Sleep and affect in adolescents: bi-directional daily associations over 28 days' ecological
momentary assessment

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Abstract

Study Objectives: To examine bi-directional, temporal associations between daily sleep and affect under naturally constrained (school) and unconstrained (vacation) sleep opportunities, while simultaneously incorporating both valence (positive versus negative) and arousal (high versus low) dimensions of affect.

Methods: Sleep and affect were measured over 2 weeks of school and 2 weeks of vacation in 205 adolescents (54.1% females, $M_{age}=16.9$ years), providing 5231 days of data. Total sleep time (TST) and sleep efficiency were measured using actigraphy and sleep diary. High- and low-arousal positive and negative affect (PA, NA) were self-reported each afternoon. Between- and within-person sleep-affect associations were tested using cross-lagged, multilevel models. Lagged outcome, day of the week, study day, and sociodemographics were controlled.

Results: Bi-directional associations between self-report sleep and affect were found on the between-person level: longer self-report TST associated with lower high and low arousal NA. Higher high arousal PA associated with longer actigraphy TST between-persons, but predicted shorter same-night actigraphy TST within-persons. Results did not differ between school and vacation. Significant within-person random effects demonstrate individual differences in daily sleep-affect associations.

Conclusions: Associations differed based on sleep measurement and affect dimensions, highlighting the complex relationship between sleep and affect. Strong between-person associations between self-report sleep and affect suggest that improving either sleep or mood may benefit the other. Although overall high arousal PA was protective of sleep duration, on a day-to-day basis, higher-than-usual high arousal PA may reduce sleep duration on nights it is

experienced. Further research needs to identify causes of individual differences in sleep-affect associations.

Keywords: adolescent, sleep, actigraphy, mood, affect, ecological momentary assessment, school, vacation

Statement of Significance

In a large, community sample of adolescents, during both school and vacation periods, this study examined temporal and bi-directional associations between daily sleep and affect both between and within individuals. An intensive longitudinal design with actigraphy and self-report measures of sleep, coupled with rigorous statistical methods provided strong tests of directionality. Findings revealed complex associations between sleep and affect that depended on the measurement of sleep and type of affect. Findings could inform future research on sleep and affect and the development of interventions to make meaningful impacts on adolescents' sleep and wellbeing on a daily basis.

Introduction

Adolescence is a critical life stage for sleep and affect regulation. Developmentally-driven delays in endogenous circadian timing¹ and reduced homeostatic sleep pressure,² increased academic and extra-curricular demands,³ and decreased parental control over bedtime⁴ all contribute to delayed sleep onset. Yet school start times dictate early wake times on weekdays, resulting in chronic sleep restriction for most adolescents.⁵ This coincides with an important developmental period for affect regulation,⁶ with heightened emotional arousal and reactivity^{7,8} and high prevalence of mood disorders.⁹ The pre-frontal cortex that regulates affect and mood is still developing,^{10,11} and sleep restriction may negatively impact such development.¹² Furthermore, emergence of psychopathology and adjustment problems during this life stage is linked to poorer lifelong outcomes, including chronic depression in adulthood.⁹ Therefore, adolescence is a critical period for understanding sleep-affect relationships.

Existing evidence from experimental and correlational studies suggest bi-directional associations between sleep and emotions, most of which have been conducted in adults, examining effects of sleep on subsequent emotion. In laboratory settings, acute total sleep deprivation over one or two nights^{13,14} and partial sleep deprivation over a week¹⁵ have been shown to elevate negative affect (NA) and dampen positive affect (PA) compared to controls. In the other direction, higher low arousal NA (loneliness) predicted poorer subjective sleep satisfaction at 7-year follow up in older adults.¹⁶ High arousal NA (hostility) has also been cross-sectionally associated with higher self-reported sleep disturbances in young adults.¹⁷

Studies examining sleep and emotions in adolescents are limited and mostly cross-sectional. These studies have typically shown that insufficient and poor sleep are associated with

worse mood,^{18,19} impaired daytime functioning,²⁰ elevated depressive symptoms, and suicidal ideation.²¹

A small number of experimental studies in adolescents highlight the impact of sleep restriction on affect. In healthy adolescents, experimentally induced sleep restriction over two nights (≤ 6.5 hours the first night, ≤ 2 hours the second night) dampened self-reported positive affect (PA), but did not elevate negative affect (NA)²² on the Positive and Negative Affect Schedule – Child version.²³ However, human-rater judgements of vocal patterns²⁴ and an interview-based catastrophizing task²² indicated elevated NA. Longer term partial sleep restriction may be necessary to impact NA. Supporting this, an at-home study with a counterbalanced, cross-over design found partial sleep restriction over five consecutive nights (average sleep duration: 6.3 hours), to elevate self-reported NA (e.g., anger, tension) and emotional regulation problems, compared to the healthy sleep condition over five consecutive nights (average sleep duration: 8.8 hours).²⁵ It is important to note that adolescents experience this cycle of weekly sleep restriction repeatedly during school terms.

Although experimental studies provide strong tests of causality, they have limited generalizability, as the conditions do not mimic naturalistic sleep restriction.²⁵ Naturalistic sleep²⁶ and affect²⁷ vary from day to day. Daily-level measures provide insight into how daily fluctuations in sleep and affect may affect each other over time,²⁸ but few studies have moved beyond between-person analyses to investigate within-person associations of daily sleep and affect in adolescents.

One such study examined how affect predicted objective sleep on between- and within-person levels over 3 days.²⁹ On the between-person level, adolescents reporting on-average higher negative social evaluative emotions (judged, rejected, embarrassed, ashamed) in evenings

also reported overall shorter sleep duration, whilst higher low arousal negative emotions (sad, depressed, lonely) were associated with longer average sleep. On the within-person level, higher-than-average high arousal PA in the evening predicted longer sleep onset latencies the same night, and higher-than-average evening negative social evaluative emotions predicted longer wake after sleep onset the same night. Previous-day affect was not controlled in testing these associations.

Few studies have examined bi-directional, daily sleep-affect associations in adolescents. In female young adults, a two-week daily study found that on the between-person level, higher overall PA predicted overall longer self-reported TST and higher sleep quality, and higher overall NA predicted shorter TST.²⁷ More specifically, low arousal PA (serenity) and NA (sadness) were driving this impact of affect on TST. On the within-person level, regardless of overall levels of sleep and affect, better sleep quality predicted greater high arousal PA (happiness) the following day, and higher-than-average daytime NA predicted shorter TST and poorer sleep quality the same night.

These findings support potential bi-directional relations between daily sleep and affect and demonstrate the importance of examining both between- and within- person associations. Preliminary evidence based on young adults and adolescents suggest that these complex associations may differ based on sleep parameters and valence, but further investigations with rigorous study designs and analytical methods are necessary to disentangle the directionality and temporal sequence of these associations.

Current Study

The current study aims to examine the bi-directional, temporal associations between sleep and affect across 28 consecutive days, including 2 school weeks, followed by 2 vacation weeks.

The following features of the study allow rigorous and detailed examining of this research question while addressing several gaps in the literature.

(1) Intense longitudinal design with within-person, time-lagged analyses were used to establish strong inference of directionality of sleep-affect association. Ecological momentary assessment (EMA) was used with real-time self-reports of affect taken in the context of participants' daily lives, maximizing ecological validity and minimizing recall bias.³⁰

(2) Noting the lack of existing studies using objective sleep measures in examining daily sleep-affect relationships, this study measured sleep using both self-report and actigraphy. In addition, both sleep duration and quality (operationalised as sleep efficiency) were examined.

(3) The sleep-affect relationship may differ on *valence* (positive versus negative) and *arousal* (high versus low) dimensions of affect. High arousal PA reflects emotions such as happiness and enthusiasm, whereas low arousal PA reflects emotions such as calmness and serenity.³¹ High arousal NA reflects emotions including anxiety and irritability, whereas low arousal NA reflects emotions such as sadness and loneliness.³¹ Both high- and low- arousal negative affect have been shown to be associated with sleep.²⁹ However, although overall PA seems to be protective of sleep duration and quality, Kalmbach and colleagues (2014)²⁷ found low arousal PA to be particularly beneficial. In fact, high arousal PA in the evenings may be detrimental for sleep (predicting longer sleep onset latencies).²⁹ This is consistent with findings from insomnia literature, which suggest promoting low arousal PA (e.g., calm and relaxed) aids sleep, and high arousal emotions may disrupt sleep.³² Few studies on sleep-affect relationship incorporated both *valence* and *arousal* dimensions of affect. This may be particularly important for adolescents, given developmental and psychosocial changes contributing to higher reactivity towards high arousal emotions.⁷

(4) Finally, the current study spanned across 2 weeks of school term and the subsequent two-week vacation, allowing us to examine sleep-affect associations under naturalistic constrained (school term) and unconstrained sleep opportunities (vacation). Sleep is known to differ substantially during these two periods, with ~1 hour increased actigraphy-assessed sleep opportunity during vacation periods.³³ Both constrained and unconstrained sleep opportunities are important aspects to consider in examining the sleep-affect relationship.

Methods

Participants

Adolescents enrolled in Years 10, 11 and 12 of high schools in Victoria, Australia, who attended the final 2 weeks of a school term, did not travel across time zones during the study period, and regularly used a smartphone with Internet connection were eligible for this study. To maximize generalizability, there were no exclusion criteria. Assuming 75% completion rate and moderate to large intraclass coefficients (0.3 to 0.5), a sample of 204 participants would provide 80% power to detect a small effect size (Cohen's $f^2 = .02$).

Design and Procedures

All study procedures were approved by Monash University Human Research Ethics Committee (#10005). Reporting follows the STROBE³⁴ for observational and CREMAS³⁵ for ecological momentary assessment study guidelines. This was a longitudinal study, and data were collected from November 2017 to July 2019. The 28-day study period allowed us to collect data over the final 2 weeks of a school term and the subsequent two-week vacation.

Adolescents were invited to participate through online advertisements, as well as in-person recruitment and posters in public areas (e.g., train stations, shopping malls). Informed consent was obtained from both participants and their parents or guardians.

Participants attended a 60-minute induction session, during which they were familiarized with study procedures and equipment. Demographic information was collected at baseline, before commencing daily measures. Participants wore an actigraphy device throughout the study period to estimate sleep-wake patterns. Sleep was also self-reported each morning (between 07:00–14:30) and affect was self-reported each afternoon (between 15:30–19:00) via smartphone (MetricWire Inc.). Time windows for surveys were set outside of typical school hours. As a

token of appreciation, participants received up to \$76 AUD cash, based on the number of daily surveys completed, with bonuses for weeks with complete entries.

Equipment and Measures

Sleep Duration and Quality. Daily sleep-wake patterns were measured objectively via wrist-worn actigraphy, the Mini Mitter Actiwatchs (-L, -64, -2, Spectrum, Pro, and Plus; Philips Respironics Inc., Pittsburgh, PA) with comparable sleep statistics.³⁶ Data were collected at 1-minute epochs and analyzed based on the “medium” threshold for sleep-wake detection in Actiware 6.0.9. Participants also self-reported sleep using items adapted from the Consensus Sleep Diary.³⁷ Total sleep time (TST) and sleep efficiency (SE) were derived and used as measures of sleep duration and sleep quality respectively.

Affect. Affect was assessed using items selected from the Positive and Negative Affect Schedule – Expanded (PANAS-X).³⁸ The 12 items chosen showed low cross-loadings with other factors, and captured both high- and low- arousal affect: high arousal PA (*Cheerful, Enthusiastic, Happy*), low arousal PA (*At Ease, Calm, Relaxed*), high arousal NA (*Afraid, Irritable, Nervous*), and low arousal NA (*Guilty, Lonely, Sad*). Participants rated each item on a 5-point Likert scale from 0 (*Very slightly or not at all*) to 4 (*Extremely*), based on how they felt at the time of the survey. Individual items were averaged to derive high- and low- arousal PA and NA (possible range: 0 to 4). Internal consistency reliabilities were calculated based on 2-level coefficient omega,³⁹ which separates estimates at the between- and within-person level. Affect dimensions showed excellent reliability at the between-person level and adequate to low reliability at the within-person level: high arousal PA: ($\omega_{\text{between}} = 0.97$, $\omega_{\text{within}} = 0.79$), low arousal PA: ($\omega_{\text{between}} = 0.98$, $\omega_{\text{within}} = 0.79$), high arousal NA: ($\omega_{\text{between}} = 0.84$, $\omega_{\text{within}} = 0.44$), low arousal NA: ($\omega_{\text{between}} = 0.88$, $\omega_{\text{within}} = 0.58$).

Statistical Analyses

To examine bi-directional relationships between sleep and affect on both between- and within-person levels, cross-lagged multilevel models were conducted across sleep measures (actigraphy and self-reported), sleep variables (TST and SE), affect valence (NA and PA), affect arousal (high and low), and direction (sleep predicting next-day affect, afternoon affect predicting same-night sleep). All models were tested at alpha of .05, and estimated using restricted maximum likelihood⁴⁰ in R v.3.6.3⁴¹ with lme4 v1.1-23 (to estimate models)⁴² and lmerTest v3.1-2 (to estimate degrees of freedom and *p*-values).⁴³ Actigraphy and sleep diary TST and SE were winsorized (1%) for all analyses. The number of daily observations ranges from 3,323 to 3,999 across the models due to missing data and cross lags. A small number of extreme values were removed for the following two models: self-reported SE predicting high- and low-arousal NA, 0.89% and 1.0% of total observations were removed for these models, respectively.

As per previous studies that have conducted daily level analyses and to provide stronger tests of directionality, all associations were tested prospectively while controlling for previous day outcomes.²⁷ Specifically, the first set of models examined sleep as a predictor of next-day affect, controlling for previous-day affect. The second set of models examined evening affect as a predictor of same-night sleep, controlling for previous-night sleep. Unadjusted models controlled for previous day outcomes. Fully adjusted models controlled for previous day outcomes, as well as additional covariates: school year level (10, 11, 12), sex (0 = Male, 1 = Female), body mass index (BMI; calculated from self-reported height and weight), ethnicity (white = 0; Asian, Indian subcontinent, Indigenous/ Torres Strait Islander, or Other = 1), born in Australia (No = 0, Yes = 1), adolescents' work status (Not working = 0, Working part-time or

casual = 1), parental marital status (married or de facto = 0, separated, divorced, widowed, or prefer not to answer = 1), study day, and day of week.

To examine whether sleep-affect associations differed between school and vacation periods, school/vacation status was added as a moderator of the association between sleep and affect. Nonsignificant interaction terms between school/vacation status and the predictor were dropped, and school/vacation status was then left in as a covariate with its main effect on the outcome tested (vacation = 0, school = 1).

Sleep and affect measures were tested in separate models, where the intercept, the lagged-outcome covariate, and the within-person predictor were included as random effects, and other covariates included as fixed effects. All models tested both between- and within-person associations between the predictor and the outcome simultaneously. Between-person effects capture how average levels of sleep and affect are associated (e.g., do individuals with longer TST on average also have overall higher high arousal PA) and are based on each individual's own mean. In contrast, within-person effects capture how daily deviations of the predictor, relative to each individual's own average, is related to the outcome (e.g., do nights with longer-than-average TST, relative to one's own average, predict higher high arousal PA the following day), and are calculated by creating person mean centered variables.

Marginal and conditional R^2 values were calculated for all models. Marginal R^2 is the proportion of total variance explained by fixed effects, whereas conditional R^2 is the proportion of total variance explained by both fixed and random effects.⁴⁴ A Cohen's f^2 type effect size was calculated as follows: nested models were run for each predictor, dropping predictors one at a time. Changes in marginal and conditional R^2 values due to each predictor were used to calculate

the Cohen's f^2 type effect size : $\frac{R_{AB}^2 - R_A^2}{1 - R_{AB}^2}$, where R_{AB}^2 is the marginal R^2 from the full model, and

R_A^2 is the marginal R^2 from the restricted model (i.e., after dropping the relevant predictor).

Results

Descriptive Statistics

From an initial 392 expressions of interest, 205 adolescents (54.1% females, age $M \pm SD = 16.92 \pm 0.87$ years) participated in the study, providing a total of 4868 ($M \pm SD = 24.4 \pm 7.9$ days/person) and 5231 ($M \pm SD = 26.2 \pm 5.4$ days/person) nights of usable actigraphy-assessed and self-reported sleep data respectively. Missing actigraphy data were mainly due to faulty hardware. Compliance for daily surveys was high (93.4% and 80.8% for morning and afternoon surveys respectively).

Table 1 shows sociodemographic information. Most participants were Asian (39.0%) or white/European (35.6%), and over half were born in Australia (66.3%). Table 2 shows descriptive statistics for sleep and affect variables. During school terms, participants' average actigraphy-assessed time-in-bed was 7.78 hours on weekdays, and 8.84 hours on weekends. On 24.4% of weekdays and 10.9% of weekends, time-in-bed was shorter than 7 hours. During vacations, average time-in-bed was 8.70 hours. On 13.2% of vacation days, time-in-bed was shorter than 7 hours. Overall, participants' sleep duration was lower than recommendations for their age group,⁴⁵ averaging 6.84 and 7.85 hours (actigraphy and self-reported respectively). On average, participants experienced good sleep quality, 81.9% and 92.6% for actigraphy and self-reported respectively. A small proportion of the sample self-reported current depressive (4.39%), anxiety (5.85%), or sleep (11.2%) disorders. Sensitivity analyses were conducted, excluding participants with current depressive/anxiety disorders, and/or sleep disorders. Changes were present in 5% of models (≤ 0.01 for coefficients and ≤ 0.01 for confidence intervals), and therefore these participants were not excluded from analyses to help representativeness of the sample.

School Term versus Vacation

School/vacation status was not a significant moderator of the daily association between sleep and affect, indicating that the strength of daily sleep-affect associations did not differ significantly between school and vacation periods. Therefore, the interaction term between school/vacation status and the predictor was dropped, and only the main effect of school/vacation status was included in all models.

Supplementary Figure S1 shows daily sleep and affect trajectories over school term and vacation. All four affect dimensions were not significantly different during school term versus vacation (Supplementary Table S1). However, adjusted for covariates, actigraphy-assessed and self-reported TST were both approximately 45 minutes longer (both $p < .001$) during vacations. Self-reported SE ($p = .04$), on the other hand, was significantly higher by 0.87% during school term.

Sleep Predicting Next-Day Affect

Adjusted, cross-lagged multilevel models with sleep predicting next-day affect are summarised in Table 3 (refer to Table 5 for unadjusted model, and Supplementary Table S1 for full results for the adjusted model, including covariates). No significant associations on either between- or within-person levels were found for actigraphy-assessed sleep and affect. On sleep diary, between individuals, overall longer TST was associated with lower NA (both high- and low-arousal, $p = .02$ and $p = .05$ respectively). Similarly, overall higher self-reported SE was associated with lower high arousal NA ($b = -0.01$, $p = .047$). This means that individuals who typically have longer self-reported sleep, also have lower NA by 0.11 and 0.09 points of high- and low-arousal NA for each additional hour slept, respectively. Similarly, higher overall self-reported SE, was significantly associated with lower overall high arousal NA (by 0.01 points for

each 1% SE). At the within- person level, self-reported sleep did not predict next-day affect (all $p > .21$).

Random effects for within-person predictors were included in all models. In cases of nonconvergence, random slopes for predictors were dropped, but random intercepts maintained. In this study, we were able to estimate both random and fixed slopes for 6 out of the 16 models where sleep predicted next-day affect. Despite nonsignificant *fixed* effects (i.e., average effects across individuals), effect sizes for *random* effects (i.e., individual differences in effects) were significant for self-reported TST predicting next-day high- and low- arousal PA ($f^2 = 0.01$, $p = .02$, and $f^2 = 0.02$, $p = .001$, respectively). This suggests that although on average, these associations were not significantly different from 0, there were significant individual differences in these associations.

Evening Affect Predicting Same-night Sleep

Adjusted, cross-lagged multilevel models with affect predicting same-night sleep are in Table 4 (refer to Table 6 for unadjusted model, and Supplementary Table S2 for full results from the adjusted model, including covariates). Low arousal PA did not significantly predict any sleep variables (all $p > .09$). Second, all significant fixed effects were found for TST as the outcome, not SE (either actigraphy or self-report; all $p > .09$).

High arousal PA was predictive of actigraphy-assessed TST on both between- and within- person levels. Between individuals, higher overall high arousal PA was associated with longer overall actigraphy TST ($b = 0.14$, $p = .02$), with each 1-point increase in high arousal PA associated with 8.4 minutes longer TST. However, within individuals, higher-than-average high arousal PA predicted *shorter* actigraphy-assessed TST ($b = -0.06$, $p = .003$); this suggests that

above and beyond the effects of covariates and lagged outcomes, evenings with one point higher-than-usual high arousal PA were associated with 3.6 minutes shorter actigraphy-assessed TST.

On the between person level, high- and low- arousal NA, and high arousal PA, were all associated with self-reported TST. High- and low- arousal NA were associated with shorter self-reported TST ($b = -0.21, p = .05$, and $b = -0.22, p = .03$, respectively). Similar to the between-person results for actigraphy-assessed TST, high arousal PA was associated with *longer* self-reported TST ($b = 0.15, p = .03$).

The following 3 out of 16 models where affect predicted same-night sleep had nonsignificant *fixed*, but significant *random* effects, indicating significant individual differences: low-arousal NA predicting same-night self-reported TST ($f^2 = 0.01, p = .006$), and high arousal PA predicting same-night self-reported TST and SE ($f^2 = 0.01, p = .006$, and $f^2 = 0.02, p = .001$, respectively).

Effects of Covariates

Results were interpreted from adjusted models, but both adjusted and unadjusted models are in Tables 3 to 6. The following associations (all on the between-person level) were significant in the unadjusted model, but were no longer significant after controlling for covariates: longer self-reported TST associated with higher high arousal PA, higher self-reported SE associated with lower low arousal NA, and higher low arousal PA, higher NA (regardless of arousal) associated with lower self-reported SE, and higher low arousal PA associated with higher self-reported SE. These differences in findings were likely driven by covariates and lagged outcomes.

Details of results related to covariates and lagged outcomes are in Tables S1 and S2.

Longer actigraphy-assessed TST the previous night consistently predicted shorter actigraphy TST on a given night (all $p < .001$). For both actigraphy and self-report measures, higher SE the previous night predicted higher current night SE (all $p < .001$ for actigraphy, all $p < .04$ for self-report). Higher previous-day NA and PA were consistent predictors of higher current day NA and PA (all $p < .001$). Significant individual differences were present for most of these associations (all $p \leq .001$; refer to Tables S1 and S2, under row “Within Lagged Outcome (random)”).

Being female and having a higher BMI were associated with significantly longer TST (all $p < .001$, and all $p < .007$, respectively) and higher actigraphy-assessed SE (all $p < .002$, and all $p < .04$, respectively). Adolescents born in Australia (versus overseas) had lower actigraphy-assessed SE (all $p < .005$). Those in higher school years (generally older) had shorter self-reported TST (all $p < .03$) and lower SE (all $p < .04$ for actigraphy-assessed and self-report). Being non-white and working part-time or casually were associated with significantly shorter TST on actigraphy and self-report respectively (all $p < .03$). Sleep also was significantly different on various days of the week. Sleep on Sunday nights had significantly lower SE (actigraphy-assessed; all $p < .001$), while sleep on Wednesday, Friday and Saturday nights were significantly longer (actigraphy-assessed and self-report; all $p < .001$).

On affect, compared to males, females had higher high arousal NA (all $p < .04$), and lower high- and low- arousal PA (all $p < .05$, and all $p < .04$, respectively). Being non-white was associated with significantly lower levels of high arousal PA (all $p < .02$). Adolescents who reported working part-time or casual had lower low arousal PA (all $p < .02$).

Discussion

This study investigated bi-directional, temporal associations between daily sleep and affect in adolescents over 28, continuous days, that included both school terms and vacations. Our findings highlighted complex interactions between sleep and affect on a day-to-day basis. Such relationship differed by the type of sleep measurement (actigraphy versus self-report), the type of affect (positive versus negative in valence; high versus low in arousal), and whether the effects were between- or within- individuals.

Sleep Measured via Self-report

When sleep was measured using self-report, all significant associations were on the between-person level. Bi-directional associations were found between longer self-reported TST and lower NA (both high and low arousal); further, higher SE predicted lower high arousal NA, whilst higher high arousal PA predicted longer TST.

Stronger between-, rather than within- person associations indicate that in a community sample of relatively healthy adolescents, overall levels of perceived sleep were more relevant for affect (and vice versa). Adolescents who typically perceived shorter and poorer sleep also reported overall higher NA and lower PA (and vice versa). These findings point towards a protective role of sleep on affect, and vice versa.

The lack of within-person effects indicate that daily fluctuations in perceived sleep (i.e., deviation from one's average sleep duration/ quality) did not exert a strong impact on next-day affect (and vice versa). Within-person daily associations may depend on adolescents' understanding and awareness of how sleep influences affect (and vice versa) on a day-to-day basis, which are yet to be developed. It is also possible that other factors may exert strong influence on daily sleep/affect. For instance, longer-than-average time spent studying, and

higher-than-average stressful demands (from family, school, or peers) predicted shorter-than-average sleep in adolescents.³

Sleep Measured via Actigraphy

When sleep was measured using actigraphy, the sleep-affect relationship appeared to be unidirectional: afternoon affect predicted same-night sleep, but sleep did not significantly predict next-day affect. This association occurred on both between- and within-individual levels. Whilst individuals with higher high arousal PA had overall longer TST, on the within-individual level, on days with higher-than-average high arousal PA, same-night actigraphy-assessed TST was significantly shorter.

Most past studies examined negative consequences of sleep. Few studies have examined how affect, in particular *positive* affect, impacts subsequent sleep. Higher levels of high arousal PA on average, predicted longer sleep on both actigraphy-assessed and self-report. This may be explained by the protective effects of high arousal PA on overall health and wellbeing.⁴⁶ Individuals who typically report high PA, are also more likely to engage in healthy behaviours, including getting sufficient sleep.⁴⁷

However, on the within-person level, days with higher-than-average high arousal PA predicted significantly *shorter* sleep. This is consistent with a previous daily study in adolescents,²⁹ and may be linked to the disruptive effects of high arousal on sleep.³² Compared to other age groups, adolescents experience heightened emotional arousal and reactivity.⁷ Therefore, daily fluctuations in high arousal emotions may be particularly disruptive for adolescents' sleep. That being said, significant individual differences (i.e., random effects) in the strength of the sleep-affect association indicate that how high arousal PA affect sleep duration may be very different from person to person. It is also possible that a common cause, such as an

exciting event, may contribute to both high arousal PA and shorter TST. The specific mechanisms behind this association in adolescents require further research.

Other measures of affect were not significantly related to objective sleep. In a previous 3-day study, higher negative social evaluative emotions were related to shorter objective sleep, and higher dysphoria was related to longer objective sleep (between-persons).²⁹ It is possible that the relatively low levels of NA in this study, which have been also been reported in other studies that have utilised the PANAS,²⁹ may have contributed to the lack of associations. The finding that actigraphy-assessed sleep did not significantly predict affect may be a broader reflection of stronger associations between self-report (versus actigraphy) sleep and affect, which studies across various populations,⁴⁸ including in adolescents,¹⁸ have also showed.

Other Findings

Further illustrating the complexity of the sleep-affect relationship, we found significant individual differences in within-person sleep-affect associations, on both directions. For example, after a night of poorer-than-usual sleep, some adolescents' next-day affect may be affected more than other adolescents. This is consistent with previous studies that found some adolescents may be more vulnerable to sleep deprivation. For example, adolescents with evening chronotype reported lower PA than those with morning chronotypes when sleep deprived.⁴⁹ Therefore, future studies are needed to further investigate potential protective and vulnerability factors (i.e., moderators) of within-person sleep-affect associations.

Within individuals, previous day levels of sleep (and affect) consistently predicted sleep (and affect) on a given day. These indicate that daily experiences of sleep (and affect) are related in an ongoing way. Finally, we found demographic differences in sleep and affect that are mostly consistent with previous findings. For example, higher school years was associated with shorter

and poorer sleep,⁵⁰ females had higher NA,^{18,51} longer TST, and higher SE,⁵² and being non-white was associated with shorter actigraphy-assessed sleep.⁵³

Limitations

This study had limitations. First, our sample consisted of community samples of adolescents with good quality sleep. These sleep-affect associations may not generalise to adolescents with mental health or sleep problems. Second, NA reported by this community sample is low overall, which is consistent with low NA levels in previous studies.²² This may have contributed to the low reliability of within-person NA, as well as non-significant findings when within-person NA was examined in relation to sleep. Third, our results showed significant individual differences in the sleep-affect relationship on the within-person level. It is beyond the scope of this manuscript to examine predictors of these individual differences, with protective and vulnerability factors of sleep-affect associations yet to be examined by future research. Finally, missing data is unavoidable in studies with intense longitudinal design, although the current study had a high completion rate across all daily measures (see details in Results section).

Conclusion and Implications

Adolescence is a critical developmental phase for sleep and affect regulation. Using an intensive longitudinal design and rigorous tests of directionality, we found between-person associations between perceived sleep and affect. Examined using actigraphy, higher overall high arousal PA was linked to longer sleep duration, but higher-than-average high arousal PA on a given day was associated with shorter sleep that night. Significant individual effects within these associations indicate the need for further research to examine protective and risk factors of within-person sleep-affect associations.

Robust associations found on the between-person level suggest that interventions that improve either sleep or mood in adolescents may benefit the other. It is also possible that factors that influence both self-report sleep and affect (e.g., health habits, stress) may drive the between-person level association, and thus an integrated approach to improve *overall* wellbeing in adolescents could improve both sleep and mood.

This study showed a protective impact of overall PA on adolescent sleep duration. Positive emotions are under-studied in sleep research and interventions. Future adolescent sleep intervention could consider incorporating strategies to enhance PA. Beyond sleep, positive psychology interventions have also been efficacious in improving life satisfaction and wellbeing,⁵⁴ and reducing mental health symptoms in adolescents.⁵⁵

Even though higher overall levels of high arousal PA may increase sleep duration, daily fluctuations in high arousal PA may be detrimental to sleep. On days when adolescents anticipate higher levels of high arousal PA (e.g., night before an outing), strategies that help reduce arousal (e.g., relaxation, wind down) and increase sleep opportunity (e.g., sleep scheduling) may prevent sleep loss.

Finally, significant individual differences in sleep-affect associations on the within-person level highlight that the relationships between daily sleep and affect are different across adolescents. Future research on protective and risk factors that predict these individual differences could help inform individualised interventions to mitigate negative consequences of sleep on mood/affect, and vice versa.

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Table 1

Table 1

Sociodemographic Variables (N=205)

Participant Characteristic	<i>M (SD) / n %</i>
Age, <i>M (SD)</i>	16.92 (0.87)
Female, <i>n (%)</i>	111 (54.1)
Body Mass Index, <i>M (SD)</i>	21.90 (4.42)
School Year, <i>n (%)</i>	
Year 10	51 (24.9)
Year 11	82 (40.0)
Year 12	72 (35.1)
Race/Ethnicity, <i>n (%)</i>	
Asian	80 (39.0)
White/European	73 (35.6)
Others	52 (25.4)
Born in Australia, <i>n (%)</i>	136 (66.3)
Working Part-time/ Casual, <i>n (%)</i>	69 (33.7)
Parents Married/ De Facto, <i>n (%)</i>	164 (80.0)
Current Depression, <i>n (%)</i>	9 (4.39)
Current Anxiety, <i>n (%)</i>	12 (5.85)
Current Sleep Disorders, <i>n (%)</i>	23 (11.2)
Bruxism	9 (4.39)
Insomnia	6 (2.93)
Hypersomnia/ Sleepwalking/ Sleep terrors/ Periodic limb movement disorder/ Restless legs syndrome	8 (3.90)
Average number of vacation days when sleep is affected by commitments, <i>n (%)</i>	0.49 (3.25)

Table 2

Table 2

Descriptive Statistics for Sleep and Affect Variables

Study Variable	<i>Mean (Standard Deviation)</i>		
	Entire Study Period	School Term	Vacation
Affect			
High Arousal Negative Affect	1.55 (0.67)	1.56 (0.66)	1.53 (0.68)
Low Arousal Negative Affect	1.44 (0.67)	1.42 (0.63)	1.46 (0.70)
High Arousal Positive Affect	2.56 (1.01)	2.55 (0.98)	2.56 (1.02)
Low Arousal Positive Affect	2.97 (1.04)	2.94 (1.03)	3.00 (1.05)
Actigraphy-Assessed Sleep			
Total Sleep Time (hours)	6.84 (1.30)	6.53 (1.21)	7.09 (1.32)
Sleep Efficiency (%)	81.94 (7.03)	82.39 (6.73)	81.57 (7.25)
Self-Reported Sleep			
Total Sleep Time (hours)	7.85 (1.50)	7.49 (1.41)	8.16 (1.51)
Sleep Efficiency (%)	92.59 (8.54)	92.66 (8.27)	92.53 (8.77)

Note. Actigraphy and self-reported sleep variables were winzorized at 1%. Values presented are grand means, averaged across all study days.

Table 3

Table 3

Sleep Predicting Next-Day Affect Adjusted for Covariates

	Negative Affect		Positive Affect	
	High Arousal	Low Arousal	High Arousal	Low Arousal
Actigraphy TST (<i>n</i> = 195, # of observations = 3323)				
Between	-0.07 [-0.19, 0.05], 0.00	-0.03 [-0.14, 0.09], 0.00	0.15 [-0.02, 0.32], 0.01	0.09 [-0.09, 0.28], 0.00
Within (fixed)	0.00 [-0.02, 0.01], 0.00	0.00 [-0.01, 0.01], 0.00	0.02 [-0.01, 0.04], -0.01	0.01 [-0.01, 0.04], 0.00
Within (random)	0.01	--	0.00	0.00
Actigraphy SE (<i>n</i> = 195, # of observations = 3323)				
Between	0.00 [-0.02, 0.01], 0.00	0.00 [-0.02, 0.01], 0.00	0.02 [-0.01, 0.04], 0.00	0.01 [-0.01, 0.04], 0.00
Within (fixed)	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [0.00, 0.00], 0.00
Within (random)	--	--	--	--
Self-reported TST (<i>n</i> = 203, # of observations = 3581)				
Between	-0.11* [-0.21, -0.02], 0.01	-0.09* [-0.19, 0.00], 0.01	0.12 [-0.02, 0.26], 0.00	0.04 [-0.11, 0.19], 0.00
Within (fixed)	0.00 [-0.02, 0.01], 0.00	0.00 [-0.01, 0.01], 0.00	0.01 [-0.01, 0.03], 0.00	0.01 [-0.01, 0.03], 0.00
Within (random)	0.01	--	0.01*	0.02**
Self-reported SE (<i>n</i> = 203, # of observations = 3578)				
Between	-0.01* [-0.03, 0.00], 0.01†	-0.01 [-0.02, 0.00], 0.01†	0.02 [-0.01, 0.04], 0.01	0.02 [0.00, 0.05], 0.01
Within (fixed)	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [0.00, 0.00], 0.00
Within (random)	--	--	--	--

Note. TST = Total Sleep Time (winsorized), SE = Sleep Efficiency (winsorized). The predictor for all models is within-person centered sleep. Values presented are unstandardized coefficients, [95% confidence intervals], and Cohen's f^2 . Random effects for within-level predictor and lagged outcomes were included in all initial models, and dropped if models did not converge (represented by --); Cohen's f^2 are presented for models with random effects for within-person predictor. Values for sample sizes are the number of individual participants and number of observations for models with corresponding predictors. †represent models with extreme values removed: $n = 201$ / # of observations = 3546 (high-arousal negative affect as outcome), and $n = 200$ / # of observations = 3532 (low-arousal negative affect as outcome). The following covariates were included in all models: previous day affect (lagged outcome), body mass index, born in Australia, sex, year level, race, work status, parental marital status, study day, and day of week. * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 4

Table 4

Affect Predicting Same-Night Sleep Adjusted for Covariates

	Actigraphy-Assessed		Self-Reported	
	TST	SE	TST	SE
High Arousal NA				
Between	-0.09 [-0.26, 0.08], 0.00	-0.19 [-1.48, 1.09], 0.00	-0.21* [-0.41, -0.01], 0.01	-0.99 [-2.35, 0.38], 0.00
Within (fixed)	0.02 [-0.06, 0.10], 0.00	0.13 [-0.26, 0.53], 0.00	-0.01 [-0.10, 0.09], 0.00	0.07 [-0.43, 0.57], 0.00
Within (random)	--	--	0.01	--
Low Arousal NA				
Between	-0.05 [-0.22, 0.13], 0.00	-0.02 [-1.32, 1.28], 0.00	-0.22* [-0.42, -0.02], 0.01	-1.15 [-2.52, 0.23], 0.00
Within (fixed)	0.03 [-0.05, 0.11], 0.00	0.11 [-0.28, 0.51], 0.00	-0.01 [-0.12, 0.10], 0.00	0.11 [-0.40, 0.62], 0.00
Within (random)	--	--	0.01**	--
High Arousal PA				
Between	0.14* [0.02, 0.25], 0.01	0.47 [-0.40, 1.35], 0.00	0.15* [0.02, 0.29], 0.01	0.66 [-0.27, 1.58], 0.00
Within (fixed)	-0.06* [-0.12, 0.00], 0.00	-0.14 [-0.43, 0.15], 0.00	-0.03 [-0.10, 0.03], 0.00	-0.06 [-0.47, 0.35], 0.00
Within (random)	0.01*	0.01	0.01**	0.02**
Low Arousal PA				
Between	0.07 [-0.04, 0.18], 0.00	0.26 [-0.57, 1.10], 0.00	0.09 [-0.04, 0.21], 0.00	0.77 [-0.11, 1.65], 0.00
Within (fixed)	0.02 [-0.04, 0.07], 0.00	-0.19 [-0.45, 0.06], 0.00	0.05 [-0.02, 0.11], 0.00	-0.13 [-0.50, 0.23], 0.00
Within (random)	0.00	--	0.01	0.01
Number of Individuals and Observations in Each Model				
<i>n</i> , # of observations	193, 3621	193, 3621	204, 3999	204, 3992

Note. TST = Total Sleep Time (winsorized), SE = Sleep Efficiency (winsorized), NA = Negative Affect, PA = Positive Affect. The predictor for all models is within-person centered evening affect. Values presented are unstandardized coefficients, [95% confidence intervals], and Cohen's f^2 . Random effects for within-level predictor and lagged outcomes were included in all initial models, and dropped if models did not converge (represented by --); Cohen's f^2 are presented for models with random effects for within-person predictor. Values for sample sizes are the number of individual participants and number of observations for models with corresponding outcomes. The following covariates were included in all models: previous day sleep (lagged outcome), body mass index, born in Australia, sex, year level, race, work status, parental marital status, study day, and day of week. * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5

Table 5

Sleep Predicting Next-Day Affect Not Adjusted for Covariates

	Negative Affect		Positive Affect	
	High Arousal	Low Arousal	High Arousal	Low Arousal
Actigraphy TST ($n = 195$, # of observations = 3323)				
Between	-0.01 [-0.12, 0.10], 0.00	0.01 [-0.09, 0.12], 0.00	0.14 [-0.02, 0.30], 0.01	0.07 [-0.10, 0.25], 0.00
Within (fixed)	0.00 [-0.02, 0.01], 0.00	0.00 [-0.01, 0.01], 0.00	0.01 [-0.01, 0.04], 0.00	0.01 [-0.01, 0.04], 0.00
Within (random)	0.00	--	0.00	0.00
Actigraphy SE ($n = 195$, # of observations = 3323)				
Between	0.00 [-0.01, 0.02], 0.00	0.00 [-0.01, 0.02], 0.00	0.01 [-0.01, 0.03], 0.00	0.01 [-0.01, 0.03], 0.00
Within (fixed)	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [0.00, 0.00], 0.00
Within (random)	--	--	--	--
Self-reported TST ($n = 203$, # of observations = 3581)				
Between	-0.13** [-0.22, -0.03], 0.02	-0.11* [-0.20, -0.01], 0.01	0.16* [0.02, 0.30], 0.01	0.07 [-0.08, 0.22], 0.00
Within (fixed)	0.00 [-0.02, 0.01], 0.00	0.00 [-0.02, 0.01], 0.00	0.01 [-0.01, 0.03], 0.00	0.01 [-0.01, 0.03], 0.00
Within (random)	0.00	--	0.01*	0.02**
Self-reported SE ($n = 203$, # of observations = 3578)				
Between	-0.02** [-0.03, -0.01], 0.02†	-0.02* [-0.03, 0.00], 0.02†	0.02 [0.00, 0.04], 0.01	0.02* [0.00, 0.05], 0.01
Within (fixed)	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [0.00, 0.00], 0.00
Within (random)	--	--	--	--

Note. TST = Total Sleep Time (winsorized), SE = Sleep Efficiency (winsorized). The predictor for all models is within-person centered sleep. Values presented are unstandardized coefficients, [95% confidence intervals], and Cohen's f^2 . Previous day affect was controlled for in all models. Random effects for within-level predictor and lagged outcomes were included in all initial models, and dropped if models did not converge (represented by --); Cohen's f^2 are presented for models with random effects for within-person predictor. Values for sample sizes are the number of individual participants and number of observations for models with corresponding predictors. †represent models with extreme values removed: $n = 201$ / # of observations = 3546 (high arousal negative affect as outcome), and $n = 200$, # of observations = 3532 (low arousal negative affect as outcome). * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 6

Table 6

Affect Predicting Same-Night Sleep Not Adjusted for Covariates

	Actigraphy-Assessed		Self-Reported	
	TST	SE	TST	SE
High Arousal NA				
Between	-0.01 [-0.20, 0.17], 0.00	0.19 [-1.15, 1.52], 0.00	-0.22* [-0.42, -0.02], 0.01	-1.62* [-3.03, -0.22], 0.01
Within (fixed)	0.03 [-0.05, 0.11], 0.00	0.14 [-0.25, 0.54], 0.00	0.00 [-0.10, 0.10], 0.00	0.04 [-0.46, 0.54], 0.00
Within (random)	--	--	0.00	--
Low Arousal NA				
Between	0.00 [-0.19, 0.19], 0.00	0.24 [-1.12, 1.60], 0.00	-0.24* [-0.44, -0.04], 0.01	-1.84* [-3.24, -0.43], 0.01
Within (fixed)	0.03 [-0.05, 0.11], 0.00	0.15 [-0.25, 0.54], 0.00	-0.02 [-0.13, 0.09], 0.00	0.11 [-0.40, 0.61], 0.00
Within (random)	--	--	0.01*	--
High Arousal PA				
Between	0.14* [0.02, 0.26], 0.01	0.31 [-0.59, 1.20], 0.00	0.19** [0.06, 0.32], 0.01	0.67 [-0.27, 1.61], 0.00
Within (fixed)	-0.06 [-0.12, 0.01], 0.00	-0.13 [-0.43, 0.16], 0.00	-0.03 [-0.10, 0.04], 0.00	-0.06 [-0.47, 0.34], 0.00
Within (random)	0.02*	0.01	0.01**	0.02**
Low Arousal PA				
Between	0.06 [-0.05, 0.18], 0.00	0.14 [-0.72, 1.00], 0.00	0.10 [-0.02, 0.23], 0.00	1.09* [0.26, 1.92], 0.01
Within (fixed)	0.02 [-0.03, 0.08], 0.00	-0.18 [-0.44, 0.08], 0.00	0.04 [-0.02, 0.11], 0.00	-0.15 [-0.50, 0.21], 0.00
Within (random)	0.01	--	0.01	0.01
Number of Individuals and Observations in Each Model				
<i>n</i> , # of observations	193, 3621	193, 3621	204, 3999	204, 3992

Note. TST = Total Sleep Time (winsorized), SE = Sleep Efficiency (winsorized), NA = Negative Affect, PA = Positive Affect. The predictor for all models is within-person centered evening affect. Values presented are unstandardized coefficients, [95% confidence intervals], and Cohen's f^2 . Previous day sleep was controlled for in all models. Random effects for within-level predictor and lagged outcomes were included in all initial models, and dropped if models did not converge (represented by --); Cohen's f^2 are presented for models with random effects for within-person predictor. Values for sample sizes are the number of individual participants and number of observations for models with corresponding outcomes. * $p < .05$, ** $p < .01$, *** $p < .001$.

Supplementary Figure S1

Figure S1. Means and 95% confidence intervals for daily total sleep time (TST), sleep efficiency (SE), and affect, across school term and vacation. In Panels A and B, actigraphy sleep variables are plotted in open circles, and self-report sleep variables in solid circles. In Panel C, high arousal positive affect is plotted in open circles, and low arousal positive affect in solid circles.

High arousal negative affect is plotted in open triangles, and low arousal negative affect in solid triangles. School term is represented by study days -12 to -1, transitional day between school term and vacation is represented by study day 0, and vacation is presented by study days 1 to 15.

Table S1

Sleep Predicting Next-Day Affect Adjusted for Covariates

	Negative Affect		Positive Affect	
	High Arousal	Low Arousal	High Arousal	Low Arousal
Actigraphy TST (n=195, # of observations=3323)				
Between	-0.07 [-0.19, 0.05], 0.00	-0.03 [-0.14, 0.09], 0.00	0.15 [-0.02, 0.32], 0.01	0.09 [-0.09, 0.28], 0.00
Within (fixed)	0.00 [-0.02, 0.01], 0.00	0.00 [-0.01, 0.01], 0.00	0.02 [-0.01, 0.04], -0.01	0.01 [-0.01, 0.04], 0.00
Within (random)	0.01	--	0.00	0.00
Vacation Status	-0.02 [-0.08, 0.05], 0.00	0.00 [-0.06, 0.06], 0.00	0.07 [-0.03, 0.16], 0.00	-0.08 [-0.17, 0.02], 0.00
Within Lagged Outcome (fixed)	0.17*** [0.14, 0.21], 0.01	0.15*** [0.10, 0.20], 0.01	0.17*** [0.12, 0.21], 0.01	0.20*** [0.16, 0.25], 0.02
Within Lagged Outcome (random)	--	0.04***	0.03***	0.03***
Body Mass Index	0.00 [-0.01, 0.02], 0.00	0.00 [-0.01, 0.02], 0.00	0.00 [-0.03, 0.02], 0.00	0.01 [-0.01, 0.04], 0.00
Born in Australia	-0.06 [-0.22, 0.10], 0.00	-0.06 [-0.21, 0.09], 0.00	0.04 [-0.19, 0.27], 0.00	0.06 [-0.19, 0.31], 0.00
Female	0.16* [0.01, 0.31], 0.01	0.07 [-0.07, 0.22], 0.00	-0.27* [-0.49, -0.05], 0.01	-0.25* [-0.48, -0.01], 0.01
Year Level	0.02 [-0.08, 0.12], 0.00	0.04 [-0.05, 0.13], 0.00	-0.11 [-0.26, 0.03], 0.01	-0.04 [-0.20, 0.11], 0.00
Non-White	-0.17* [-0.33, 0.00], 0.01	-0.14 [-0.30, 0.02], 0.01	-0.27* [-0.51, -0.03], 0.01	0.04 [-0.21, 0.30], 0.00
Working	0.10 [-0.05, 0.26], 0.01	0.11 [-0.04, 0.26], 0.01	-0.07 [-0.30, 0.16], 0.00	-0.30* [-0.54, -0.05], 0.02
Parental Marital Status	0.04 [-0.15, 0.23], 0.00	0.11 [-0.07, 0.29], 0.00	0.06 [-0.22, 0.33], 0.00	0.14 [-0.15, 0.43], 0.00
Study Day	0.00* [-0.01, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.01 [0.00, 0.01], 0.00	0.00 [-0.01, 0.01], 0.00
Day of Week (effect size)	0.00	0.00	0.00	0.00
Monday	0.01 [-0.05, 0.06]	0.00 [-0.06, 0.05]	-0.02 [-0.10, 0.07]	0.01 [-0.08, 0.09]
Tuesday	0.02 [-0.03, 0.08]	0.01 [-0.05, 0.06]	-0.04 [-0.13, 0.05]	0.00 [-0.09, 0.08]
Wednesday	0.04 [-0.02, 0.09]	0.02 [-0.04, 0.07]	-0.03 [-0.12, 0.06]	-0.01 [-0.09, 0.08]
Friday	0.04 [-0.02, 0.10]	-0.01 [-0.07, 0.04]	-0.04 [-0.13, 0.05]	0.00 [-0.09, 0.09]
Saturday	-0.02 [-0.07, 0.04]	-0.01 [-0.07, 0.05]	-0.07 [-0.16, 0.02]	0.01 [-0.08, 0.10]
Sunday	0.03 [-0.03, 0.09]	0.02 [-0.04, 0.07]	-0.06 [-0.15, 0.03]	0.00 [-0.09, 0.08]
Actigraphy SE (n=195, # of observations=3323)				
Between	0.00 [-0.02, 0.01], 0.00	0.00 [-0.02, 0.01], 0.00	0.02 [-0.01, 0.04], 0.00	0.01 [-0.01, 0.04], 0.00
Within (fixed)	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [0.00, 0.00], 0.00
Within (random)	--	--	--	--
Vacation Status	-0.01 [-0.07, 0.06], 0.00	0.00 [-0.06, 0.06], 0.00	0.05 [-0.04, 0.15], 0.00	-0.09 [-0.18, 0.00], 0.00
Within Lagged Outcome (fixed)	0.16*** [0.12, 0.21], 0.01	0.15*** [0.10, 0.20], 0.01	0.17*** [0.12, 0.21], 0.01	0.21*** [0.16, 0.25], 0.02

Within Lagged Outcome (random)	0.03***	0.04***	0.03***	0.04***
Body Mass Index	0.00 [-0.02, 0.02], 0.00	0.00 [-0.01, 0.02], 0.00	0.00 [-0.03, 0.02], 0.00	0.01 [-0.01, 0.04], 0.00
Born in Australia	-0.07 [-0.23, 0.10], 0.00	-0.06 [-0.22, 0.09], 0.00	0.04 [-0.20, 0.28], 0.00	0.08 [-0.17, 0.33], 0.00
Female	0.14 [-0.01, 0.29], 0.01	0.06 [-0.08, 0.21], 0.00	-0.25* [-0.47, -0.03], 0.01	-0.26* [-0.49, -0.02], 0.01
Year Level	0.02 [-0.08, 0.12], 0.00	0.04 [-0.05, 0.14], 0.00	-0.10 [-0.25, 0.05], 0.00	-0.04 [-0.20, 0.11], 0.00
Non-White	-0.15 [-0.31, 0.02], 0.01	-0.13 [-0.29, 0.02], 0.01	-0.37** [-0.61, -0.13], 0.03	0.02 [-0.23, 0.27], 0.00
Working	0.11 [-0.04, 0.27], 0.01	0.11 [-0.04, 0.26], 0.01	-0.09 [-0.33, 0.14], 0.00	-0.31* [-0.55, -0.06], 0.02
Parental Marital Status	0.05 [-0.14, 0.24], 0.00	0.11 [-0.07, 0.29], 0.00	0.04 [-0.24, 0.32], 0.00	0.13 [-0.16, 0.43], 0.00
Study Day	0.00 [-0.01, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.01 [0.00, 0.01], 0.00	0.00 [-0.01, 0.01], 0.00
Day of Week (effect size)	0.00	0.00	0.00	0.00
Monday	0.01 [-0.05, 0.06]	0.00 [-0.06, 0.05]	-0.01 [-0.10, 0.07]	0.01 [-0.08, 0.09]
Tuesday	0.02 [-0.03, 0.08]	0.01 [-0.05, 0.06]	-0.04 [-0.12, 0.05]	0.00 [-0.08, 0.09]
Wednesday	0.03 [-0.03, 0.09]	0.02 [-0.04, 0.07]	-0.03 [-0.11, 0.06]	0.00 [-0.09, 0.08]
Friday	0.04 [-0.02, 0.10]	-0.01 [-0.07, 0.04]	-0.03 [-0.12, 0.06]	0.01 [-0.08, 0.10]
Saturday	-0.02 [-0.08, 0.04]	-0.01 [-0.07, 0.05]	-0.06 [-0.15, 0.03]	0.01 [-0.07, 0.10]
Sunday	0.03 [-0.03, 0.09]	0.02 [-0.04, 0.07]	-0.06 [-0.14, 0.03]	0.00 [-0.09, 0.08]
Self-reported TST (n=203, # of observations=3581)				
Between	-0.11* [-0.21, -0.02], 0.01	-0.09* [-0.19, 0.00], 0.01	0.12 [-0.02, 0.26], 0.00	0.04 [-0.11, 0.19], 0.00
Within (fixed)	0.00 [-0.02, 0.01], 0.00	0.00 [-0.01, 0.01], 0.00	0.01 [-0.01, 0.03], 0.00	0.01 [-0.01, 0.03], 0.00
Within (random)	0.01	--	0.01*	0.02**
Vacation Status	-0.02 [-0.08, 0.04], 0.00	-0.02 [-0.08, 0.04], 0.00	0.05 [-0.05, 0.14], 0.00	-0.08 [-0.17, 0.01], 0.00
Within Lagged Outcome (fixed)	0.16*** [0.12, 0.21], 0.01	0.15*** [0.10, 0.20], 0.01	0.17*** [0.13, 0.20], 0.01	0.20*** [0.15, 0.24], 0.01
Within Lagged Outcome (random)	0.04***	0.03***	--	0.05***
Body Mass Index	0.00 [-0.02, 0.02], 0.00	0.00 [-0.01, 0.02], 0.00	0.00 [-0.02, 0.03], 0.00	0.02 [-0.01, 0.04], 0.00
Born in Australia	-0.05 [-0.20, 0.11], 0.00	-0.03 [-0.18, 0.12], 0.00	0.04 [-0.18, 0.27], 0.00	0.09 [-0.15, 0.33], 0.00
Female	0.15* [0.01, 0.29], 0.01	0.08 [-0.06, 0.22], 0.00	-0.25* [-0.46, -0.04], 0.01	-0.22 [-0.44, 0.00], 0.01
Year Level	0.01 [-0.08, 0.10], 0.00	0.02 [-0.07, 0.11], 0.00	-0.10 [-0.24, 0.04], 0.01	-0.04 [-0.19, 0.11], 0.00
Non-White	-0.12 [-0.28, 0.04], 0.01	-0.13 [-0.28, 0.02], 0.01	-0.30* [-0.53, -0.06], 0.02	-0.01 [-0.25, 0.24], 0.00
Working	0.11 [-0.04, 0.27], 0.01	0.13 [-0.02, 0.28], 0.01	-0.11 [-0.34, 0.12], 0.00	-0.30* [-0.54, -0.06], 0.02
Parental Marital Status	0.06 [-0.12, 0.24], 0.00	0.08 [-0.09, 0.26], 0.00	0.07 [-0.19, 0.34], 0.00	0.12 [-0.16, 0.41], 0.00
Study Day	0.00 [-0.01, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [-0.01, 0.00], 0.00
Day of Week (effect size)	0.00	0.00	0.00	0.00
Monday	-0.01 [-0.06, 0.05]	-0.01 [-0.06, 0.05]	0.03 [-0.06, 0.11]	0.05 [-0.04, 0.13]

Tuesday	0.03 [-0.02, 0.09]	0.00 [-0.06, 0.05]	-0.03 [-0.11, 0.06]	0.01 [-0.07, 0.09]
Wednesday	0.04 [-0.01, 0.10]	0.01 [-0.04, 0.06]	-0.02 [-0.11, 0.06]	0.02 [-0.07, 0.10]
Friday	0.06* [0.00, 0.12]	-0.01 [-0.06, 0.05]	-0.03 [-0.12, 0.05]	0.00 [-0.09, 0.08]
Saturday	0.01 [-0.05, 0.06]	-0.01 [-0.07, 0.04]	-0.05 [-0.14, 0.03]	0.01 [-0.07, 0.10]
Sunday	0.04 [-0.01, 0.10]	0.02 [-0.03, 0.08]	-0.05 [-0.14, 0.03]	0.01 [-0.07, 0.09]
Self-reported SE (n=203, # of observations=3578)				
Between	-0.01* [-0.03, 0.00], 0.01	-0.01 [-0.02, 0.00], 0.01†	0.02 [-0.01, 0.04], 0.01	0.02 [0.00, 0.05], 0.01
Within (fixed)	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [0.00, 0.00], 0.00
Within (random)	--	--	--	--
Vacation Status	-0.02 [-0.08, 0.04], 0.00	-0.01 [-0.07, 0.04], 0.00	0.04 [-0.05, 0.13], 0.00	-0.09 [-0.18, 0.00], 0.00
Within Lagged Outcome (fixed)	0.16*** [0.12, 0.21], 0.01	0.14*** [0.09, 0.19], 0.01	0.16*** [0.12, 0.21], 0.01	0.20*** [0.16, 0.25], 0.02
Within Lagged Outcome (random)	0.04***	0.02***	0.03***	0.05***
Body Mass Index	0.00 [-0.01, 0.02], 0.00	0.00 [-0.01, 0.02], 0.00	0.00 [-0.02, 0.03], 0.00	0.02 [-0.01, 0.04], 0.01
Born in Australia	-0.03 [-0.17, 0.10], 0.00	-0.01 [-0.14, 0.12], 0.00	0.05 [-0.18, 0.28], 0.00	0.11 [-0.13, 0.35], 0.00
Female	0.09 [-0.04, 0.21], 0.01	0.01 [-0.11, 0.13], 0.00	-0.21* [-0.43, 0.00], 0.01	-0.19 [-0.42, 0.03], 0.01
Year Level	0.00 [-0.09, 0.08], 0.00	0.00 [-0.08, 0.08], 0.00	-0.09 [-0.23, 0.05], 0.01	-0.03 [-0.18, 0.12], 0.00
Non-White	-0.09 [-0.23, 0.05], 0.01	-0.08 [-0.21, 0.05], 0.00	-0.37** [-0.61, -0.14], 0.03	-0.04 [-0.29, 0.20], 0.00
Working	0.12 [-0.01, 0.25], 0.01	0.14* [0.01, 0.27], 0.01	-0.12 [-0.34, 0.11], 0.00	-0.29* [-0.53, -0.05], 0.02
Parental Marital Status	0.00 [-0.16, 0.16], 0.00	0.01 [-0.14, 0.17], 0.00	0.07 [-0.20, 0.34], 0.00	0.13 [-0.15, 0.42], 0.00
Study Day	0.00 [-0.01, 0.00], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [0.00, 0.01], 0.00	0.00 [-0.01, 0.00], 0.00
Day of Week (effect size)	0.00	0.00	0.00	0.00
Monday	0.00 [-0.05, 0.06]	0.00 [-0.05, 0.05]	0.03 [-0.05, 0.11]	0.04 [-0.04, 0.12]
Tuesday	0.04 [-0.02, 0.09]	0.00 [-0.06, 0.05]	-0.02 [-0.10, 0.06]	0.01 [-0.07, 0.09]
Wednesday	0.04 [-0.01, 0.10]	0.01 [-0.05, 0.06]	-0.01 [-0.09, 0.07]	0.02 [-0.06, 0.10]
Friday	0.06 [0.00, 0.11]	-0.01 [-0.06, 0.05]	-0.02 [-0.11, 0.06]	0.01 [-0.07, 0.09]
Saturday	0.00 [-0.05, 0.06]	-0.02 [-0.07, 0.03]	-0.04 [-0.13, 0.04]	0.02 [-0.07, 0.10]
Sunday	0.04 [-0.01, 0.10]	0.03 [-0.03, 0.08]	-0.05 [-0.13, 0.04]	0.01 [-0.07, 0.09]

Note. TST=Total Sleep Time (winsorized), SE=Sleep Efficiency (winsorized). The predictor for

all models is within-person centered sleep. Values presented are unstandardized coefficients,

[95% confidence intervals], and Cohen's f^2 . Random effects for within-level predictor and lagged

outcomes were included in all initial models, and dropped if models did not converge

(represented by --); Cohen's f^2 are presented for models with random effects for within-person

predictor. Values for sample sizes are the number of individual participants and number of observations for models with corresponding predictors. †represent models with extreme values removed: $n=201$ / # of observations=3546 (high arousal negative affect as outcome), and $n=200$ / # of observations=3532 (low arousal negative affect as outcome). The following covariates were included in all models: body mass index, born in Australia, sex, year level, race, work status, parental marital status, study day, and day of week. For day of week: A single Cohen's f^2 is presented for day of week, before individual unstandardized coefficients and [95% confidence intervals] for each day; Thursday was used as the reference level. $*p < .05$, $**p < .01$, $***p < .001$.

Table S2

Affect Predicting Same-Night Sleep Adjusted for Covariates

	Actigraphy-Assessed		Self-Reported	
	TST	SE	TST	SE
High Arousal NA				
Between	-0.09 [-0.26, 0.08], 0.00	-0.19 [-1.48, 1.09], 0.00	-0.21* [-0.41, -0.01], 0.01	-0.99 [-2.35, 0.38], 0.00
Within (fixed)	0.02 [-0.06, 0.10], 0.00	0.13 [-0.26, 0.53], 0.00	-0.01 [-0.10, 0.09], 0.00	0.07 [-0.43, 0.57], 0.00
Within (random)	--	--	0.01	--
Vacation Status	-0.75*** [-0.89, -0.61], 0.03	0.31 [-0.37, 0.99], 0.00	-0.81*** [-0.97, -0.65], 0.02	1.11* [0.22, 2.00], 0.00
Within Lagged Outcome (fixed)	-0.05* [-0.09, 0.00], 0.00	0.04 [0.00, 0.09], 0.00	-0.03 [-0.06, 0.01], 0.00	0.03 [-0.01, 0.07], 0.00
Within Lagged Outcome (random)	0.04***	0.04***	--	0.00
Body Mass Index	0.03** [0.01, 0.05], 0.01	0.16* [0.01, 0.31], 0.01	-0.01 [-0.04, 0.01], 0.00	-0.12 [-0.28, 0.04], 0.00
Born in Australia	0.00 [-0.19, 0.20], 0.03	-2.29** [-3.73, -0.85], 0.02	0.06 [-0.16, 0.28], 0.00	-0.87 [-2.38, 0.65], 0.00
Female	0.38*** [0.20, 0.56], 0.02	2.11** [0.78, 3.44], 0.02	0.12 [-0.09, 0.32], 0.00	-1.06 [-2.46, 0.34], 0.00
Year Level	-0.10 [-0.21, 0.02], 0.00	-0.98* [-1.86, -0.11], 0.01	-0.14* [-0.28, -0.01], 0.01	-1.03* [-1.95, -0.11], 0.01
Non-White	-0.30** [-0.50, -0.11], 0.01	-0.29 [-1.76, 1.18], 0.00	-0.18 [-0.41, 0.04], 0.00	0.96 [-0.59, 2.51], 0.00
Working	-0.10 [-0.29, 0.09], 0.00	0.36 [-1.05, 1.78], 0.00	-0.25* [-0.47, -0.03], 0.01	-0.67 [-2.17, 0.83], 0.00
Parental Marital Status	-0.04 [-0.26, 0.19], 0.00	0.67 [-1.02, 2.36], 0.00	-0.09 [-0.35, 0.17], 0.00	-1.04 [-2.81, 0.74], 0.00
Study Day	-0.02*** [-0.03, -0.01], 0.00	-0.05* [-0.09, 0.00], 0.00	-0.01** [-0.02, -0.01], 0.00	0.05 [-0.01, 0.10], 0.00
Day of Week (effect size)	0.03	0.00	0.02	0.00
Monday	0.06 [-0.07, 0.19]	-0.05 [-0.68, 0.59]	0.01 [-0.14, 0.16]	-0.67 [-1.51, 0.18]
Tuesday	0.09 [-0.04, 0.22]	0.24 [-0.40, 0.87]	0.07 [-0.09, 0.22]	0.17 [-0.68, 1.02]
Wednesday	0.20** [0.07, 0.33]	-0.30 [-0.93, 0.34]	0.16* [0.01, 0.31]	-0.24 [-1.09, 0.60]
Friday	0.51*** [0.37, 0.64]	0.53 [-0.14, 1.19]	0.44*** [0.28, 0.59]	-0.46 [-1.33, 0.41]
Saturday	0.39*** [0.25, 0.52]	-0.08 [-0.74, 0.58]	0.38*** [0.22, 0.53]	-0.32 [-1.19, 0.54]
Sunday	-0.07 [-0.20, 0.06]	-0.65 [-1.30, 0.00]	-0.11 [-0.26, 0.04]	-0.70 [-1.52, 0.11]
Low Arousal NA				
Between	-0.05 [-0.22, 0.13], 0.00	-0.02 [-1.32, 1.28], 0.00	-0.22* [-0.42, -0.02], 0.01	-1.15 [-2.52, 0.23], 0.00
Within (fixed)	0.03 [-0.05, 0.11], 0.00	0.11 [-0.28, 0.51], 0.00	-0.01 [-0.12, 0.10], 0.00	0.11 [-0.40, 0.62], 0.00
Within (random)	--	--	0.01**	--
Vacation Status	-0.75*** [-0.89, -0.61], 0.03	0.31 [-0.37, 0.99], 0.00	-0.80*** [-0.96, -0.64], 0.02	1.11* [0.22, 1.99], 0.00
Within Lagged Outcome (fixed)	-0.05* [-0.09, -0.01], 0.00	0.04 [0.00, 0.09], 0.00	-0.02 [-0.06, 0.02], 0.00	0.03 [-0.01, 0.07], 0.00

Within Lagged Outcome (random)	0.04***	0.04***	0.02***	0.02**
Body Mass Index	0.03** [0.01, 0.05], 0.01	0.16* [0.01, 0.31], 0.01	-0.01 [-0.03, 0.01], 0.00	-0.12 [-0.28, 0.05], 0.00
Born in Australia	0.01 [-0.18, 0.20], 0.00	-2.28** [-3.71, -0.84], 0.02	0.08 [-0.14, 0.30], 0.00	-0.86 [-2.37, 0.65], 0.00
Female	0.37*** [0.20, 0.55], 0.02	2.09** [0.77, 3.41], 0.02	0.10 [-0.10, 0.30], 0.00	-1.10 [-2.49, 0.29], 0.00
Year Level	-0.10 [-0.21, 0.02], 0.00	-0.99* [-1.87, -0.12], 0.01	-0.12 [-0.26, 0.01], 0.00	-1.01* [-1.94, -0.09], 0.01
Non-White	-0.30*** [-0.49, -0.10], 0.01	-0.27 [-1.74, 1.20], 0.00	-0.21 [-0.44, 0.01], 0.00	0.93 [-0.61, 2.48], 0.00
Working	-0.10 [-0.29, 0.09], 0.00	0.34 [-1.08, 1.76], 0.00	-0.22 [-0.44, 0.00], 0.01	-0.62 [-2.12, 0.89], 0.00
Parental Marital Status	-0.04 [-0.26, 0.19], 0.00	0.66 [-1.03, 2.36], 0.00	-0.04 [-0.30, 0.22], 0.00	-0.99 [-2.76, 0.78], 0.00
Study Day	-0.02*** [-0.03, -0.01], 0.00	-0.05* [-0.09, 0.00], 0.00	-0.01** [-0.02, -0.01], 0.00	0.05 [-0.01, 0.10], 0.00
Day of Week (effect size)	0.03	0.00	0.02	0.00
Monday	0.06 [-0.07, 0.19]	-0.05 [-0.68, 0.59]	0.01 [-0.14, 0.16]	-0.67 [-1.52, 0.18]
Tuesday	0.09 [-0.04, 0.21]	0.23 [-0.41, 0.87]	0.07 [-0.08, 0.22]	0.16 [-0.69, 1.01]
Wednesday	0.20** [0.07, 0.33]	-0.30 [-0.93, 0.34]	0.17* [0.02, 0.32]	-0.24 [-1.09, 0.60]
Friday	0.50*** [0.37, 0.64]	0.52 [-0.15, 1.19]	0.44*** [0.29, 0.60]	-0.46 [-1.34, 0.41]
Saturday	0.39*** [0.25, 0.52]	-0.08 [-0.74, 0.58]	0.37*** [0.22, 0.52]	-0.32 [-1.18, 0.55]
Sunday	-0.07 [-0.20, 0.06]	-0.65* [-1.30, 0.00]	-0.12 [-0.26, 0.03]	-0.71 [-1.52, 0.11]
High Arousal PA				
Between	0.14* [0.02, 0.25], 0.01	0.47 [-0.40, 1.35], 0.00	0.15* [0.02, 0.29], 0.01	0.66 [-0.27, 1.58], 0.00
Within (fixed)	-0.06* [-0.12, 0.00], 0.00	-0.14 [-0.43, 0.15], 0.00	-0.03 [-0.10, 0.03], 0.00	-0.06 [-0.47, 0.35], 0.00
Within (random)	0.01*	0.01	0.01**	0.02**
Vacation Status	-0.75*** [-0.88, -0.61], 0.03	0.40 [-0.29, 1.09], 0.00	-0.79*** [-0.95, -0.63], 0.02	1.08* [0.19, 1.97], 0.00
Within Lagged Outcome (fixed)	-0.05* [-0.09, -0.01], 0.00	0.07*** [0.03, 0.10], 0.00	-0.02 [-0.06, 0.02], 0.00	0.03* [0.00, 0.07], 0.00
Within Lagged Outcome (random)	0.04***	--	0.02***	--
Body Mass Index	0.03** [0.01, 0.05], 0.01	0.16* [0.01, 0.31], 0.01	-0.01 [-0.03, 0.01], 0.00	-0.13 [-0.29, 0.04], 0.00
Born in Australia	0.02 [-0.17, 0.21], 0.00	-2.10** [-3.54, -0.66], 0.02	0.08 [-0.14, 0.30], 0.00	-0.79 [-2.31, 0.73], 0.00
Female	0.41*** [0.23, 0.58], 0.03	2.23** [0.89, 3.57], 0.03	0.12 [-0.09, 0.32], 0.00	-0.94 [-2.35, 0.48], 0.00
Year Level	-0.09 [-0.20, 0.03], 0.00	-0.88 [-1.76, 0.00], 0.01	-0.11 [-0.25, 0.02], 0.00	-0.93 [-1.86, 0.00], 0.01
Non-White	-0.23* [-0.42, -0.03], 0.01	0.00 [-1.51, 1.50], 0.00	-0.13 [-0.36, 0.10], 0.00	1.35 [-0.23, 2.93], 0.01
Working	-0.10 [-0.28, 0.09], 0.00	0.49 [-0.92, 1.90], 0.00	-0.25* [-0.47, -0.03], 0.01	-0.60 [-2.11, 0.90], 0.00
Parental Marital Status	-0.06 [-0.28, 0.16], 0.00	0.54 [-1.16, 2.24], 0.00	-0.09 [-0.35, 0.17], 0.00	-1.00 [-2.78, 0.79], 0.00
Study Day	-0.02*** [-0.03, -0.01], 0.00	-0.04 [-0.08, 0.00], 0.00	-0.01** [-0.02, -0.01], 0.00	0.04 [-0.01, 0.09], 0.00
Day of Week (effect size)	0.03	0.00	0.02	0.00
Monday	0.06 [-0.07, 0.19]	0.01 [-0.63, 0.65]	0.00 [-0.14, 0.15]	-0.66 [-1.51, 0.18]

Tuesday	0.09 [-0.04, 0.22]	0.21 [-0.43, 0.86]	0.07 [-0.08, 0.22]	0.17 [-0.68, 1.02]
Wednesday	0.20** [0.07, 0.33]	-0.31 [-0.95, 0.33]	0.16* [0.01, 0.31]	-0.23 [-1.07, 0.62]
Friday	0.50*** [0.37, 0.64]	0.49 [-0.19, 1.16]	0.43*** [0.28, 0.59]	-0.47 [-1.34, 0.40]
Saturday	0.39*** [0.26, 0.52]	-0.19 [-0.85, 0.48]	0.36*** [0.21, 0.52]	-0.33 [-1.19, 0.53]
Sunday	-0.07 [-0.20, 0.07]	-0.74* [-1.40, -0.09]	-0.12 [-0.27, 0.02]	-0.71 [-1.53, 0.10]
Low Arousal PA				
Between	0.07 [-0.04, 0.18], 0.00	0.26 [-0.57, 1.10], 0.00	0.09 [-0.04, 0.21], 0.00	0.77 [-0.11, 1.65], 0.00
Within (fixed)	0.02 [-0.04, 0.07], 0.00	-0.19 [-0.45, 0.06], 0.00	0.05 [-0.02, 0.11], 0.00	-0.13 [-0.50, 0.23], 0.00
Within (random)	0.00	--	0.01	0.01
Vacation Status	-0.75*** [-0.88, -0.61], 0.02	0.29 [-0.40, 0.97], 0.00	-0.79*** [-0.95, -0.63], 0.02	1.07* [0.18, 1.97], 0.00
Within Lagged Outcome (fixed)	-0.05* [-0.10, -0.01], 0.00	0.04 [0.00, 0.09], 0.00	-0.02 [-0.06, 0.02], 0.00	0.03* [0.00, 0.07], 0.00
Within Lagged Outcome (random)	0.04***	0.04***	0.02***	--
Body Mass Index	0.03** [0.01, 0.05], 0.01	0.16* [0.01, 0.31], 0.01	-0.01 [-0.04, 0.01], 0.00	-0.14 [-0.30, 0.03], 0.00
Born in Australia	0.01 [-0.18, 0.20], 0.00	-2.28** [-3.72, -0.85], 0.02	0.06 [-0.16, 0.28], 0.00	-0.86 [-2.38, 0.66], 0.00
Female	0.38*** [0.20, 0.56], 0.02	2.16** [0.83, 3.49], 0.02	0.09 [-0.11, 0.30], 0.00	-0.93 [-2.34, 0.48], 0.00
Year Level	-0.09 [-0.21, 0.02], 0.00	-0.97* [-1.84, -0.10], 0.01	-0.12 [-0.25, 0.01], 0.00	-0.97* [-1.90, -0.04], 0.01
Non-White	-0.29** [-0.48, -0.10], 0.01	-0.27 [-1.72, 1.19], 0.00	-0.19 [-0.42, 0.03], 0.00	1.10 [-0.45, 2.64], 0.00
Working	-0.10 [-0.29, 0.09], 0.00	0.42 [-1.00, 1.85], 0.00	-0.25* [-0.47, -0.03], 0.01	-0.45 [-1.97, 1.07], 0.00
Parental Marital Status	-0.05 [-0.28, 0.17], 0.00	0.61 [-1.09, 2.30], 0.00	-0.09 [-0.35, 0.17], 0.00	-1.06 [-2.84, 0.73], 0.00
Study Day	-0.02*** [-0.03, -0.01], 0.00	-0.05* [-0.09, 0.00], 0.00	-0.01** [-0.02, 0.00], 0.00	0.04 [-0.01, 0.09], 0.00
Day of Week (effect size)	0.03	0.00	0.02	0.00
Monday	0.06 [-0.07, 0.19]	-0.04 [-0.68, 0.59]	0.01 [-0.14, 0.16]	-0.65 [-1.50, 0.20]
Tuesday	0.09 [-0.04, 0.22]	0.24 [-0.40, 0.87]	0.07 [-0.08, 0.23]	0.16 [-0.69, 1.02]
Wednesday	0.20** [0.07, 0.33]	-0.29 [-0.93, 0.34]	0.17* [0.02, 0.32]	-0.25 [-1.10, 0.60]
Friday	0.51*** [0.37, 0.64]	0.52 [-0.14, 1.19]	0.44*** [0.29, 0.60]	-0.46 [-1.33, 0.42]
Saturday	0.39*** [0.26, 0.52]	-0.08 [-0.74, 0.58]	0.37*** [0.22, 0.53]	-0.33 [-1.19, 0.54]
Sunday	-0.07 [-0.20, 0.07]	-0.65* [-1.30, 0.00]	-0.12 [-0.26, 0.03]	-0.70 [-1.52, 0.12]
Number of Individuals and Observations in Each Model				
<i>n</i> , # of observations	193, 3621	193, 3621	204, 3999	204, 3992

Note. TST=Total Sleep Time (winsorized), SE=Sleep Efficiency (winsorized), NA=Negative

Affect, PA=Positive Affect. The predictor for all models is within-person centered evening

affect. Values presented are unstandardized coefficients, [95% confidence intervals], and

Cohen's f^2 . Random effects for within-level predictor and lagged outcomes were included in all

initial models, and dropped if models did not converge (represented by --); Cohen's f^2 are presented for models with random effects for within-person predictor. Values for sample sizes are the number of individual participants and number of observations for models with corresponding outcomes. The following covariates were included in all models: body mass index, born in Australia, sex, year level, race, work status, parental marital status, study day, and day of week. For day of week: A single Cohen's f^2 is presented for day of week, before individual unstandardized coefficients and [95% confidence intervals] for each day; Thursday was used as the reference level. $*p < .05$, $**p < .01$, $***p < .001$.