of day on emotional states variables controlling for potential confounders

Only effects of interest are reported, namely, interaction between chronotype and time of day, and main effect of chronotype (between-subjects variable). In preliminary analyses, we verified the ANCOVA's assumption of non-significance of the interaction between time of day and the covariates.

Four mixed-model ANCOVAs were conducted with FS' score while controlling for each of the four covariates (i.e., psychopathological symptoms, sleep quality, sleep length, and perceived sufficient sleep). Results showed that the interactions between chronotype and time of day on FS' score remained non-significant, with the previously found main effects of chronotype failing to reach significance.

Four other mixed-model ANCOVAs were performed with EAPNC-Positive affect's score while controlling for the same four covariates. All interactions between time of day and chronotype on EAPNC-Positive affect's score remained non-significant when controlling for each of the four covariates. Regarding the main effects of chronotype on EAPNC-Positive affect's score, when controlling for psychopathological symptoms, no main effect of chronotype was found. However, while controlling for sleep quality, the main effect of chronotype on EAPNC-Positive affect's score was borderline significant, $F_{(2, 186)} = 2.98$, $p = .05$, $\eta_p^2 = .031$. When introducing sleep length as a covariate, the main effect of chronotype remained significant, $F_{(2, 186)} = 3.93$, $p = .021$, $\eta_p^2 = .041$. The same was true when taking perceived sufficient sleep as a covariate, since a significant main effect of chronotype was still found, $F_{(2, 186)} = 3.28$, $p = .040$, $\eta_p^2 = .034$.

Another set of four mixed-model ANCOVAS was performed with EAPNC-Negative affect's score while controlling for the same covariates. Results for the interaction time of day x chronotype and the main effect of chronotype remained non-significant.

One last set of four mixed-model ANCOVAS was performed with STAIC-S' score while controlling for the same covariates. Once again, all interactions between time of day and chronotype on STAIC-S' score remained non-significant when controlling for each of the four covariates. When controlling for psychopathological symptoms as a covariate, the main effect of chronotype lost significance, with the covariate manifesting a large main effect, $F_{(1, 186)} = 40.71$, $p < .001$, $\eta_p^2 = .181$. Another mixed-model ANCOVA was conducted while controlling for sleep quality, and the previously found main effect of chronotype failed to reach significance when controlling for this covariate. Regarding the mixed-model ANCOVA with sleep length as a covariate, chronotype still exerted a significant main effect on STAIC-S' score, $F_{(2, 186)} = 3.82$, $p = .024$, $\eta_p^2 = .039$. One last mixed-model ANCOVA was conducted introducing perceived sufficient sleep as a covariate, where chronotype still exerted a marginally significant main effect on STAIC-S' score, $F_{(2, 186)} = 2.96$, $p = .054$, $\eta_p^2 = .031$.

Discussion

The present study examined the potential influence of chronotype and time of day on adolescent's oscillations of emotional states while controlling for psychopathological symptoms and sleep-related variables (sleep quality, sleep length, and perceived sufficient sleep). Overall, our results do not support an interactive effect of time of day and chronotype on adolescent's emotional states. Nevertheless, independent effects of both factors on measures of emotional states were found.

Effects of time of day on measures of emotional states

Findings suggest that time of day exerts an effect over all measures of emotional states, except for negative affect. Time of day influences both momentary mood and positive affect, which show significant improvements from morning to afternoon in the general sample. The same pattern was also found by Barber et al. (1998) in a previously mentioned study with 7th-grade students, where results showed an increment in positive affect during the morning, reaching a peak in the afternoon. Díaz-Morales et al. (2015) found similar fluctuations in adolescent's emotional state throughout the school day, such that students reported the lowest mood in the morning, improving progressively through the afternoon. Time of day also exerts an effect over anxiety-state in our study, which significantly dropped from morning to afternoon in the general sample. These results are in line with the previously mentioned study conducted with adolescents by Barber et al. (1998), where anxiety levels exhibited a pattern of diurnal fluctuation, being the highest during the early morning and decreasing steadily throughout the day. Besides the effect of time of day, an alternative explanation for the emotional states' oscillations could reside in the fact that adolescents were tested right at the beginning of the school day and close to its end, which may have influenced their mood's improvement to some extent (Ryan et al. 2010).

Negative affect, however, registers no significant diurnal pattern in our study. The absence of diurnal oscillation of negative affect was also found in a study conducted by Wood and Magnello (1992) that assessed variations along the day in self-reported levels of energy, mood, and affect. Wood and Magnello (1992) found that unlike positive affect that fluctuated along four time-points (wake up time; 10 a.m. to 12 p.m.; 2 to 3 p.m.; bedtime), negative affect exhibited no diurnal peaks or troughs. A plausible explanation might be that negative affect is inherently different from positive affect and may not be influenced by the same factors. The authors state that factors inducing negative affect are

largely external to the subject, depending more on environment-related features, which show no consistent diurnal pattern. In line with this idea, Murray et al. (2002) propose that negative affect does not exhibit a systematic diurnal pattern of variation due to evolutionary underpinnings: the mechanism responsible for negative affect is hypothesized to be of a reactive nature, having no defined diurnal fluctuation due to the unpredictability of unpleasant situations.

Effects of chronotype on measures of emotional states without controlling for psychopathological symptoms and sleep variables

Initial analyses uncovered main effects of chronotype on all employed measures of emotional states, albeit of small magnitude, except for negative affect. Chronotype exerted an effect over momentary mood, with morning-types experiencing significantly better momentary mood than intermediate- and evening-types, the same pattern of results reported by Díaz-Morales et al. (2015).

Chronotype also influenced positive affect, with morning-types experiencing higher levels of positive affect throughout the day when compared to the other chronotypes. These findings tie in with the idea that morningness is accompanied by improved subjective well-being, higher positive affect, and life satisfaction (Biss and Hasher 2012; Randler et al. 2014; Jankowski 2015). Our results also yielded a significant effect of chronotype on levels of anxiety-state, such that when comparing the scores attained by adolescents in different chronotype groups, anxiety-state was significantly higher in evening-types than in intermediate- and morning-types. Similarly, Díaz-Morales' (2016) reported that anxiety was positively associated with eveningness in adolescents, with a greater proportion of evening-types (33.8%) being found in the high anxiety group, compared to morning-types (23.8%). These findings seem in line with

several reports in the literature of a link between eveningness and higher levels of anxiety (Antypa et al. 2016; Díaz-Morales 2016; Cox and Olatunji 2019).

Notably, as our results point out, negative affect does not seem to be influenced by chronotype. Reports on the relationship between morningness-eveningness and negative affect have shown conflicting evidence, as some authors contend that morning-types experience less negative affect compared to evening-types (*e.g.,* Randler et al. 2014; Simor et al. 2015), while others found no correlation whatsoever (*e.g.,* Biss and Hasher 2012; Dagys et al. 2012; Carciofo et al. 2014). In our study, the lack of association between chronotype and negative affect is consistent with the theory that only positive affect is closely tied to human circadian rhythms, as it is known to fluctuate along the 24-hour cycle (Watson et al. 1999; Murray et al. 2002; Biss and Hasher 2012).

Effects of chronotype on measures of emotional states while controlling for psychopathological symptoms and sleep variables

Starting with the associations between chronotype and potential covariates, higher eveningness scores associate with worse overall sleep quality, sleeping fewer hours during weekdays and evaluating the amount of sleep during the week as not enough to feel good. These findings further corroborate the understanding that eveningness is associated with poorer sleep, with evening-types reporting more daytime somnolence and difficulty with sleep onset and sleep maintenance (Merikanto et al. 2016; Li et al. 2018), as well as insufficient sleep, sleep disturbance, greater sleep irregularity, and higher sleep debt (Koscec et al. 2014; Li et al. 2018; Cox and Olatunji 2019). Additionally, eveningness was also associated with more psychopathological symptom in the present study, in line with recent literature reporting links between eveningness and increased risk for mental health problems in adolescents, such as depressive symptoms, anxiety

symptoms, and behavioural issues (Alvaro et al. 2014; Schlarb et al. 2014; Díaz-Morales 2016; Merikanto et al. 2017; Li et al., 2018; Gariépy et al. 2019).

Psychopathological symptoms and sleep seem to be important variables in chronotype's influence over momentary mood. Since the variables employed as covariates (psychopathological symptoms, sleep quality, sleep length, and perceived sufficient sleep) exhibited significant variability amongst chronotypes in the present study, one can note that this may be contributing to the presence of a significant effect when these disparities are not accounted for. Simply put, higher morningness associates with less psychopathological symptoms, better sleep quality, and longer sleep length, which in turn contribute to an improved momentary mood. Moreover, this finding suggests that how adolescents feel in a particular moment can be a rather complex construct, amenable to variations in sleep and psychopathology. Proper sleep is a vital component of overall health and well-being, particularly in adolescent's normative development (Bruin et al. 2017), with perceived sufficient sleep being a predictor of mood and subjective well-being (Stoica 2015). Mood and subjective well-being are also particularly compromised by sleep deprivation, being even more susceptible to it than cognitive or physical performance (Pilcher and Huffcutt 1996). Interestingly, in the present study, although sleep length was on average 8.52 hours (SD=1.27), reported values go as low as 4 hours, meaning that some adolescents were experiencing partial sleep deprivation (sleeping less than 5 hours in the 24-hour cycle), which might have influenced their emotional states (Pilcher and Huffcutt 1996; Gulec et al. 2013).

Regarding specifically positive affect, chronotype's influence remains significant regardless of sleep impact, seeming to be above and beyond the shared variance between the controlled sleep valances (quality, length, and perceived sufficient sleep). Differences amongst chronotypes regarding positive affect levels have been reported in the literature

(Murray et al. 2002; Biss and Hasher 2012; Díaz-Morales and Escribano 2014). However, the effects of chronotype on positive affect become non-significant when controlling for psychopathological symptoms. This may be due to the significant differences found between chronotypes regarding psychopathological symptoms, with morning-types experiencing significantly less psychopathological symptoms than intermediate- and evening-types in our study. This is consistent with accumulating evidence that morning-types are less prone to experience psychopathological symptoms and exhibit better indicators of mental health, such as adaptative psychological traits (Gulec et al. 2013; Antúnez et al. 2015; Jankowski 2015). Hsu et al. (2012), in a study with 2919 students (mean age = 19.4), reported that morningness related to lower scores on a vast range of psychopathology dimensions and symptoms, namely, somatization, interpersonal sensitivity, depression, anxiety, hostility, paranoid ideation, and suicidal ideation. Thus, it may be a case of disparities in psychopathological symptoms between chronotypes contributing to the relationship between chronotype and positive affect, rather than a pure influence stemming from inherent circadian-related characteristics.

Regarding anxiety-state, chronotype's influence remains significant regardless of sleep length and perceived sufficient sleep, suggesting that chronotype's effect on anxiety-state is superior to the variance shared by each one of these variables. However, the previously found association becomes non-significant when controlling for psychopathological symptoms and overall sleep quality, indicating that these factors influence the level of anxiety-state amongst chronotypes. Once again, this may be due to the significant associations (albeit of small magnitude) found between morningness-eveningness and psychopathological symptoms and sleep quality, with higher morningness being associated with less psychopathological symptoms and better sleep quality in the present study.

Interaction chronotype x time of day on measures of emotional states

The results of the present study do not support the hypothesized interaction chronotype x time of day over adolescent's emotional states, the main focus of our research. A potential interaction might have been hindered by an insufficiently large sample size, which might have curbed the findings' generalization and given rise to type II errors, i.e., the absence of significant interaction effects may be a false negative. Another plausible explanation resides in the fact that the employed classification criterion for chronotype could have been too broad and some borderline intermediate-types were inaccurately classified as morning- or evening-types, thus diluting the effects of a potential interaction. One can speculate that interaction effects might have been detected if only extreme morning- and evening-types were included, selected through stricter cut-off points, such as the 10th and 90th percentile (e.g., Russo et al. 2007; Alvaro et al. 2014) or alternative more restrictive criteria employed in other studies that found significant interactive effects (e.g., Jankowski 2014). Furthermore, it is possible that testing morning- and evening-types in even earlier and later moments (before school starting time and in the evening, for instance) is needed for the interactive effect chronotype x time of day emerge as statistically significant. Finally, the lack of interaction effects may also be simply due to the main effect of diurnal circadian oscillations in emotional states and positive affect that are observed transversally in all chronotypes (Barber et al. 1998; Murray et al. 2002; Díaz-Morales et al. 2015).

Limitations and future directions

The present findings add to a growing body of research highlighting the role of circadian preference and time of assessment on adolescent's emotional states. Following a chronotype-based paradigm under normal day-night conditions (Schmidt et al. 2007), we employed a research design with a scrupulous control of data collection procedures and

a particular emphasis on time accuracy. Our study shed some light on the independent effects of time of day and chronotype on adolescent's emotional states; however, these findings must be considered in the context of the study limitations, with the first one being the fact that our results relied on self-report data and subjective estimates of circadian preferences that can be biased and may not thoroughly reflect the underlying physiology (Meltzer 2017). Another limitation of our work is the modest sample size (N = 190), which might have undermined the observation of certain effects.

Future studies might benefit from assessing emotional states in additional moments throughout the day, namely in the evening (e.g., Jankowski 2014). Moreover, it seems advisable to consider an alternative explanation for time of day's effects in the present study, as well as in others employing a similar methodology (e.g., Díaz-Morales et al. 2015): the difference between emotional states in the first and last hour of the school day with better emotional states in the afternoon may reflect the approaching of the end of the school day, and not exactly a time of day's effect. Hence, time of day's effects over adolescents' emotional states could be better clarified in a context where the influence of external factors could be reduced, e.g., during school's summer break, where there are no mandatory classes and imposed schedules. In such conditions with usually less societal demands and a higher sense of self-direction, adolescents could follow their natural circadian rhythm and engage in activities that promote satisfaction and positive emotions.

Despite these limitations, the present study offers some insight on adolescent's emotional states oscillations during the school day, as well as the influence of morningness-eveningness. The present study uncovered consistent effects of time of day, despite its interaction with chronotype not reaching significance. Some associations between chronotype and emotional states seemed to be influenced by sleep and/or

psychopathological symptoms. Future studies on the topic are encouraged to control for sleep-related variables and psychopathological symptoms.

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Declaration of interest statement

We wish to confirm that there are no known conflicts of interest associated with this publication.

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Table 1

Mean scores (and standard deviations) for the scales employed on the present study.

Scales	*M (SD)*	Range	Skewness	Kurtosis
CSM	33.09 (6.57)	15 - 48	-.14	-.42
[Emotional states' measures]				
FS a.m.	5.20 (1.35)	1 - 7	-.89	.58
p.m.	5.76 (1.33)	1 - 7	-1.46	2.46
EAPNC-PA a.m.	46.46 (11.94)	18 - 72	-.30	-.61
p.m.	49.86 (13.09)	16 - 75	-.35	-.45
EAPNC-NA a.m.	22.32 (8.80)	15 - 59	1.75	2.79
p.m.	22.03 (9.99)	15 - 74	2.05	4.74
STAIC-S a.m.	31.11 (5.90)	20 - 52	.79	1.05
p.m.	29.38 (6.35)	20 - 49	.65	.26
[Potential confounders to control for]				
SDQ	12.99 (5.18)	2 - 27	.27	-.33
Sleep length	8.52 (1.27)	4 - 14.5	.18	2.85
Perceived sufficient sleep	2.76 (1.37)	0 - 4	-.56	-1.15
Sleep quality	6.74 (3.35)	0 - 18	.64	.63

Note. CSM = Composite Scale of Morningness' score; FS = Faces Scale's score; a.m. = morning's administration; p.m. = afternoon's administration; EAPNC-PA = Positive and Negative Affect Scale for Children – Positive affect scale's score. EAPNC-NA = Positive and Negative Affect Scale for Children – Negative affect scale's score; STAIC-S = score of Anxiety-State Scale from State-Trait Anxiety Inventory for Children; SDQ = Strengths and Difficulties Questionnaire's total score; Sleep length = the difference between rise time and bedtime on weekdays; Perceived sufficient sleep = score from 0 (getting insufficient sleep all weeknights) to 4 (getting sufficient all weeknights); Sleep quality = Basic Scale on Insomnia and Quality of Sleep's (6 items) score.

Table 2

Chronotypes' percentiles and distribution by gender.

Percentile	CSM	Chronotype	Females	Males	Total
			N	*N*	*N*
25th	≤ 28	E	20	24	44
50th	[29-37]	I	48	57	105
75th	≥ 38	M	20	21	41

Note. CSM = Composite Scale of Morningness' score; E = evening-types; I = intermediate-type; M = morning-types.

Table 3

Intercorrelation coefficients between morningness-eveningness scores, emotional states' measures in different times of the day, and potential covariates/confounders.

		Covariates to be considered			
		SDQ	Sleep quality	Sleep length	Perceived sufficient sleep
	CSM	-.18*	-.27***	.26***	. 36***
Emotional states					
FS					
a.m. | p.m.	.33*** | .13 *ns*	-.19** | -.28***	-.15* | -.14 *ns*	.23** | .15*	.27*** | .14 *ns*
EAPNC-PA					
a.m. | p.m.	.34*** | .20**	-.29 *** | -.30***	-.30*** | -.21*	.15* | .16*	.15* | .16*
EAPNC-NA					
a.m. | p.m.	-.19* | -.05 *ns*	.37*** |.41***	.32*** | .19*	-.09 *ns* | -.13 *ns*	-.19** | -.18**
STAIC-S					
a.m. | p.m.	-.26***|-.11 *ns*	.40*** |.40***	.37*** | .23**	-.23** | -.12 *ns*	-.21** | -.15*

*Note. ns = non-significant. *p< 0.05; **p<0 .01; ***p<0.001. a.m. = morning's administration; p.m. = afternoon's administration; CSM = Composite Scale of Morningness' score; FS = Faces Scale's score; EAPNC-PA = Positive and Negative Affect Scale for Children – Positive affect scale's score. EAPNC-NA = Positive and Negative Affect Scale for Children – Negative affect scale's score; STAIC-S = score of Anxiety-State Scale from State-Trait Anxiety Inventory for Children; SDQ = Strengths and Difficulties Questionnaire's total score; Sleep length = the difference between rise time and bedtime on weekdays; Perceived sufficient sleep = score from 0 (getting insufficient sleep all weeknights) to 4 (getting sufficient sleep all weeknights); Sleep quality = Basic Scale on Insomnia and Quality of Sleep's (6 items) score.*

Table 4

Scores' means and standard deviations of each emotional states' measure by chronotype and time of day.

		Time of day		
		a.m.	p.m.	Overall
		M (SD)	*M (SD)*	*M (SD)*
FS	E	4.73 (1.52)	5.59 (1.51)	5.16 (1.51)
	I	5.23 (1.28)	5.76 (1.27)	5.50 (1.28)
	M	5.63 (1.20)	5.93 (1.29)	5.78 (1.26)
	Overall	5.20 (1.35)	5.76 (1.33)	
EAPNC-PA	E	43.25 (12.88)	47.25 (12.62)	45.25 (10.96)
	I	45.84 (11.83)	49.45 (13.49)	47.64 (11.49)
	M	51.51 (9.61)	53.71 (11.91)	52.61 (9.65)
	Overall	46.46 (11.94)	49.86 (13.09)	
EAPNC-NA	E	24.34 (11.04)	21.98 (9.55)	23.16 (9.29)
	I	22.48 (8.61)	22.77 (11.06)	22.62 (8.78)
	M	19.73 (5.53)	20.20 (7.12)	19.96 (5.46)
	Overall	22.32 (8.80)	22.03 (9.99)	
STAIC-S	E	32.30 (6.26)	30.18 (6.35)	31.24 (6.31)
	I	29.72 (6.00)	29.67 (6.64)	30.70 (6.32)
	M	28.27 (4.24)	27.80 (5.41)	28.04 (4.83)
	Overall	31.11 (5.90)	29.38 (6.35)	

Note. E = evening-types; I = intermediate-types; M = morning-types; a.m. = morning's administration; p.m. = afternoon's administration; FS = Faces Scale's score; EAPNC-PA = Positive and Negative Affect Scale for Children – Positive affect scale's score; EAPNC-NA = Positive and Negative Affect Scale for Children – Negative affect scale's score; STAIC-S = score of Anxiety-State Scale from State-Trait Anxiety Inventory for Children.

Table 5

Mixed-model ANOVAs results for emotional states' measures by time of day and chronotype

		df	*F*	η_p^2	*p*
FS	Time of day	1	26.79	.125	<.001
	Chronotype	2	3.20	.033	.043
	Time of day x Chronotype	2	1.88	.020	.156
EAPNC-PA	Time of day	1	13.69	.068	<.001
	Chronotype	2	5.01	.051	.008
	Time of day x Chronotype	2	.32	.003	.725
EAPNC-NA	Time of day	1	.61	.003	.436
	Chronotype	2	1.91	.020	.151
	Time of day x Chronotype	2	1.66	.017	.193
STAIC-S	Time of day	1	11.59	.051	.001
	Chronotype	2	4.68	.048	.010
	Time of day x Chronotype	2	1.28	.013	.282

Note. FS = Face Scale's score; STAIC-S = score of Anxiety-State Scale from State-Trait Anxiety Inventory for Children; EAPNC-PA = Positive and Negative Affect Scale for Children – Positive affect scale's score. EAPNC-NA = Positive and Negative Affect Scale for Children – Negative affect scale's score.