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Internalizing symptoms and chronotype in youth: A longitudinal assessment of anxiety, depression and tripartite model

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Abstract

Biological rhythm theories highlight the reciprocal relations between dysregulated circadian patterns and internalizing psychopathology. Chronotype characterizes individuals' diurnal preference, as some exhibit more morningness or eveningness. Previous research suggests that eveningness prospectively predicts depression in adolescence. Anxiety often co-occurs with depression, but little is known about longitudinal, reciprocal associations between chronotype and anxiety, and whether this relationship remains after controlling for depression. We assessed different forms of anxiety (social, panic, separation), positive/negative affect, anxious arousal (from tripartite theory), and depression, in relation to chronotype to better understand the specificity and directionality of associations between chronotype and internalizing problems in adolescence. Community youth participated in three assessment time points: T1, T2 (18-months post-T1), and T3 (30-months post-T1) as part of a larger longitudinal study. Youth completed self-report measures of anxiety, depression, positive and negative affect, and chronotype. Regression analyses showed that eveningness: (1) concurrently associated with decreased separation anxiety, elevated symptoms of depression and low levels of positive affect, (2) was prospectively predicted by elevated depression, (3) did not predict later symptoms of anxiety. The reciprocal, prospective relationship between chronotype and internalizing psychopathology is specific to depression during adolescence.

Keywords

circadian; mood; developmental; child; adolescent

1. Introduction

Adolescence is an important transitional period for circadian rhythms and psychopathology. Individuals tend to prefer to go to bed early and rise early during childhood (morningness),

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rapidly transition to staying up later and waking later throughout adolescence (eveningness), and then gradually return to earlier bed and rise times in adulthood (Roenneberg et al., 2004). Preferences in bed and rise times are often referred to as "chronotype," and despite this general evolution in sleep and wake patterns throughout the lifespan, individuals vary on both the timing and intensity of this transition. Those exhibiting stronger eveningness tend to experience more negative outcomes, including both problems with physical well-being (Roenneberg et al., 2012; Urbán et al., 2011) and poor mental health, including depression (Alvaro et al., 2014; Chiu et al., 2017; Drennan et al., 1991; Hidalgo et al., 2009; Kitamura et al., 2010; Merikanto et al., 2013). To date, most of the research on mental health and chronotype has focused on depression, especially within youth populations (Chiu et al., 2017; de Souza and Hidalgo, 2014; Gulec et al., 2013; Haraden et al., 2017; for review, see Adan et al., 2012). Despite the high rate of comorbidity between depression and different forms of anxiety (ranging between 15% to 75%; Angold et al., 1999; Avenevoli et al., 2001), the relationship between anxiety and chronotype has been understudied, and findings from existing research are mixed.

The tripartite model proposed by Clark and Watson (1991) has been widely examined and used to characterize the comorbidity between anxiety and depression. The tripartite model specifically posits that the two disorders share a nonspecific component of general affective distress, negative affect (NA), which underlies this observed comorbidity. Anxiety and depression can then be distinguished by their relatively unique elements of physiological hyperarousal (PH) and low levels of positive affect (PA), respectively (Cannon and Weems, 2006). The tripartite model offers a way to conceptualize the unique versus shared associations between internalizing disorders and their relationships with chronotype, which may resolve inconsistent associations in the literature.

The primary goal of the current study was to establish a more comprehensive understanding of the relationship between chronotype and symptoms of anxiety, after controlling for depression during adolescence. Our group has previously established that a history of depression among youth predicts individual differences in chronotype, and also that chronotype predicts later depression (Haraden et al., 2017). Thus, this study focused on whether elevated eveningness was specific to anxiety, depression, or whether it was related to both, given the strong co-occurrence between anxiety and depression (Angold et al., 1999; Avenevoli et al., 2001). We additionally investigated the longitudinal and concurrent relationships between chronotype and the shared (NA) and relatively unique features of depression (PA) and anxiety (PH) as articulated in the tripartite model during adolescence in order to further parse their unique and specific contributions to chronotype.

1.1 Chronotype and Internalizing Psychopathology

Individuals exhibit meaningful differences in their timing of sleep and peak levels of alertness. The striking shift from morningness to eveningness during adolescence has been associated with the onset of puberty, such that post-pubertal youth show a greater evening preference compared to their pre-pubertal counterparts (Carskadon et al., 1993; Roenneberg et al., 2004). Recent evidence also suggests that depression prospectively predicts individual differences in an evening preference in adolescence, above and beyond the influence of

pubertal status (Haraden et al., 2017). Taken together, normative development (e.g., puberty) and mental health status (e.g., depression) predict individual differences in chronotype during adolescence.

Given the profusion of research supporting a relationship between chronotype and depression, and as depression is highly related to anxiety, a new line of research has begun investigating the relationship between chronotype and anxiety. Some work has found that holding an evening preference is related to elevations in symptoms of anxiety (Díaz-Morales, 2016; Hsu et al., 2012; Lemoine et al., 2013; Pabst et al., 2009; Park et al., 2015; Prat and Adan, 2013) whereas other work has not found a relationship between anxiety and an evening preference (Alvaro et al., 2017, 2014; Antypa et al., 2015). In samples of late adolescents and adults (i.e., college students, adult psychiatric patients, and youth/adult community members), an evening preference has been concurrently related to elevated levels of anxiety, via symptoms (Hsu et al., 2012; Prat and Adan, 2013), diagnoses (Lemoine et al., 2013) and a related construct, anxious temperament (Hsu et al., 2012). Despite the heterogeneity in the composition of the samples, similar relationships were found between anxiety (symptoms, diagnoses and anxious temperament) and chronotype, such that elevations of anxiety are related to an evening preference. A similar pattern has emerged within samples of adolescents at earlier stages of development, such that an evening preference has been related to higher levels of anxiety in a community sample (Díaz-Morales, 2016) and a female-only sample (Pabst et al., 2009). Further, in a longitudinal sample of adults from the community, primary care and mental health organizations, Antypa et al. (2015) initially found that broad internalizing psychopathology was associated with an evening preference; however, when the disorders were examined independently, depression was the only variable related to an evening preference. When controlling for depression, Alvaro and colleagues (2014, 2017) similarly found no relationship between anxiety and chronotype among an adolescent sample.

Methodological features may account for the inconsistent associations between anxiety and chronotype found in previous studies. First, the majority of studies have not considered the comorbidity between anxiety and depression when examining their respective relationships with chronotype (Díaz-Morales, 2016; Hsu et al., 2012; Lemoine et al., 2013; Pabst et al., 2009; Park et al., 2015; Prat and Adan, 2013). Results may therefore be capturing nonspecific affective distress (NA) shared by both disorders rather than a unique association between anxiety and chronotype. The studies that controlled for depression did not find a significant relationship between anxiety and chronotype (Alvaro et al., 2017, 2014; Antypa et al., 2015), suggesting that the previously identified relationship between anxiety and chronotype may indeed be attributable to a shared internalizing dimension (NA), rather than a unique aspect of anxiety. Second, most research has used cross-sectional designs (Alvaro et al., 2014; Díaz-Morales, 2016; Hsu et al., 2012; Lemoine et al., 2013; Pabst et al., 2009; Park et al., 2015; Prat and Adan, 2013), which are unable to establish temporal relationships between variables. Prospective designs are necessary to understand the longitudinal temporal associations between anxiety, depression, and chronotype. Finally, previous research often lumps anxiety into a single construct despite the heterogeneity of different anxiety disorders and their distinct developmental trajectories (Costello et al., 2003). Some forms of anxiety (i.e., separation anxiety) demonstrate peak prevalence during early childhood, and decline

markedly over subsequent development, whereas others (i.e., social anxiety, panic disorder and generalized anxiety disorder) increase during adolescence (Costello et al., 2003; Kessler et al., 2005). Alvaro and colleagues (2014, 2017) accounted for separate forms of anxiety within their analyses both cross-sectional (2014) and longitudinally (2017). Although chronotype showed a consistent relation with both depression and insomnia across studies, it did not predict anxiety subtypes. However, in the longitudinal analysis (Alvaro et al., 2017), chronotype predicted individual differences in generalized anxiety disorder and panic disorder. In both studies, Alvaro and colleagues (2014, 2017) included additional covariates in all analyses, making it difficult to identify the relation between aspects of anxiety and chronotype. Isolating the different forms of anxiety throughout development allows for a more comprehensive account of the relationship with chronotype and may identify unique associations when accounting for depression.

Although some previous research has supported a relationship between anxiety and an evening preference, findings may be driven by variance shared between anxiety and depression. Further investigation is needed to understand the unique temporal relations between chronotype and anxiety while accounting for the variance shared by anxiety and depression. Conceptualizing internalizing symptoms according to the tripartite model (Clark and Watson, 1991) allows for the examination of the association between relatively unique (PA and PH) and shared (NA) elements of anxiety and depression with chronotype. As no existing study has parsed apart the shared versus unique characteristics of anxiety and depression in association with chronotype longitudinally during adolescence, we sought to advance extant knowledge by examining how symptoms and mood features (using the tripartite model in addition to symptoms) of depression and different forms of anxiety relate to chronotype.

1.3 Current Study

In the current study, we built upon our previous work focusing on depression (Haraden et al., 2017) by examining the relationships between internalizing symptoms (i.e., depression and different forms of anxiety) and chronotype during adolescence to further understand the unique and shared associations of anxiety and depression with individual differences in chronotype. With this overarching aim, we examined three possible models to explain the relationship between chronotype and internalizing symptoms. The association between chronotype and internalizing could be: 1) relatively specific to one symptom domain and not the other (e.g., chronotype related to depression only), 2) shared between symptom domains (i.e., chronotype related to NA – shared component of anxiety and depression), or 3) specific to both, but not shared (i.e., chronotype related to PA and PH, but not NA). We investigated these possibilities both concurrently and prospectively.

In the first set of analyses, we examined symptoms of anxiety and depression and their concurrent relationships to chronotype, allowing us to address the first possibility – *is the concurrent association between chronotype and internalizing symptoms specific to either depression or anxiety?* We then tested whether individual differences in anxiety prospectively predicted chronotype, and whether chronotype subsequently predicted later anxiety to examine the possibility of a bidirectional relationship, as we found previously that

depression predicts later chronotype and individual differences in chronotype predict prospective elevations of depression (Haraden et al., 2017). Next, we examined the relationship between the tripartite model and chronotype both concurrently and prospectively to address the second possibility – *is the association between chronotype and internalizing shared between anxiety and depression*? – and third possibility – *is the relationship specific to both but not shared?* Introducing constructs described in the tripartite model allows for an investigation of how a shared component of anxiety and depression is related to chronotype.

2. Method

2.1 Participants & Procedures

The current study used data from a multi-site longitudinal study examining risk-factors for psychopathology within youth (Hankin et al., 2015). Data from a single site was used to create the sample for the current study due to availability of measures at all timepoints. Specifically, a 48-month assessment was conducted exclusively at the Denver site. Thus, the current sample represents participants recruited from the Greater Denver area only. The current sample was representative from the area from which it was recruited in terms of ethnic makeup (Hankin et al., 2015). Participants of the larger longitudinal study were initially recruited via brief informational letters sent to families within the broader Denver area. Caregivers with a child in third, sixth or ninth grade then contacted the university to be scheduled for a baseline visit. Inclusion criteria included English language fluency, absence of autism spectrum disorder or psychotic disorder, and IQ>70 as assessed via parent report. For further information regarding the study and additional participant characteristics, see Hankin et al. (2015). Youth and a caregiver were then followed repeatedly at regular intervals over 48-months. The current study examined participants' responses at three time points: T1, T2 (18-months post-T1) and T3 (30-months post-T1). Within the larger longitudinal study, T1 corresponded to the 18-month follow-up, T2 corresponded to the 36-month follow-up and T3 represented the 48-month follow-up. T1 consisted of 294 youth (58% female) who were between the ages of 9 – 17.5 years old (M=12.08, SD=2.27). For ethnicity, 11% reported being Latinx; for race, youth indicated the following: 75.4% White, 6.8% African American, 3.6% Asian/Pacific Islander, 1% American Indian/Alaskan Native, 6.5% more than one race and 6.8% Other. At T2, the sample consisted of 282 youth (57% female; 96.9% retention) and at T3, the sample consisted of 202 (56% female; 70.8% retention). There were no significant differences between those who participated at T2 and those who did not by gender (t=−0.71, p=0.48), depression (t=0.76, p=0.45), or anxiety symptoms (t=0.64, p=0.53). Participants that completed T3 did not differ significantly from those who did not on any previous scores of anxiety (t<|0.69|, p>0.49), depression (t<|1.68|, p >0.09), or chronotype (t=−1.31, p=0.19).

2.2 Measures

Chronotype was measured via youth self-report with the Morningness/Eveningness Scale in Children (MESC; Carskadon et al., 1993). The MESC contains 10 items that identify circadian preferences (morningness versus eveningness) by inquiring about preferred timing of activities. Participants were posed a scenario and were instructed to select the statement

that best fits them and are scored on a 1 – 4 or 5 scale (e.g., "*Gym class is set for 7:00 in the morning. How do you think you'll do?* Answer choices: "My best!", "Okay", "Worse than usual", "Awful!"). Higher scores indicate a greater preference for morning with a theoretical minimum of 10 and maximum of 43. The MESC has good reliability and validity (Díaz-Morales, 2015; Giannotti et al., 2002) and internal consistency in this study was acceptable ($\alpha = 0.78$). Chronotype was measured at a single timepoint (T2).

Anxiety symptoms were assessed via youth self-report with the Multidimensional Anxiety Scale for Children (MASC; March et al., 1997), a widely used measure of anxiety in children and adolescents, at T1, T2 and T3. The MASC contains 39 items that assess physical symptoms of anxiety (PH), harm avoidance (HA), social anxiety (SOC) and separation anxiety (SEP). Each item presents a symptom of anxiety and then instructs the participant to indicate how true that has been for them on a four-point scale ranging from *(0)* – "*Never True*" to *(3)* – "*Very True*". Composite scores for each of the subscales were computed based on a summation of each of the ratings pertaining to the type of anxious symptom. The HA subscale has questionable validity (Grills-Taquechel et al., 2008; van Gastel and Ferdinand, 2008), and has been found to be uncorrelated or negatively correlated with the three other subscales (Baldwin and Dadds, 2007; Snyder et al., 2015). Therefore, we chose to exclude the HA subscale. The subscales that we chose to focus on (physical symptoms, social anxiety and separation anxiety scales) have been clearly associated with risk for their specific disorders (van Gastel and Ferdinand, 2008; Wei et al., 2014). The physical symptoms subscale was used as a proxy for physiological hyperarousal within the tripartite model. This subscale shares common elements with physiological hyperarousal (e.g., heart racing, difficulty catching breath, feeling dizzy) and is highly correlated ($r = .70$) with common measures of PH (e.g., Revised Children's Manifest Anxiety Scale – RCMAS physiological anxiety subscale; Muris et al., 2002). The MASC shows good reliability and validity (March et al., 1997). Internal consistency was good for the total MASC ($\alpha > .89$), physical symptoms ($\alpha > .84$), social anxiety ($\alpha > .86$), and separation anxiety ($\alpha > .69$) across all timepoints.

Positive and Negative Affect were assessed by youth self-report with the Positive and Negative Affectivity Schedule for Children (PANAS-C; Laurent et al., 1999) at T1 and T2. The PANAS-C contains 27 items consisting of emotion words that participants are instructed to identify the frequency with which they experience each emotion. The PANAS-C contains a 12-item Positive Affect scale and a 15-item Negative Affect scale and has shown good reliability and validity (Crawford and Henry, 2004). Internal consistency was good for both timepoints ($\alpha > 0.8$).

Depression symptoms were measured via youth self-report with the Children's Depression Inventory (CDI; Kovacs, 1992), a widely-used self-report questionnaire to measure depression symptoms in youth. The CDI contains 27 items instructing youth to identify one of three statements that was most similar to themselves over the previous 2 weeks (e.g., 0-*I am sad once in a while to* 2-*I am sad all the time*), with higher total scores indicating more elevated symptoms and a range of 0 to 54. The CDI has good reliability and validity (Klein et al., 2005). Internal consistency was good across all timepoints ($\alpha \geq .87$).

Pubertal status was assessed via the Pubertal Development Scale (PDS; Petersen et al., 1988) which has good reliability and validity (Petersen et al., 1988; Shirtcliff et al., 2009). The PDS is a commonly used questionnaire to determine pubertal status among children and adolescents. Youth are asked about various aspects of physical development and are instructed to indicate the item that best describes them (e.g., *Would you say your height:* Answer choices: "Has not begun to increase yet," "Has just started to increase," "Has been increasing for a while," "Seems to have reached its maximum") with some items pertaining to specific sexes (e.g., menses, breast growth, facial hair). We followed standard scoring separately for boys and girls. Internal consistency in this study was acceptable for both boys ($\alpha = 0.89$) and girls ($\alpha = 0.62$). Pubertal status was included in analyses due to its relationship with chronotype, such that post-pubertal youth are more likely to hold an evening preference (Carskadon et al., 1993; Roenneberg et al., 2004). The current study assessed pubertal status of the participants at T2.

3. Results

The current study was preregistered through the Open Science Framework. All preregistration documents can be accessed here: https://osf.io/jhs8f/?view_only=51ce3ec035ac4286b7909108343564b0.

3.1 Data Analytic Plan

Analyses were conducted using linear regressions, implemented in R (R Core Team, 2017) with the "lavaan" package (Rosseel, 2012) and missing data were addressed through the implementation of Full Information Maximum Likelihood (FIML). All analyses included both pubertal status and gender as covariates. To address our first possibility – specificity of relationship between internalizing symptoms and chronotype – we first examined the *concurrent* relationship (at T2) between anxiety and chronotype by including all subscales of anxiety as independent variables predicting chronotype to first establish a relationship between the variables. Next, we introduced depression as a covariate to the same model to examine the unique associations between the subscales of anxiety and chronotype while accounting for the shared variance between anxiety and depression. Then, we investigated the *prospective* relationship between anxiety and chronotype by including all anxiety subscales from T1 as independent variables to predict chronotype at T2 (18-months post-T1), while controlling for T2 anxiety subscale scores. We then introduced depression as a covariate at both T1 and T2 to examine the specificity of the relationship between internalizing aspects of psychopathology and chronotype. Finally, we used linear regression to assess whether chronotype (T2) predicted later symptoms of anxiety (T3) by including chronotype as the independent variable to predict each anxiety subscale while controlling for pubertal status, gender and T2 levels of the corresponding anxiety subscale. This prospective analysis was not repeated for symptoms of depression as these results are reported elsewhere (Haraden et al., 2017).

We followed an identical procedure, introducing PA, NA and PH as the independent variables to predict chronotype both concurrently and prospectively while controlling for pubertal status and gender, to examine the relationship between the tripartite model and

chronotype. These analyses addressed our second (the association is shared) and third (specific to both, but not shared) possibilities of the relationship between internalizing, as designated by the tripartite theory, and chronotype.

3.2 Preliminary Results

Table 1 reports descriptive statistics and correlations for demographic information, chronotype and psychopathology measurements for the sample. Chronotype measurements (M=26.7, SD=5.35) fell within established norms (Carskadon et al., 1993), and the mean was consistent with an intermediate-type. There were no gender differences in chronotype (t=−1.42, p=0.16), CDI at T1 (t=1.52, p=0.13), MASC physical or separation symptoms at T2 or T3 (t<|1.86|, p>0.06; t<|1.91|, p>0.06), or PA at T1 or T2 (t=−0.29, p=0.77; t=−0.79, p=0.43). Gender differences arose for CDI at T2 (t=2.43, p=0.02), MASC social anxiety symptoms at all timepoints (t>2.92, p<0.004), MASC physical and separation symptoms (t=2.79, p=0.006; t=2.66, p=0.008), and NA at T1 and T2 (t>2.75, p<0.006), with girls consistently reporting higher levels of anxiety and NA than boys.

3.3 Symptoms of Anxiety and Depression with Chronotype

3.3.1 Concurrent Associations (T2)—Table 2 reports statistics for each regression analysis. Chronotype was associated concurrently with separation anxiety (β=0.211, p=0.002, SE=0.067), physical symptoms (β=−0.252, p<0.001, SE=0.068) and social anxiety (β=−0.145, p=0.049, SE=0.074). Results indicate that youth with higher levels of separation anxiety showed a greater preference towards morning, whereas those with higher levels of physical symptoms and social anxiety had a greater preference towards evening.

In the next regression analysis, we used the same model and included symptoms of depression as an additional covariate. Separation anxiety was still related to chronotype (β=0.168, p=0.013, SE=0.068), whereas physical symptoms of anxiety (β=−0.144, p=0.06, SE=0.077) and social anxiety (β=−0.052, p=0.51, SE=0.078) were unrelated to chronotype, indicating that the initial concurrent associations found between physical symptoms and social anxiety with chronotype were accounted for by variance shared with depression. Symptoms of depression were also related to chronotype (β=−0.24, p=0.001, SE=0.075), such that higher levels of depression were related to an evening preference. Thus, higher levels of separation anxiety related to a greater morning preference, above and beyond the effects of depression symptoms, gender, and pubertal status.

3.3.2 Prospective Relationships (across 18-months)—To examine the prospective relationship between different forms of anxiety and chronotype, we conducted additional regressions to test whether individual differences in anxiety predicted later individual differences in chronotype. We included all subscales of the MASC from T1 as independent variables to predict chronotype at T2 while controlling for T2 levels of anxiety, gender and pubertal status as well as symptoms of depression at both timepoints. No subscale of anxiety from T1 significantly predicted later individual differences in chronotype (for physical symptoms, β=0.06, p=0.54, SE=0.094; for separation anxiety, β=−0.01, p=0.94, SE=0.09; for social anxiety, β=0.02, p=0.85, SE=0.09). Symptoms of depression at T1 (β=−0.18, p=0.02, SE=0.075) were associated with individual differences in chronotype (more

eveningness) at T2. These results suggest that depression symptoms are related to later individual differences in chronotype, whereas symptoms of anxiety are not.

3.4 Chronotype Predicting Anxiety

To further examine the relationship between chronotype and symptoms of anxiety, we conducted a separate regression analysis in which individual differences in chronotype (T2) predicted each subscale of anxiety (T3) while controlling for previous anxiety (T2), gender and pubertal status. As demonstrated in Table 3, chronotype did not predict later symptoms of anxiety (β<|0.05|, p>0.28).

3.5 Tripartite Model and Chronotype

3.5.1 Concurrent Associations—We included PA (relatively depression specific), NA (shared variance between anxiety and depression), as assessed by the PANAS-C, and PH (relatively anxiety specific) as assessed by the MASC physical symptoms subscale as independent variables in the regression model with gender and pubertal status as covariates to predict concurrent levels of chronotype. PA (β=0.216, p<0.001, SE=0.059), was significantly related to chronotype, whereas PH (β=−0.117, p=0.12, SE=0.075) and NA (β=−0.139, p=0.068, SE=0.076) were not related to chronotype. This analysis suggests that lower levels of PA, which are relatively specific to depression, are related to an eveningness preference.

3.5.2 Prospective Associations—We then examined the prospective associations between features of the tripartite model and chronotype by entering PA, NA and PH at T1 to predict individual differences in chronotype at T2 while controlling for T2 levels of PA, NA and PH as well as gender and pubertal status. PA, NA, and PH were not *prospectively* related to chronotype (β<|0.114|, p>0.21). PA (β=0.183, p=0.006, SE=0.067) continued to show a *concurrent* relationship with chronotype, while PH (β=−0.114, p=0.21, SE=0.09) and NA (β=−0.148, p=0.06, SE=0.078) were not concurrently related to chronotype.

4. Discussion

Chronotype has been previously shown to relate to with both anxiety and depression in youth (Adan et al., 2012; Alvaro et al., 2014; Díaz-Morales, 2016; Haraden et al., 2017; Hsu et al., 2012; Lemoine et al., 2013; Prat and Adan, 2013). With the high rates of comorbidity between depression and anxiety (Angold et al., 1999; Avenevoli et al., 2001), it has been unclear whether this relationship is driven specifically by depression, anxiety, or some shared component between the two. The results of the present study indicate that the relationship between internalizing symptoms and chronotype among adolescents is specific to depression. Higher levels of depression remained robustly related both concurrently and prospectively to having an evening preference even after controlling for additional aspects of internalizing psychopathology (i.e., separation anxiety, social anxiety and physical symptoms) and variables known to predict chronotype (i.e., gender and pubertal status). A similar pattern emerged when examining relationships between chronotype and internalizing problems through the lens of the tripartite model (PA, NA and PH), such that low levels of PA (relatively depression specific) were related to a greater tendency toward eveningness,

whereas NA (shared between anxiety and depression) and PH (relatively specific to anxiety) were not related to chronotype.

Further, the specificity of the relationships between depression/PA and chronotype, beyond the symptoms of anxiety, varied depending on whether they were examined prospectively or concurrently. Chronotype was concurrently related to symptoms of separation anxiety and depression as well as PA, such that higher levels of separation anxiety were related to morningness, whereas high levels of depression symptoms and low PA were associated with eveningness. When examined prospectively, symptoms of depression were the only remaining association with an evening preference, whereas PA (a construct relatively unique to depression) was not a significant predictor of chronotype. Further, individual differences in chronotype (T2) did not predict later anxiety symptoms (T3). Taken together, the overall association between internalizing psychopathology and chronotype is specific to symptoms of depression and PA, with symptoms of depression showing both concurrent and prospective relationships with an evening preference. Consistent with previous work, this suggests a bidirectional relationship between depression and chronotype such that depression predicts chronotype, which has also been shown to subsequently predict later depression (Adan et al., 2012; Haraden et al., 2017; Hidalgo et al., 2009).

Within the tripartite model (Clark and Watson, 1991), PA represents a construct that is primarily associated with depression, while also showing relationships with other forms of psychopathology (e.g., substance misuse, social anxiety, schizotypy) (Watson and Naragon-Gainey, 2010; Wills et al., 1999). As seen within the current study, PA is not isomorphic with symptoms of depression. Symptoms of depression were related to eveningness chronotype both *concurrently* and *prospectively*, but PA was only associated with eveningness chronotype *concurrently*. This highlights a more complex conceptualization of PA and suggests further investigation. Stanton and Watson (2015) analyzed the lower order structure of PA and found two facets, Joviality and Experience Seeking, with different relationships to psychopathology. Joviality, a mix of attentiveness and cheerfulness, showed relations with overall well-being, whereas Experience Seeking, particularly maladaptive behaviors, showed stronger relations to externalizing psychopathology. Such externalizing behaviors (e.g., substance use, impulsivity) have also been shown to be associated with an evening preference (Adan et al., 2012). Placed within the current study, PA may have stronger concurrent relations with an evening preference due to the high relation between the Experience Seeking facet and eveningness. Elevations in experience seeking behaviors may not be sustainable in the long-term relationship, as negative consequences may discourage the longevity of an individual's behaviors, resulting in the concurrent relationship rather than one that is prospective. However, further work is necessary to properly investigate this question.

Investigating the mechanisms and risks of chronotype and depression may allow for a more comprehensive understanding of the bidirectional relationship between chronotype and depression. As the current study measured chronotype at a single timepoint, the directionality of the relation between chronotype and any potential mechanisms were limited. Recent work has begun to explore PA as a potential mediator within the relationship between chronotype and depression (Hasler et al., 2010). PA has been shown to have a

circadian rhythm (Boivin et al., 1997; Murray et al., 2002) in which alterations in the timing of the magnitude and variability of the PA rhythm may impact an individual's likelihood to engage with their surroundings. Preliminary findings have shown that PA rhythms vary as a function of chronotype with evening types showing later peak times (acrophase) and blunted variation (amplitude) (Hasler et al., 2012; Porto et al., 2006). With adolescents in school, Díaz-Morales et al. (2015) suggested that although there were no fluctuation differences in mood across chronotype groups throughout the school-day, holding an evening preference exhibited the lowest mood levels. In a community sample of adults using an Ecological Momentary Assessment sampling procedure, Miller and colleagues (2015) demonstrated that individuals with an evening preference experienced delayed acrophase, and lower amplitudes of PA during the week when compared to those with a morning preference. Such delays and lower amplitudes may then impact an individual's engagement with their environment, resulting in low mood, anhedonia and apathy, withdrawal and eventually depression. Individuals with a delayed acrophase may result in a mismatch with their peers, and when others are at their peak, such as feeling most sociable and engaging in positive social activities (e.g., going to the mall, getting food, or playing video games/sports), an adolescent with an evening preference may not be as motivated to engage in those activities. Later in the day, that same individual may then be at their peak when their peers are beginning to wind down, limiting opportunities to engage in rewarding social encounters. In a sample of adolescence from the community (Díaz-Morales et al., 2014), an evening preference was significantly related to greater frequency of conflict within their household. This may result in a greater exposure to interpersonal stress, and ultimately later elevations in depressive symptoms. Future works needs to further examine these associations.

Interestingly, separation anxiety showed significant concurrent relationships with chronotype even when symptoms of depression were taken into account. Higher levels of separation anxiety were related to morningness. Although this may appear to be contrary to previous research showing that increases in psychopathology are related to a later preference, it may reflect developmental trends in chronotype and separation anxiety. Separation anxiety peaks during childhood (Costello et al., 2003; Kessler et al., 2005) during which time youth also demonstrate a greater preference toward morningness (Roenneberg et al., 2004). Although we did include puberty as a covariate, there is a wide age range of participants who are pre-pubertal. Therefore, it is more likely that those reporting a greater tendency toward morning are also younger and have a higher likelihood of reporting elevations in symptoms of separation anxiety (see correlations in Table 1).

The current study had a number of strengths. The age of the current sample captured an important developmental period for both chronotype and internalizing psychopathology. Chronotype goes through a developmental shift during puberty (Roenneberg et al., 2004), while the first onset of many internalizing disorders most commonly occurs during this period (puberty)(Costello et al., 2003). Participants were sampled from the general community, ultimately enhancing the generalizability of results. Symptoms of depression, anxiety and components of the tripartite model were measured at multiple assessments resulting in more accurate analyses since responses were collected prospectively rather than retrospectively (Moffitt et al., 2010). At the same time, study limitations offer opportunities for future research. Chronotype was only measured at a single timepoint; this limited our

ability to examine change of chronotype across this developmental window. Although multiple forms of anxiety were examined, additional diagnoses or syndromes (GAD, PTSD) may show relationships with chronotype as reflected in adult populations (Hasler et al., 2013; Vardar et al., 2008; Yun et al., 2015), while youth is understudied. Additionally, circadian rhythms were not assessed directly and no behavioral measure of diurnal activity patterns was collected in this study. Future studies should measure chronotype longitudinally throughout this transitional period of adolescence in order to examine change in late/early preferences and how they may be related to depression and PA.

4.1 Conclusions

The current study examined the associations between internalizing aspects of psychopathology and chronotype both concurrently and prospectively during adolescence. Our findings suggest that the relationship between chronotype and internalizing psychopathology is mostly specific to depression when measured via symptoms. It is also important to highlight that chronotype showed concurrent associations with separation anxiety such that high levels of separation anxiety were related to a greater morning preference. Positive Affect (PA) was also related to chronotype concurrently, but not prospectively, with low levels of PA associated with a greater evening preference. Future studies examining bidirectional associations between chronotype and symptoms of internalizing disorders throughout development are required to elucidate potential mechanisms (e.g., PA) and provide information around intervention targets.

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Highlights

- Circadian preferences develop across the lifespan
- Eveningness (”night owl”) is associated with depression and anxiety
- Adolescents have greater eveningness and higher risk for depression and anxiety
- Specificity of eveningness to anxiety, and longitudinal direction are unclear
- Eveningness is linked to depression and low positive affect in youth

Table 1

Descriptive Statistics & Correlations

	Age	DEP T1	DEP T2	PH T1	SOC T1	SEP T1	PH T2	SOC T2	SEP T2	PH T3	SOC T3	SEP T3	PA T1	NA T1	PA T2	NA T2	Chronotype	Puberty
Age	**13.59 (2.3)**	0.221	0.197	***0.038***	0.133	−0.312	***0.029***	***0.054***	−0.288	***0.008***	***0.043***	−0.317	***0.007***	0.161	***−0.106***	0.118	−0.199	0.651
DEP T1		**4.59 (4.85)**	0.561	0.472	0.466	***0.112***	0.376	0.355	***0.032***	0.363	0.312	***0.087***	−0.385	0.548	−0.253	0.402	−0.339	0.211
DEP T2			**5.00 (5.33)**	0.407	0.464	***0.054***	0.568	0.531	***0.106***	0.54	0.505	0.167	−0.209	0.382	−0.372	0.649	−0.332	0.19
PH T1				**6.22 (5.63)**	0.469	0.458	0.643	0.38	0.293	0.586	0.33	0.22	***−0.088***	0.674	***−0.116***	0.466	−0.163	***0.072***
SOC T1					**7.34 (5.66)**	0.406	0.346	0.653	0.212	0.272	0.547	0.144	−0.225	0.53	−0.171	0.409	−0.2	0.243
SEP T1						**4.73 (4.45)**	0.196	0.21	0.589	0.175	***0.14***	0.507	***0.051***	0.401	***0.045***	0.159	***0.047***	−0.146
PH T2							**6.52 (6.19)**	0.485	0.357	0.763	0.42	0.283	***−0.083***	0.459	−0.214	0.626	−0.251	***0.092***
SOC T2								**7.63 (5.97)**	0.341	0.37	0.717	0.0189	−0.172	0.43	−0.215	0.5	−0.202	0.179
SEP T2									**3.59 (3.37)**	0.216	0.275	0.668	0.126	0.22	***0.029***	0.259	***0.078***	−0.184
PH T3										**7.33 (6.63)**	0.5	0.374	***0.013***	0.445	−0.156	0.555	−0.223	***0.066***
SOC T3											**8.46 (5.58)**	0.311	***−0.138***	0.375	−0.141	0.432	−0.176	0.208
SEP T3												**4.31 (3.53)**	***0.08***	0.188	−0.014	0.229	***0.003***	−0.157
PA T1													**43.23 (8.35)**	−0.133	0.476	***−0.067***	0.182	−0.065
NA T1														**24.71 (7.93)**	***−0.109***	0.457	−0.156	0.137
PA T2															**41.78 (7.99)**	−0.242	0.272	***−0.096***
NA T2																**25.79 (8.99)**	−0.274	0.134
Chronotype																	**26.7 (5.35)**	−0.176
Puberty																		**13.69 (3.05)**

Age at T2; DEP - CDI Score; PH -Physical Symptoms; SOC - Social Anxiety; SEP - Separation Anxiety; PA - Positive Affect; NA - Negative Affect P

Chronotype - Higher scores indicate greater preference for morning.

Mean (SD) on Diagonal.

Bold–Italic = Non-significant ($p > 0.05$).

Table 2

Regression Coefficients T1 - T2

	Anxiety & Chronotype												Tripartite Model & Chronotype					
	Concurrent						Prospective											
	Not Including Depression			Controlling for Depression			Not Including Depression			Controlling for Depression			Concurrent			Prospective		
	Beta	**SE**	***p*-value**	**Beta**	**SE**	***p*-value**	**Beta**	**SE**	***p*-value**	**Beta**	**SE**	***p*-value**	**Beta**	**SE**	***p*-value**	**Beta**	**SE**	***p*-value**
Gender	0.04	0.06	0.561	0.02	0.06	0.685	0.03	0.06	0.638	0.04	0.06	0.565	0.01	0.06	0.807	0.01	0.06	0.815
Puberty	−0.08	0.07	0.224	−0.07	0.06	0.252	−0.07	0.07	0.293	−0.06	0.07	0.377	−0.13	0.06	0.036	−0.12	0.06	0.042
PH T1	-	-	-	-	-	-	0.01	0.09	0.951	0.06	0.09	0.538	-	-	-	0.00	0.09	1.000
SOC T1	-	-	-	-	-	-	−0.08	0.09	0.367	0.02	0.09	0.846	-	-	-	-	-	-
SEP T1	-	-	-	-	-	-	0.05	0.09	0.597	−0.01	0.09	0.939	-	-	-	-	-	-
DEP T1	-	-	-	-	-	-	-	-	-	−0.18	0.08	0.017	-	-	-	-	-	-
PA T1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.07	0.241
NA T1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.08	0.960
PH T2	−0.25	0.07	<0.001	−0.14	0.08	0.060	−0.25	0.09	0.004	−0.16	0.09	0.087	−0.12	−0.08	0.118	−0.11	0.09	0.206
SOC T2	−0.14	0.07	0.049	−0.05	0.08	0.505	−0.10	0.09	0.258	−0.06	0.09	0.529	-	-	-	-	-	-
SEP T2	0.21	0.07	0.002	0.17	0.07	0.013	0.19	0.08	0.025	0.16	0.08	0.054	-	-	-	-	-	-
DEP T2	-	-	-	−0.24	0.07	0.001	-	-	-	−0.16	0.08	0.056	-	-	-	-	-	-
PA T2	-	-	-	-	-	-	-	-	-	-	-	-	0.22	0.06	<0.001	0.18	0.07	0.006
NA T2	-	-	-	-	-	-	-	-	-	-	-		−0.14	0.08	0.068	−0.15	0.08	0.060

Gender: 0 = Female, 1 = Male

DEP - CDI Score; PH - Physical Symptoms; SOC - Social Anxiety; SEP - Separation Anxiety; PA - Positive Affect; NA - Negative Affect

Table 3

Chronotype Predicting Anxiety

	Physical Symptoms			Social Anxiety			Separation Anxiety		
	Beta	**SE**	***p*-value**	**Beta**	**SE**	***p*-value**	**Beta**	**SE**	***p*-value**
Gender	−0.03	0.05	0.47	−0.09	0.05	0.09	−0.06	0.55	0.28
Puberty	0.01	0.05	0.77	0.06	0.05	0.23	−0.06	0.06	0.34
Chronotype	−0.05	0.05	0.27	−0.03	0.05	0.56	−0.05	0.06	0.37
PH T2	0.75	0.03	<0.001	-	-	-	-	-	-
SOC T2	-	-	-	0.69	0.03	<0.001	-		-
SEP T2	-	-	-	-	-	-	0.65	0.04	<0.001

Gender: 0 = Female, 1 = Male

PH - Physical Symptoms; SOC - Social Anxiety; SEP - Separation Anxiety