Vulnerability to sleep-related affective disturbances? A closer look at dysfunctional beliefs and attitudes about sleep as a moderator of daily sleep-affect associations in young people

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Abstract

Study objectives: Sleep and affect are closely related. Whether modifiable cognitive factors moderate this association is unclear. This study examined whether Dysfunctional Beliefs and Attitudes about Sleep moderate the impact of sleep on next-day affect in young people.

Methods: Four hundred and sixty-eight young people (205 adolescents, 54.1% female, M ± SDage = 16.92 ± 0.87; 263 emerging adults, 71.9% female, M ± SDage = 21.29 ± 1.73) self-reported sleep and affect, and wore an actigraph for 7-28 days, providing >5000 daily observations. Linear mixed-effects models tested whether Dysfunctional Beliefs and Attitudes about Sleep moderated daily associations between self-reported and actigraphic sleep duration, sleep efficiency, and next-day affect on between- and within-person levels. Both valence (positive/negative) and arousal (high/low) dimensions of affect were examined. Covariates included age, sex, race/ethnicity, day of week, and previous-day affect.

Results: Dysfunctional Beliefs and Attitudes about Sleep significantly moderated sleep and high arousal positive affect associations on between- but not within-person levels. Individuals with higher Dysfunctional Beliefs and Attitudes about Sleep (+1 SD) and lower average sleep duration (actigraphic: p = .020; self-reported: p = .047) and efficiency (actigraphic: p = .047) had significantly lower levels of high arousal positive affect. After adjusting for multiple comparisons, Dysfunctional Beliefs and Attitudes about Sleep did not moderate relationships between sleep duration and low arousal positive affect (p ≥ .340).

Conclusions: Young people with more unhelpful beliefs about sleep and shorter, or poorer, sleep may experience dampened levels of high arousal positive affect. DBAS may constitute a modifiable factor increasing affective vulnerability on a global but not day-to-day level. Intervention studies are needed to determine if changing Dysfunctional Beliefs and Attitudes about Sleep may reduce sleep-related affect disturbances in young people.

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Introduction

Biopsychosocial changes such as delays in circadian phase and reduced homeostatic sleep drive, and early school/work schedules, contribute to irregular and restricted sleep duration that may increase risk of psychological distress in young people (adolescents and emerging adults). As a result, compared to recommended sleep duration (7-9 hours for emerging adults; 9-10 hours for adolescents), young people often receive less sleep duration. Neurodevelopmental changes in the limbic system and prefrontal cortex during adolescence and emerging adulthood may also contribute to increased emotional reactivity, arousal levels, and higher vulnerability for psychological disorders. Therefore, adolescents and emerging adults are vulnerable populations where it is important to explore sleep-related factors that may contribute to affective disturbances. In this manuscript, we will refer to the 10-25 age group as “young people,” since adolescence can be broadly defined as the age range of 10-19 years, which overlaps and continues into emerging adulthood (18-25 years).

Affect can be conceptualized within two dimensions that appear to be supported by separate neurophysiological processes, with distinct
impact on functioning: (a) valence, polarity of affective content (eg, desirable/positive vs. aversive/negative), and (b) arousal, degree of physiological intensity (eg, high/low) of an emotional state. In relation to emotion regulation, low arousal positive affect (eg, calm, content) appears to perform a contentment/soothing role while high arousal positive affect (eg, happy, excited) performs a drive/achievement role. In terms of valence, low positive affect and high negative affect constitute distinct transdiagnostic risk factors that increase psychological vulnerability to psychological disorders (eg, anxiety and depression) across the lifespan. Affective arousal also seems to contribute differently to different affective psychopathologies. For example, while high arousal negative affect is often inherent in anxiety disorders, low arousal negative affect may be more prominent in social anxiety.

The association between sleep and affective outcomes is well-established. For instance, a recent meta-analysis of studies in adolescents showed that shorter sleep is associated with increased risk for affective disturbances (eg, symptoms of depression, anxiety), lower levels of positive affect (eg, feeling less happy), and higher levels of negative affect (eg, feeling more sad). Experimental research in adolescents and adults showed an increase in negative affect and reduction in positive affect during sleep restriction (4-6.5 hours time in bed: 1 day to 1 week). These effects were reversed once ideal sleep conditions (eg, 9.5 hours time in bed) were reinstated, suggesting potential causal impact of sleep on affect. Ecological measurement assessment studies examining the impact of poorer quality and shorter sleep duration on next-day affect are rare. A 6-week prospective study in adolescents showed that poorer previous-day self-reported sleep quality predicted next-day negative affect, but negative affect had a smaller impact on sleep quality the same night. Similar studies in adolescents have linked poorer daily sleep quality with higher negative affect, and shorter sleep duration with lower positive affect. Further, the relationship between affect and sleep also appears to differ depending on affective arousal levels. For example, adolescents reported shorter sleep onset latency on days that they experienced higher levels of low arousal positive affect (on average), compared to days where they experienced elevated high arousal positive affect.

Emerging studies have tested daily sleep-affect associations, but it remains unclear what factors may moderate these associations. One potential moderating factor is Dysfunctional Beliefs and Attitudes about Sleep (DBAS), a cognitive vulnerability modifiable via psychological interventions such as cognitive behavioral therapy for insomnia. DBAS refers to the extent that a person endorses unrealistic beliefs, expectations, and worrying related to sleep, and is an established predictor of sleep-related difficulties in individuals with, and without, insomnia. Cross-sectionally, unhelpful thoughts and beliefs about sleep moderated the relationship between self-reported sleep quality and negative mood such that in people with more unhelpful thoughts and beliefs about sleep, poorer sleep quality shared stronger associations with negative mood. Thus, it is possible that on a day-to-day basis, individuals with higher DBAS may experience greater negative affect following a night of poorer or shorter sleep. For example, an individual holding the belief that “I cannot function without 8 hours of sleep” may experience greater distress after a night of short sleep, compared to those who do not endorse this belief. Understanding modifiable moderators such as DBAS in daily sleep-affect associations could help inform early interventions for young people at elevated risk for sleep disturbances and psychological distress. Finally, self-reported (eg, via sleep diary) and actigraphy-measured sleep outcomes may show different associations with mood and affect. Thus, we explored both self-reported and actigraphy-assessed sleep as predictors in this study.

The current study aimed to examine the role of DBAS in the prospective day-to-day associations between sleep duration (operationalised as total sleep time [TST]) and quality (operationalised as sleep efficiency [SE]) with affect in a community sample of young people on between- and within-person levels. Affect was examined across different valence (positive and negative) and arousal (high and low) dimensions. We hypothesized that after adjusting for covariates (previous-day affect, age, gender, race/ethnicity, differences between collated study datasets, and day of the week):

1. More unhelpful beliefs about sleep (ie, higher DBAS) will predict higher negative affect (low and high arousal), and lower positive affect (low and high arousal).
2. More unhelpful beliefs about sleep will moderate associations between sleep and next-day affect. Specifically, we expect a stronger relationship between poorer sleep (duration and efficiency) and worse next-day affect at higher levels of unhelpful beliefs about sleep.

Methods

Participants

We analyzed data from 468 participants collated from three projects approved by the Monash University Human Research Ethics Committee: (a) the Study of Teenage Emotions, Performance, and Sleep (STEPS); (b) Activity, Coping, Emotions, Stress & Sleep (ACES); and (c) Diet, Exercise, Stress, Emotions, Speech, and Sleep study (DESTRESS). All participants, and one guardian of adolescents (under 18 years old) where applicable, provided informed consent including permission for data to be utilized in future studies. All projects recruited from the general community, and required participants to have access to a smartphone with Internet connection and ability to read and write in English. STEPS required no planned travel across time zones during the study data collection period. Both ACES and DESTRESS excluded participants with self-reported major physical or mental health conditions that significantly affect daily physical activity and sleep. Although STEPS did not have specific exclusion on physical and or mental health conditions, all participants were required to be attending school. STEPS recruited adolescents (n = 205) attending Year 10-12, and data collection was conducted between December 2017 and July 2019. For each participant, STEPS collected daily data over 4 continuous weeks (the final 2 weeks of a school term, and the subsequent 2-week vacation). Detailed procedures from STEPS have been previously described. ACES (included n = 163) and DESTRESS (included n = 100) recruited emerging adults between 18 and 25 years old and collected daily observations over 12 and 7 days, respectively. Data collection for the ACES project was conducted between April and December 2017, and for DESTRESS between May and August 2018. Detailed procedures for ACES and DESTRESS have been previously described.

Design and procedures

Reporting follows the STROBE guidelines for observational studies. The three included studies utilized a prospective ecological momentary assessment design. Participants attended an induction session to collect study equipment and completed the DBAS and demographic questionnaires online during the first (or/and second for STEPS) week of the study. Sleep data were collected via wrist-worn actigraphy, and sleep and affect were also self-reported via a smartphone application (MetricWire). In STEPS, the self-reported sleep survey was available between 07:00 and 14:30 and the affect survey between 15:30 and 19:00. In ACES/DESTRESS, self-reported sleep was measured between 11:00 and 15:00, and affect was measured three times daily at 11:00-15:00 (morning), 15:30-19:30 (afternoon), and 20:00-02:00 (evening). Only the afternoon survey was utilized in our analyses. All participants were reimbursed for their time.
Dysfunctional Beliefs and Attitudes about Sleep scale (DBAS-16)

Sleep Diary.

Measures

Self-reported sleep

Daily self-reported sleep was measured using the Consensus Sleep Diary. TST and SE (percentage of total sleep duration divided by time in bed; with time in bed being the difference between self-reported bedtime and risetime) were derived.

Actigraphy sleep

Sleep was estimated from wrist actigraphy devices. STEPS utilized several models of Mini Mitter actiwatches (Actiwatch Spectrum Pro, Spectrum Plus, Actiwatch-2, Actiwatch-64, and Actiwatch-L; Mini Mitter, Respiroscopes, Bend, OR) with comparable estimates of sleep parameters. Actigraphy was scored using combined information from sleep diary, ambient light (when available), and activity patterns scored with 1-minute epochs and “medium” threshold for sleep-wake detection in Actiware (v. 5.5). ACES and DESTRESS utilized the ActiGraph’s wGT3X-BT and used the ActilLife software (v.6.13.3) with the Cole-Kripke algorithm to score sleep parameters. A recent study in adults showed that Actiwatch models set on “medium” threshold (used in STEPS) provided comparable TST (Actiwatch: 444.6 ± 53.7 minutes; Actigraph: 449.7 ± 39.5) and SE (Actiwatch: 92.4%, ± 2.1%; Actigraph: 91.6%, ± 2.5%) estimates with ActiGraph models (used in DESTRESS/ACES) with Actigraph scored using the Cole-Kripke algorithm.

Dysfunctional Beliefs and Attitudes about Sleep scale-16 (DBAS-16)

The DBAS-16 is a 16-item scale that examines self-reported cognitions about sleep across four domains: perceived consequences of insomnia (eg, “Without an adequate night’s sleep, I can hardly function the next-day”), worry/helplessness about sleep (eg, “I am worried that I may lose control over my abilities to sleep”), sleep expectations (eg, “I must get 9 hours of sleep to feel refreshed and function well the next-day”), and medications (eg, “Medication is probably the only solution to sleeplessness”). The DBAS-16 is a validated scale with good psychometric properties in young people. Items were scored on a 0 (“Strongly Disagree”) to 10 (“Strongly Agree”) scale, and then averaged with higher scores suggesting more negative beliefs and higher concerns about sleep. In the STEPS project item 1 (“I need 8 hours of sleep to feel refreshed and function well during the day”) was adapted to “…9 hours of sleep…” to comply with recommendations around optimal amount of sleep for adolescents. Internal consistency for DBAS was within the acceptable to high range for ACES (0.87), DESTRESS (0.85), and STEPS (0.82), respectively.

Positive and Negative Affect Schedule (PANAS)

Daily affect was assessed using 12 items selected from the 60-item PANAS-X. As the original PANAS lacks low arousal positive affect items, items were chosen via factor analysis based on low cross-loadings with other descriptors. Participants rated how much they experienced affective descriptions on a 5-point Likert scale ranging from “Very Slightly or Not at All” (1) to “Extremely” (5). Four separate affect domains (3 items averaged for each variable) were derived: (a) low arousal negative affect (“guilty,” “lonely,” “sad”), (b) high arousal negative affect (“afraid,” “irritable,” “nervous”), (c) low arousal positive affect (“at ease,” “calm,” “relaxed”); and (d) high arousal positive affect (“cheerful,” “enthusiastic,” “happy”). Omega coefficients were calculated to examine internal consistency at the between- and within-person levels for each affect domain. Negative affect showed adequate to high between, but not within, reliability estimates at high (ωwithin = 0.56, ωbetween = 0.86) and low (ωwithin = 0.56, ωbetween = 0.86) arousal intensity levels. In contrast, positive affect showed excellent within- and between-person reliability at both high (ωwithin = 0.80, ωbetween = 0.97) and low (ωwithin = 0.81, ωbetween = 0.98) arousal intensity.

Covariates

Age (years), biological sex assigned at birth (male, female), race/ethnicity (Caucasian/White European, Asian, Other), day of week (Monday-Sunday), differences across collated project datasets (ACES, DESTRESS, STEPS), and previous-day affect.

Statistical analysis

Data were analyzed using R (v. 4.1.3), with α = 0.050. A total of 16 multilevel linear mixed-effects models (LMMs) were constructed using the lme4 (v. 1.1-29) and lmerTest (v. 3.1-3) packages, and the restricted maximum likelihood (REML) approach. In each model, one of the four previous-day sleep predictors (actigraphy-assessed TST, actigraphy-assessed SE; self-reported TST, self-reported SE) were tested as a predictor of each of the four next-day affect outcomes. DBAS was specified as a moderator across all LMMs.

Sleep variables were decomposed into between- and within-person level predictors to examine whether associations with next-day affect were driven by differences between individuals (eg, generally long vs. short sleepers), or by the deviations of the previous night’s sleep from each participant’s own average (ie, do nights with shorter-than-average TST, relative to one’s own mean, predict higher levels of low arousal negative affect the next-day). Within-level variables were winsorized at the top and bottom 0.5%. All models controlled for age, sex, race/ethnicity, project (ie, categorical variable “ACES,” “DESTRESS,” or “STEPS”), and day of the week based on prior literature.

Visual inspection of model diagnostics indicated that assumptions for analyses were met. All available data were utilized, with the number of daily observations varying across models due to missing data. Missing data were handled via pairwise deletion. Percentage of missingness ranged between 0% and 27% across variables. A table outlining the mean and standard deviation of data present across variables is given in the Supplementary Material (Table A.2). We also explored missingness patterns across planned covariates included in analyses and observed more missing survey data for male, non-Caucasian/White European individuals, on Wednesdays/Thursdays; and a higher proportion of missing actigraphic sleep data in DESTRESS participants. In relation to DESTRESS, this is likely due to the optional actigraphy component for this study that also required individuals to attend Monash University for equipment pickup and familiarization.

Sensitivity analyses were conducted for multivariate outliers, identified as those outside the range of 99.9% of data points (0.01% level), across models. Results below are reported with outliers excluded if the coefficients of main predictors (sleep parameters, DBAS) and interactions did not change more than 10% after removing multivariate outliers. Data from school and vacation periods in STEPS were included, as our sensitivity analyses showed that daily associations between sleep and affect during these two periods were not significantly different. Finally, in relation to adequate power (of at least 0.80), our study complies with literature recommendations of a minimum sample size of 30-50 individuals for multilevel models.
Table 1 summarises characteristics of participants (n = 468) across study variables. Participants were on average 19.37 (SD = 2.59) years old, 64.1% were female, and over half were of Asian (57.1%) descent. In STEPS, a small proportion of the sample self-reported current depressive (4.39%), anxiety (5.85%) or sleep (11.2%) disorders; in a previous study, sensitivity analyses excluding these participants did not lead to meaningful changes in the associations between sleep and mood outcomes thus they were not excluded. ACES and DESTRESS excluded participants with severe physical and mental health conditions but did not further assess milder comorbid conditions. In the total sample, average TST was 7:48 and 7:03 hours, and average SE was 83.9%, and 85% based on self-reported and actigraphy data respectively, with large individual differences.

Main results of models are given in Tables 2a and 2b. Adjusted statistical significance values for multiple comparisons are denoted with the symbol *. 

Main and moderating effects of DBAS on affect

Negative affect
Overall, DBAS showed weak associations with negative affect. After adjusting for multiple comparisons, the main and moderating effects of DBAS on negative affect (high or low arousal) were not statistically significant (adjusted p-values > .360).

Positive affect
After adjusting for multiple comparisons, main effects of DBAS on low arousal positive affect were not statistically significant (adjusted p-values > .340). Higher DBAS was associated with lower levels of high arousal positive affect in models involving self-reported (p = .047), and actigraphy (p = .020) TST, as well as actigraphy SE (p = .047). In these same three models, the interaction between DBAS and between-person level sleep variables was also significant (adjusted p-values ranged from .020 to .047). The interactions between DBAS and within-person level sleep variables were all nonsignificant (adjusted p-values > .133). After adjusting for multiple comparisons, we observed no statistically significant moderating effects of DBAS on sleep and low arousal positive affect associations (adjusted p-values > .340).

Fig. 1 shows the associations of between-person sleep variables and positive affect for when DBAS scores were high (1 SD above the mean) and low (1 SD below the mean). Three models showed consistent interaction patterns: higher DBAS was associated with stronger associations between sleep and high arousal positive affect. Specifically, for individuals with lower DBAS scores, no significant associations emerged between any sleep variables and positive affect (p ≥ .308). For individuals with higher DBAS, longer self-reported (p = .019) and actigraphy (p = .009) TST and higher actigraphy SE (p = .012) were associated with significantly higher levels of high arousal positive affect.

Main effects of sleep variables and covariates on affect
After adjusting for multiple comparisons, there were no significant main effects of sleep variables on negative (high and low arousal) (p-values ≥ .575) nor positive (high and low arousal) (p-values ≥ .060) affect. Previous-day affect was a significant predictor of next-day affect above and beyond other predictors across all models (all p-values < .001). The effects of age, gender, race/ethnicity, project differences, and day of the week are summarized in Table A1 in the Supplement.

Discussion
In a large community sample of young people, unhelpful thoughts and beliefs about sleep moderated the associations between sleep and high arousal positive affect at the between-person (ie, overall levels), but not at the within-person (ie, daily fluctuations predicting next-day outcome) level. Individuals with high DBAS may not experience the acute impact of sleep on their affective experiences the following day, but rather, stronger unhelpful beliefs about sleep may confer a cognitive vulnerability for affective disturbances in young people with generally short or poor sleep.

In the context of moderation, we did not find main effects of DBAS, except within the high arousal positive affect models, after adjusting for multiple comparisons. Consequently, the first hypothesis was only partially supported. Instead, we found significant between-person level interactions between sleep and DBAS with high arousal positive affect. Contrary to our second hypothesis that higher DBAS will strengthen associations between poorer sleep and worse next-day affect, we found that higher DBAS strengthens associations between better sleep and average levels of high arousal positive affect. It is worth noting that the effect sizes are relatively small. For example, in the context of short self-reported sleep of 6 hours, those
with higher (1 standard deviation above average) DBAS reported around "Moderately" high arousal positive affect, compared to "Quite a bit" in those with lower (1 standard deviation below average) DBAS. While the majority of past literature focused on negative emotions and consequences (including negative affect), our findings highlight the importance of examining high arousal positive affect when investigating sleep-affect associations and considering the role of sleep as an affective buffer. This may be particularly important as low levels of high arousal positive affect (eg, happiness) is a core aspect of low mood and depression (anhedonia).\textsuperscript{13} In this sample, we found that individuals with higher DBAS and disrupted sleep were more likely to experience significantly dampened levels of high arousal positive affect. A possible explanation for this finding is that sleep restriction and high levels of DBAS may have a combined effect on the capacity of individuals to attend to positive events. On one hand, shorter sleep dampens positive affect\textsuperscript{47,48} but also reduces the amount of attention allocated to subsequently presented positive events.\textsuperscript{47} On the other hand, individuals endorsing higher levels of unhelpful beliefs about sleep may catastrophize about, and be preoccupied with, negative events such as the impact of sleep loss on daytime functioning.\textsuperscript{49} As a result, individuals with more unhelpful beliefs about sleep may utilize more maladaptive coping strategies (eg, a negative automatic bias to perceived sleep-related threats and cognitions)\textsuperscript{50} during poorer sleep periods that may in turn diminish, or reduce attention to, positive affective experiences.

Contrary to expectations, we also did not find significant main effects or interactions between DBAS and sleep on negative affect. The limited role DBAS played in the relationship between sleep and negative affect was somewhat surprising as both DBAS and impaired sleep are implicated in elevated negative affect in past research with young people.\textsuperscript{48,50} Our finding may be due to our sample’s low levels of negative affect. The average high and low arousal negative affect fell within the “Very slightly or not at all” to “A little” range respectively, possibly leading to a floor effect. It may also be that higher DBAS constitutes a sleep-related vulnerability in individuals with higher negative affect, such as those with symptoms of depression and anxiety. This hypothesis, however, need to be tested in future research.

Finally, the role of DBAS in moderating sleep and affect relationships varied depending on how sleep (actigraphy vs. diaries) and affect (high vs. low arousal/valence) were measured. For example, we found that most assessed sleep parameters, except self-reported SE, showed interactions with DBAS on high arousal positive affect. These findings are consistent with previous studies showing that compared to actigraphic sleep, self-reported sleep tends to show stronger associations with mood and affect in adolescent and adult samples.\textsuperscript{25,51} The time of day when affect was measured may explain differences in affective arousal findings, as low arousal positive affect (eg, relaxation) may be stronger in the morning and high arousal positive affect (eg, pride and happiness) in the evening.\textsuperscript{52} However, the exact reasons for the observed heterogeneity between
actigraphy and self-reported assessed sleep interactions with DBAS across arousal dimensions require further research.

Strengths and limitations

Several methodological strengths allowed detailed examination of our research questions: (a) the inclusion of both high and low arousal dimensions of affect is uncommon in the field, and important as each dimension appears to independently contribute to psychopathology; (b) a naturalistic design with daily sleep monitoring over multiple weeks, with a large sample size; (c) a focus on young people as a developmentally critical period for sleep and affect; (d) the examination of both between- and within-person effects; (e) the inclusion of both self-reported (diary) and actigraphy-assessed sleep provides granularity to our results and allowed us to explore associations between different aspects of sleep (self-reported sleep perceptions vs. inferred sleep/wake timing via activity patterns) and affect; and (f) controlling for previous-day affect, which may not be accounted for by previous ecological momentary assessment studies, strengthens conclusions regarding causality of the impact of sleep on next-day affect and directionality of findings.

Our findings need to be interpreted with the following limitations in mind. First, the coefficient omega reliability of both negative affect subscales on the within-person level was within the adequate range but low. Second, while the actigraphy devices used across projects are comparable, it is possible that device-specific variations in measurement of sleep-wake patterns were present. Thirdly, in adults, associations between previous-day sleep with next-day affect may vary depending on time of day when affect was measured. In this paper, affect was only measured in the afternoon and findings may not generalize to other times of day. Fourthly, we tested an a priori hypothesis where sleep was the predictor, DBAS moderator, and affect the outcome; other plausible model configurations (eg, DBAS as the outcome, or the mediator) were not tested. Also, we did not examine other aspects of sleep, such as the timing and intraindividual variability of sleep; for example, more variable sleep has been associated with higher DBAS scores in adults with insomnia. Finally, participants in the samples were relatively healthy young individuals, and findings may differ in populations with current sleep and/or mental health conditions, such as individuals with insomnia (who may report higher levels of DBAS).

Implications

This study showed how sleep-specific cognitive vulnerabilities and daily sleep interacted to impact positive and negative affect. Young people with more unhelpful beliefs about sleep reported lower levels of high arousal positive affect when experiencing shorter, or poorer, sleep. This vulnerability was evident on between-person levels, but not on a day-to-day basis.

Young people who often report sleep-related and affective difficulties, may be particularly vulnerable to negative consequences of poor and short sleep on affect. Changing unhelpful thoughts and beliefs about sleep, a modifiable factor, may help to protect young

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Table A1

DBAS, Dysfunctional Beliefs and Attitudes about Sleep; N, number of individuals; SE, Sleep Efficiency; TST, total sleep duration

Table 2b

Effects of sleep and DBAS on next-day positive affect

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Self-reported TST</th>
<th>Actigraphy TST</th>
<th>Self-reported SE</th>
<th>Actigraphy SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>High arousal positive affect as outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep (Between)*</td>
<td>-0.18, -0.22, [-0.46, 0.02]</td>
<td>-0.24, -0.29, [-0.53, -0.04]</td>
<td>0.10, 0.01, [0.01, 0.03]</td>
<td>0.20, -0.04, [-0.08, 0.01]</td>
</tr>
<tr>
<td>Sleep (Within)</td>
<td>0.03, [-0.01, 0.07]</td>
<td>0.05, [0.00, 0.09]</td>
<td>0.00, [-0.01, 0.01]</td>
<td>0.01, [-0.02, 0.00]</td>
</tr>
<tr>
<td>DBAS*</td>
<td>-0.06, -0.56, [-0.98, -0.15]</td>
<td>-0.95, -0.62, [-1.00, -0.24]</td>
<td>0.05, 0.04, [0.32, 0.39]</td>
<td>1.50, -0.99, [-1.76, -0.21]</td>
</tr>
<tr>
<td>Sleep (Between) × DBAS*</td>
<td>0.08, 0.06, [0.01, 0.12]</td>
<td>0.10, 0.06, [0.03, 0.13]</td>
<td>0.01, 0.00, [-0.00, 0.00]</td>
<td>0.10, 0.01, [0.00, 0.02]</td>
</tr>
<tr>
<td>Sleep (Within) × DBAS*</td>
<td>0.00, [-0.01, 0.01]</td>
<td>-0.01, [-0.02, 0.00]</td>
<td>0.00, [-0.00, 0.00]</td>
<td>0.00, [-0.00, 0.00]</td>
</tr>
<tr>
<td>Previous-day affect</td>
<td>0.22, [0.20, 0.26]</td>
<td>0.21, [0.18, 0.24]</td>
<td>0.23, [0.20, 0.25]</td>
<td>0.21, [0.18, 0.23]</td>
</tr>
<tr>
<td>Random effect [Sleep]</td>
<td>p = .047, .00</td>
<td>p = .020, .01</td>
<td>p = .020, .00</td>
<td>p = .047, .01</td>
</tr>
<tr>
<td>N (Observations); Outliers</td>
<td>411 (5559); 4</td>
<td>389 (5211); 0</td>
<td>413 (5570); 2</td>
<td>389 (5211); 0</td>
</tr>
</tbody>
</table>
| N refers to number of individual participants included in each model. Observations refers to number of observations, in total, included in each model. Outliers refers to number of multivariate outliers identified at 0.05%.

* Denotes models with multivariate outliers removed. Bold highlights p < 0.05. Values presented are unstandardized coefficients, [95% confidence intervals] for unstandardized coefficients, statistical significance (p-value), and Cohen's f₂. * Denotes statistical significance values adjusted for multiple comparisons using the p-adjust function with the Benjamini-Hochberg method. * Denotes values presented as standardized coefficients for between-level predictors, unstandardized coefficients, [95% confidence intervals] for unstandardized coefficients, statistical significance (p-value), and Cohen's f₂. Standardized coefficients were calculated for between-person effects by rerunning all models using standardized scores of between-person predictors. Random effects for within-level predictors, and previous-day affect, were included in all initial models, and dropped if models did not converge (represented by —). Statistical significance (p-value), and Cohen's f₂ are presented for models with included random effects. Following covariates were included in all models: previous-day affect, age, sex, race/ethnicity, project, and day of week. Values for covariates are reported in Supplementary Table A1.
people's high arousal positive affect. Incorporating targeted cognitive interventions for unhelpful thoughts and beliefs about sleep (e.g., catastrophizing after poor sleep) may be particularly helpful in young people experiencing both sleep difficulties and affective disturbances. Consideration of other types of sleep-related attitudes, such as the extent that individuals prioritize sleep as a time commitment,\textsuperscript{56} may also benefit sleep education programs.

**Conclusions**

Poor sleep and affect disturbances are common in young people and contribute to poorer mental health. This study investigated whether young people holding unhelpful beliefs and attitudes about sleep are more vulnerable to the impact of sleep disturbances on emotional health. Results showed that young people with more unhelpful sleep beliefs had dampened levels of high arousal positive affect after periods of shorter, poorer quality sleep. Fostering healthy and balanced attitudes about sleep may offer protective benefits for the emotional health of young people. Future daily sleep-affect association studies could consider assessing both affective valence and arousal dimensions, controlling for previous-day affect, and exploring sleep parameters beyond duration and quality.

**Author contributions**

EC led the conceptualization, analysis, and preparation of this research article under supervision of BB and JFW. All authors contributed to the writing of this manuscript.

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**Data availability**

Data may be made available upon request to the corresponding author.

**Declaration of conflict of interest**

None. All authors have approved the final article.

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**Appendix A. Supporting information**

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.sleh.2023.07.008.

**References**

