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ORIGINAL ARTICLE

Attention-Deficit/Hyperactivity Disorder Dimensions and Sluggish Cognitive Tempo Symptoms in Relation to College Students' Sleep Functioning

Stephen P. Becker · Aaron M. Luebbe · Joshua M. Langberg

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Abstract This study examined separate inattentive, hyperactive, and impulsive dimensions of attention-deficit/hyperactivity disorder (ADHD), as well as sluggish cognitive tempo (SCT) symptoms, in relation to college students' sleep functioning. Participants were 288 college students (ages 17–24; 65 % female; 90 % non-Hispanic White; 12 % self-reported having an ADHD diagnoses) who completed measures of ADHD/SCT symptoms and sleep functioning. Participants reported obtaining an average of 6.8 h of sleep per night (only 26 % reported obtaining ≥8 h of sleep) and having a sleep onset latency of 25 min. 63 % were classified as "poor sleepers," and poor sleepers had higher rates of ADHD and SCT symptoms than "good sleepers". Path analysis controlling for ADHD status and psychiatric medication use was used to determine associations between psychopathology and sleep functioning domains. Above and beyond covariates and other psychopathologies, hyperactivity (but not impulsivity) was significantly associated with poorer sleep quality, longer sleep latency, shorter sleep duration, and more use of sleep medications. SCT symptoms (but not inattention) were significantly associated with poorer sleep quality and increased nighttime sleep disturbance (e.g., having bad dreams, waking up in the middle of the night, feeling too cold or too hot). Both inattention and SCT were associated with greater daytime dysfunction. Regression analyses demonstrated that hyperactivity predicted sleep quality above and beyond the influence of daytime dysfunction, and inattention and SCT predicted daytime dysfunction above and beyond sleep quality. Further studies are needed to examine the interrelations of nighttime sleep functioning, ADHD/SCT, and daytime dysfunction, as well to elucidate mechanisms contributing to related functional impairments.

Keywords ADHD · Daytime sleepiness · Sleep problems · Sleep quality · Sluggish cognitive tempo

S. P. Becker (✉) · A. M. Luebbe
Department of Psychology, Miami University, 90 North Patterson Avenue, Oxford, OH 45056, USA
e-mail: beckersp@miamioh.edu

S. P. Becker · J. M. Langberg
Division of Behavioral Medicine and Clinical Psychology, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA

J. M. Langberg
Department of Psychology, Virginia Commonwealth University, Richmond, VA, USA

Introduction

Children and adolescents with attention-deficit/hyperactivity disorder (ADHD) frequently experience a range of sleep impairments, including more sleep onset difficulties, sleep disordered breathing, and daytime sleepiness than youth without ADHD [1]. ADHD is a heterogeneous disorder, however, and some studies have sought to examine whether inattentive and hyperactive-impulsive symptoms are uniquely associated with various domains of sleep functioning. Extant research suggests that youth displaying both inattentive and hyperactive/impulsive symptoms [ADHD combined type (ADHD-C)] have more nighttime sleep problems than youth displaying inattention but not clinically elevated hyperactivity/impulsivity [ADHD predominantly inattentive type (ADHD-I)], including increased movement during sleep, difficulty falling asleep, restlessness during sleep, waking up during the night, and waking up too early in the morning [2–4, cf. 5]. Thus, hyperactive/

impulsive symptoms appear to be related to nocturnal sleep difficulties, whereas inattention is especially linked to daytime sleepiness among youth with ADHD [3, 5, 6].

Far fewer studies have examined the relation between ADHD symptoms and sleep in young adults, even though research suggests that 60–80 % of adults with ADHD experience sleep disorder symptoms [7]. Studies conducted with adults appear to converge with research with youth, whereby hyperactivity–impulsivity is more strongly linked than inattention to nighttime sleep problems [8–10], and inattention is more strongly linked to daytime sleepiness and greater sleep need [9, 11; see 12 for an exception].

Whereas factor analytic studies consistently demonstrate that a two-factor model consisting of inattentive and hyperactive-impulsive symptom dimensions characterizes ADHD in childhood and adolescence [13], several studies find that a two-factor model is less optimal than a three-factor model in adulthood, whereby inattention is retained as its own factor and hyperactivity and impulsivity are separated as distinct dimensions [14–17]. Despite studies supporting this three-factor model of ADHD in adults, the few studies examining ADHD dimensions and sleep in adults have relied on the two-factor structure that does not tease apart hyperactive and impulsive symptoms [8–10]. We are unaware of any study conducted to date that has examined distinct inattentive, hyperactive, and impulsive symptom dimensions in relation to young adults' sleep functioning.

In considering the distinction between hyperactivity and impulsivity, we hypothesized that hyperactive symptoms would be more strongly associated with sleep impairments than impulsive symptoms. By definition, ADHD hyperactivity includes fidgeting, feelings of restlessness, and being on the go as if driven by a motor [18], and these symptoms may be particularly detrimental for sleep latency as well as nighttime sleep problems (e.g., waking in the middle of the night). In contrast, ADHD impulsivity is characterized by talking too much, blurting, and interrupting/intrusive behaviors [18], which, although impairing in daily life, may be less impairing for sleep specifically. If this distinction between hyperactivity and impulsivity in relation to sleep functioning is supported, clinicians may be able to increase the specificity in which they assess for sleep dysfunction among adults displaying ADHD symptoms. For example, since some individuals with ADHD-C show high rates of impulsivity but few symptoms of hyperactivity, they may be at less risk for sleep problems, whereas individuals with ADHD-C displaying prominent hyperactive symptoms may require further assessment and potential treatment for sleep problems. Furthermore, if hyperactive and impulsive symptoms demonstrate differential associations with sleep functioning domains, such findings would lend additional validity to the separation of hyperactivity/impulsivity in adulthood.

Consistent with previous research conducted with youth [3, 5, 6] and adults [9, 11], we hypothesized that ADHD inattention would be more strongly associated with daytime dysfunction than with sleep problems. However, there has recently been significant interest in the construct of sluggish cognitive tempo (SCT) [see 19, 20] as a psychopathology that is distinct from, but strongly associated with, ADHD inattention in children [21–25] and adults [15, 26]. There has likewise been increased interest in the degree to which SCT is linked to external correlates, with recent studies demonstrating a significant link between SCT and poorer academic and social functioning even after controlling for ADHD symptoms [21–25, 27–31]. Approximately 5 % of adults display clinically elevated SCT, and approximately half of adults with ADHD also have SCT [26]. Given that SCT is characterized by sluggish, daydreamy, confused, slow, and lethargic behaviors, it is not surprising that a link between SCT and daytime sleepiness has been proposed [1, 3, 19, 32]. Extant research conducted with adults demonstrates that SCT and daytime sleepiness are distinct constructs [33], even though they are also strongly associated [33, 34]. Therefore, it is important to determine if ADHD inattention remains significantly associated with daytime sleepiness after controlling for SCT, as such findings may inform clinical care and also contribute to ongoing interest in elucidating the differential correlates of inattention and SCT.

Finally, when examining how ADHD and SCT symptoms relate to sleep functioning, it is also important to consider the bidirectional nature of nocturnal sleep problems and daytime sleepiness. For instance, it is likely that nighttime sleep problems contribute to increased daytime sleepiness [35–37]. Although mixed findings have been reported when testing this possibility with ADHD-specific populations [6, 38], Wiebe and colleagues [39] recently found that restless sleep more adversely affected the daytime sleep functioning of children with ADHD in comparison to typically developing children. Likewise, daytime sleepiness may in some cases contribute to nighttime sleep problems [40, 41]. For example, excessive daytime sleepiness may lead to an increase in the consumption of caffeine, in turn contributing to poorer nighttime sleep [42, 43]. Given these reciprocal, transactional processes, we also investigated whether ADHD or SCT dimensions contributed unique variance to the prediction of overall sleep quality when controlling for daytime dysfunction, and likewise, whether psychopathology dimensions predicted daytime dysfunction when controlling for sleep quality.

In sum, the purpose of the present study was to examine separate ADHD inattentive, hyperactive, and impulsive dimensions, in addition to SCT symptoms, in relation to various domains of young adults' sleep functioning while controlling for correlated demographic variables. This

study included young adult college students, as both ADHD symptoms [44] and sleep problems [45, 46] have a negative effect on college student functioning. It was hypothesized that ADHD hyperactive symptoms would be especially detrimental for overall sleep quality and sleep dysfunction whereas both ADHD inattentive and SCT symptoms would be associated with greater daytime dysfunction. Finally, we further hypothesized that hyperactivity would add unique variance to the prediction of sleep quality after controlling for daytime dysfunction, and, likewise, that inattention and SCT would add unique variance to the prediction of daytime dysfunction after controlling for sleep quality.

Methods

Participants

Participants were 288 undergraduate students attending a public university in Ohio. Participants ranged in age from 17 to 24 years of age ($M = 18.95$, $SD = 1.06$) and approximately two-thirds were female (65 %, $n = 187$). The majority (90 %) of participants were Caucasian; the remaining participants were Asian (4 %), African American (3 %), Multiracial (2 %), or Other (1 %). Most participants were in their first ($n = 173$) or second ($n = 78$) year of college. Thirty-five participants (12 %) reported that they had previously received a professional diagnosis of ADHD, and 30 participants (10 %) reported that they regularly take a psychiatric medication. Specifically, 25 participants reported taking a medication typically prescribed for ADHD (e.g., methylphenidate) and five participants reporting taking a medication typically prescribed for anxiety/depression (e.g., paroxetine); no participants reported regularly taking a medication for sleep problems although some participants indicated sporadic or occasional use of sleep medications on the measure of sleep functioning (described below).

Procedure

The Institutional Review Board at Miami University approved this study prior to collecting data. Participants completed the study measures as part of larger survey while enrolled in an introductory psychology course and received course credit for participation.

Measures

ADHD and SCT Symptoms

ADHD and SCT symptoms were assessed with the *Barkley Adult ADHD Rating Scale-IV* (BAARS-IV) [14]. For 27 items and using a four-point scale (1 = *sometimes*, 4 = *very often*), participants indicated the extent to which statements best described their behavior during the past 6 months. The BAARS-IV is comprised of four subscales supported by past factor analytic work [14, 15]: ADHD Inattention (nine items; $\alpha = .86$; e.g., "lose things necessary for tasks or activities"), ADHD Hyperactivity (five items; $\alpha = .63$; e.g., "fidget with hands or feet or squirm in seat"), ADHD Impulsivity (four items; $\alpha = .82$; e.g., "have difficulty awaiting my turn") and SCT (nine items; $\alpha = .86$; e.g., "prone to daydreaming when I should be concentrating on something or working"). The 18 ADHD items correspond to *DSM-IV* criteria [18]. Subscales have demonstrated internal consistency and reliability over a 2–3 week period [14].

Sleep Functioning

Sleep quality and disturbance was assessed with the *Pittsburgh Sleep Quality Index* (PSQI) [47]. The PSQI has nine items (including one multi-part item with 10 subitems) that assess seven well-validated components of sleep: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. Scoring is based on four-point scale with higher scores reflecting poorer sleep functioning over the past month. Four items (e.g., assessing sleep duration; sleep latency) are open-ended responses that, based on participants' answers, are converted to the four-point scale. A Global PSQI score can also be calculated, with a cutoff of >5 used to classify "good sleepers" and "poor sleepers" [47]. Since the purpose of the present study was to examine distinct components of sleep functioning, the Global PSQI score was not used in primary analyses. However, the percentage of participants classified as good versus poor sleepers was examined for descriptive purposes. The PSQI is internally consistent [48], is reliable across 4 weeks [47], correlates with other measures of sleep disturbance and daily diaries of sleep activity [49], and has been used with college students [e.g., 46]. The PSQI sleep dysfunction component is significantly associated with measures of daytime sleepiness [49].

Statistical Analyses

First, descriptive statistics were conducted to examine the percentage of participants classified as "good" versus "poor" sleepers and to determine if poor sleepers had higher rates of ADHD and SCT symptoms than good sleepers. Bivariate correlations were then examined to test the hypothesis that ADHD symptom dimensions and SCT symptoms would be associated with sleep functioning domains. Specifically, it was examined whether (1)

hyperactivity was more strongly associated than impulsivity with sleep problems, and (2) both inattention and SCT would evidence their strongest correlations with daytime dysfunction. In addition, correlation analyses were used to examine whether demographic, ADHD status, and/or psychiatric medication status variables were significantly correlated ($p < .05$) with sleep functioning and needed to be included as covariates in the path model.

Next, the associations between ADHD/SCT symptoms and sleep functioning domains were evaluated by estimating a path model using Mplus Version 5.1 [50]. Path modeling allows for the simultaneous incorporation of multiple independent and dependent variables, and thus, controls for alpha inflation (i.e., Type I error) associated with examining multiple, separate linear regression models. Consistent with best-practice recommendations [51], full information maximum likelihood (FIML) estimation was used to accommodate the few instances of missing data. Because the estimated path model was fully saturated (i.e., 0 degrees of freedom), it demonstrated perfect fit to the data and model fit statistics are therefore not used or reported. Path models provide standardized path coefficients that closely correspond to correlation coefficients [52] and can be interpreted as a measure of effect size, with values $\leq$.10 considered a small effect, values of .30 considered a medium effect, and values $\geq$.50 considered a large effect [53].

Finally, multiple regression analyses were conducted to examine whether any of the psychopathology dimensions (i.e., hyperactivity, impulsivity, inattention, SCT) added unique variance to the prediction of sleep quality and daytime dysfunction when controlling for the association between these nighttime and daytime sleep variables.

Results

Sleep Characteristics

Participants reported obtaining an average of 6.88 h ($SD = 1.14$) of sleep per night and taking an average of 25 min ($SD = 18.5$) to fall asleep. Only 26 % of participants ($n = 76$) reported obtaining 8 or more hours of sleep each night, whereas 37 % of participants ($n = 106$) reported obtaining 6.5 or fewer hours of sleep each night. Based on participants' Global PSQI score, 63 % ($n = 181$) of participants were categorized as "poor sleepers." Participants classified as poor sleepers reported obtaining an average of 6.5 h ($SD = 1.08$) of sleep each night whereas participants classified as good sleepers reported obtaining an average of 7.5 h ($SD = 0.90$) of sleep each night. Likewise, poor sleepers reported having a longer sleep onset than good sleepers (31 and 15 min, respectively). Independent samples t tests indicated that poor sleepers had higher rates of SCT, ADHD inattention, ADHD hyperactivity, and ADHD impulsivity symptoms than good sleepers (all $ps < .01$).

Correlation Analyses

Variable means, standard deviations, and intercorrelations are displayed in Table 1. As expected, hyperactivity was significantly positively associated with all of the PSQI variables with the exception of habitual sleep efficiency. In contrast, impulsivity was only significantly positively correlated with the sleep disturbance and daytime dysfunction variables. ADHD inattention and SCT evidenced generally similar correlations with the PSQI variables with two differential associations. Specifically, both inattention and SCT were significantly positively associated with sleep quality, sleep latency, sleep disturbance, use of sleep medication, and daytime dysfunction. As expected, both inattention and SCT were more strongly associated with daytime dysfunction ($rs = .48$ and .51, respectively) in comparison to these other sleep domains ($rs = .08$–25 and .13–.29, respectively). Also, in partial support of the distinction between SCT and inattention, SCT (but not inattention) was significantly positively correlated with sleep duration and habitual sleep efficiency.

In terms of participant characteristics, age, sex, and race were not significantly associated with any of the PSQI scores and are therefore not considered further. Participants who self-reported having previously received a professional diagnosis of ADHD had higher sleep latency and daytime dysfunction scores, as well as a higher Global PSQI score, than participants who did not report being previously diagnosed with ADHD. Participants who reported taking psychiatric medication also had higher sleep latency, daytime dysfunction, and Global PSQI scores than participants who did not report typically taking any psychiatric medication. Given these results, ADHD status and medication status were included as covariates in the path model and regression analyses.

Path Analysis

A path model in which the seven PSQI components were regressed on ADHD symptom dimensions, SCT symptoms, ADHD status, and psychiatric medication status was estimated. Results are displayed in Fig. 1. After controlling for the other independent variables, participant age was significantly negatively associated with sleep quality, sleep latency, and daytime dysfunction. In addition, above and beyond the other independent variables, having an ADHD diagnosis remained significantly associated with sleep latency.

Table 1 Correlations of participant characteristics and ADHD/SCT symptoms with sleep functioning domains

Variable	*M* ± *SD*	Sleep quality (1.25 ± 0.70)	Sleep latency (2.17 ± 1.67)	Sleep duration (1.00 ± 0.83)	Habitual sleep efficiency (0.47 ± 0.76)	Sleep disturbance (1.13 ± 0.50)	Use of sleep meds (0.28 ± 0.66)	Daytime dysfunction (0.93 ± 0.76)	Global PSQI score (7.24 ± 3.57)
Participant characteristics									
Age	18.95 ± 1.06	−.09	−.02	−.05	−.004	.05	.02	−.01	−.03
Sex	–	−.11	−.02	−.04	.05	.08	−.05	−.01	−.03
Race	–	−.03	.04	−.10	−.08	.04	−.04	−.02	−.03
ADHD status	–	.06	.23***	.04	.01	.01	.001	.12*	.16**
Medication status	–	.07	.18**	.04	.03	.02	.01	.14*	.15*
Psychopathology symptoms									
ADHD hyperactivity	8.98 ± 2.65	.25***	.28***	.18**	.10	.25***	.18**	.27***	.37***
ADHD impulsivity	6.44 ± 2.46	.10	.09	.05	.04	.23***	.06	.19**	.16**
ADHD inattention	15.10 ± 4.62	.23***	.24***	.11	.08	.25***	.17**	.48***	.37***
SCT	18.45 ± 4.97	.28***	.25***	.13*	.13*	.29***	.19**	.51***	.41***

$N = 288$. For sex, male = 0, female = 1. For race, non-Caucasian = 0, Caucasian = 1. For ADHD status, no diagnosis of ADHD = 0, diagnosis of ADHD = 1. For medication status, no psychiatric medications taken = 0, psychiatric medications taken = 1

ADHD attention-deficit/hyperactivity disorder, *PSQI* Pittsburgh Sleep Quality Index, *SCT* sluggish cognitive tempo

* $p < .05$; ** $p < .01$; *** $p < .001$

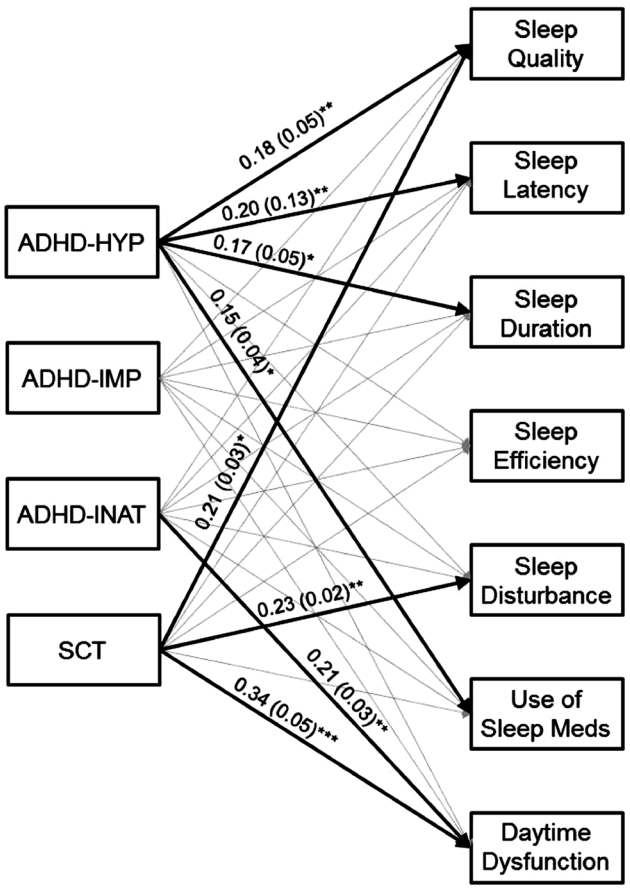

Fig. 1 Estimated path model ($N = 288$). Standardized parameter estimates are reported outside parentheses; unstandardized parameter estimates are reported inside parentheses. All other paths are nonsignificant ($p > .05$). ADHD status and medication status variables were included as covariates in the model but are not displayed for clarity purposes (neither was significantly associated with any of the sleep domains in the path model with the exception of ADHD status being positively associated with sleep latency, $p = .045$). *ADHD* attention-deficit/hyperactivity disorder, *HYP* hyperactivity, *IMP* impulsivity, *INAT* inattention, *SCT* sluggish cognitive tempo. *$p < .05$; **$p < .01$; ***$p < .001$

As also shown in Fig. 1, after controlling for ADHD status, psychiatric medication use status, and the other psychopathology variables included in the path model, hyperactive symptoms remained significantly positively associated with sleep quality, sleep latency, sleep duration, and the use of sleep medication, with small-to-medium effects for each of these associations (βs = 0.15–0.20). When controlling for ADHD/medication use status and the other psychopathology dimensions, impulsive symptoms were no longer significantly associated with any of the sleep functioning domains. These results indicate that hyperactive symptoms are consistently associated with sleep problems whereas impulsive symptoms are not. Of note, although inattention did not remain significantly associated with any of the nighttime sleep functioning domains when

the other psychopathology dimensions were included in the model, SCT symptoms were the only psychopathology dimension to remain significantly associated with sleep disturbance, and SCT (along with hyperactivity) also remained significantly associated with poorer sleep quality.

Lastly, above and beyond participant characteristics, hyperactivity, and impulsivity, both SCT and inattentive symptoms remained significantly associated with daytime dysfunction, with a medium effect found for SCT ($\beta = 0.34$) and a small-to-medium effect found for ADHD inattention ($\beta = 0.21$). In addition, just as inattention, SCT, and impulsivity were reduced to nonsignificance in predicting nighttime sleep problems when hyperactivity was included in the model (aside from a positive association between SCT and sleep disturbance), neither hyperactivity nor impulsivity remained significantly associated with daytime dysfunction above and beyond inattention and SCT.

Regression Analyses

As expected, daytime dysfunction was significantly correlated with all of the nighttime sleep dimensions: sleep quality ($r = .44$, $p < .001$), sleep latency ($r = .20$, $p < .001$), sleep duration ($r = .32$, $p < .001$), habitual sleep efficiency ($r = .17$, $p = .004$), sleep disturbance ($r = .22$, $p < .001$), and use of sleep medications ($r = .19$, $p = .001$). Since daytime dysfunction was most strongly associated with sleep quality and this variable is an index of overall sleep functioning, it was used in the regression analyses testing the hypothesis that inattention and SCT would add unique variance to the prediction of daytime dysfunction after accounting for the contribution of sleep quality in relation to daytime dysfunction. We likewise expected hyperactivity to add unique variance to the prediction of sleep quality after accounting for the relation between daytime dysfunction and sleep quality. As summarized in Table 2, both of these hypotheses were supported. As described above, both ADHD status and medication status were included as covariates in the regression models. Above and beyond ADHD/medication status and daytime dysfunction (Step 1), hyperactivity alone added unique to the prediction of sleep quality (Step 2; Table 2, top panel). Also, as expected, after controlling for the contribution of ADHD/medication status and sleep quality (Step 1), both inattention and SCT added unique variance to the prediction daytime dysfunction (Step 2; Table 2, bottom panel). Taken together, these results demonstrate that hyperactivity is uniquely associated with sleep quality whereas both inattention and SCT are associated with daytime dysfunction, and importantly, these associations are not accounted for by the interrelation of sleep quality and daytime dysfunction.

Discussion

This study examined ADHD dimensions and SCT symptoms in relation to college students' nighttime sleep functioning and daytime dysfunction. Since up to two-thirds of college students can be classified as poor sleepers [46] and a third of college students report being overly tired during the day [44], it is important to identify unique correlates of these sleep domains in general, nonclinical samples of college students. This study builds upon prior work by examining the ADHD hyperactive and impulsive dimensions separately, as well as by considering symptoms of SCT that frequently co-occur with ADHD. Results indicated that hyperactive symptoms are particularly detrimental for young adults' nighttime sleep functioning, whereas both inattention and SCT are associated with daytime dysfunction. SCT symptoms were also associated with poorer sleep quality and nighttime sleep disturbance. Importantly, these associations were not attributable to the relationship between poor nighttime sleep quality and daytime dysfunction.

Sleep Characteristics of College Students in the Present Study

Across the full sample, participants reported obtaining an average of 6.8 h of sleep per night and having a sleep onset latency of 25 min. Only one-fourth of participants in the present study reported getting 8 or more hours of sleep each night, which is the average amount of sleep needed in young adulthood [54]. This finding indicates that the majority of college students are obtaining insufficient sleep, many remarkably so given that almost 40 % of participants in our sample reported getting 6.5 or fewer hours of sleep each night.

In line with such a high rate of sleep insufficiency, almost two-thirds of college students in the present study were classified as "poor sleepers," a percentage almost identical to another recent study of college student sleep functioning using the PSQI [46]. In the current study, participants classified as poor sleepers reported obtaining an average of 6.5 h of sleep per night and having a sleep onset latency of 31 min, in contrast to an average of 7.5 h of sleep per night and a sleep onset latency of 15 min among the participants classified as good sleepers (thus, even "good sleepers" typically obtain less-than-adequate sleep). In addition, poor sleepers had higher rates of SCT, inattentive, hyperactive, and impulsive symptoms than students classified as "good sleepers".

ADHD and SCT Symptoms in Relation to Sleep Functioning Domains

Although previous studies have examined inattentive and hyperactive/impulsive symptoms in relation to sleep

Table 2 Multiple regression models predicting sleep quality and daytime dysfunction

	Step 1 model summary				Step 2 model summary			
	B	*SE*	*β*	*t*	*B*	*SE*	*β*	*t*
DV: sleep quality	$\Delta F(3,284) = 22.11^{***}$, $R^2 = .19$				$\Delta F(4,280) = 2.16$, $R^2 = .21$			
ADHD status	.01	.17	.01	.07	−.04	.17	−.02	−.25
Medication status	.02	.18	.01	.12	.03	.18	.01	.14
Daytime dysfunction	.40	.05	.43	8.03***	.36	.06	.40	6.30***
ADHD hyperactivity	–	–	–	–	.05	.02	.17	2.64**
ADHD impulsivity	–	–	–	–	−.01	.02	−.04	−.70
ADHD inattention	–	–	–	–	−.01	.01	−.08	−.91
SCT	–	–	–	–	.01	.01	.08	.95
DV: daytime dysfunction	$\Delta F(3,284) = 23.74^{***}$, $R^2 = .20$				$\Delta F(4,280) = 19.69^{***}$, $R^2 = .38$			
ADHD status	.07	.19	.03	.36	−.04	.17	−.02	−.25
Medication status	.21	.20	.08	1.06	.11	.18	.05	.63
Sleep quality	.47	.06	.43	8.03***	.34	.06	.31	6.30***
ADHD hyperactivity	–	–	–	–	−.01	.02	−.03	−.47
ADHD impulsivity	–	–	–	–	.004	.02	.01	.22
ADHD inattention	–	–	–	–	.03	.01	.21	2.75**
SCT	–	–	–	–	.04	.01	.28	3.85***

$N = 288$. For ADHD status, no diagnosis of ADHD = 0, diagnosis of ADHD = 1. For medication status, no psychiatric medications taken = 0, psychiatric medications taken = 1

ADHD attention-deficit/hyperactivity disorder, *SCT* sluggish cognitive tempo

* $p < .05$; ** $p < .01$; *** $p < .001$

functioning, several factor analytic studies suggest that adult ADHD is best characterized by separate inattention, hyperactivity, and impulsivity dimensions [14–17]. This is the first study to our knowledge to evaluate separate hyperactivity and impulsivity dimensions in relation to young adults' sleep functioning. Although one might expect hyperactivity and impulsivity to show similar correlations to sleep functioning, we found hyperactivity to be significantly associated with five of the six nighttime sleep domains, whereas impulsivity was associated with only two of these domains (sleep disturbance and daytime dysfunction). Path analysis further confirmed the distinctiveness of impulsivity and hyperactivity in young adults. When ADHD status, psychiatric medication status, and all four ADHD/SCT variables were simultaneously included in the path model, hyperactivity emerged as the clear and consistent predictor of nighttime sleep problems (see Fig. 1). Specifically, above and beyond the other predictor variables included in the model, hyperactivity was associated with poorer sleep quality, longer sleep latency, shorter sleep duration, and increased use of sleep medication. In contrast, impulsivity was not significantly associated with any of the sleep functioning domains in the path model analysis.

Previous studies using subjective measures of sleep offer mixed findings in terms of whether or not ADHD is associated with sleep duration, with some studies reporting shorter sleep duration in individuals with ADHD in comparison to controls [55–57], some studies reporting no differences between ADHD and non-ADHD groups [9, 58, 59], and still other studies reporting longer sleep duration in individuals with ADHD [60–62]. It is interesting that the hyperactive dimension showed a different relation to sleep latency and sleep duration than the impulsive or inattentive dimensions of ADHD (positive and null associations, respectively). Results of the present study suggest that it may be important to examine these separate ADHD dimensions when examining sleep duration and latency, as the failure of previous studies to take these distinct factors into account may have contributed to the mixed findings reported to date.

Clinically, our results draw attention to potential importance of prioritizing the assessment of hyperactivity (as opposed to impulsivity) when considering ADHD symptoms and possible sleep difficulties. Some individuals with ADHD may experience clinically impairing symptoms of impulsivity, but unless hyperactive symptoms are also present, these individuals appear less likely to experience nighttime sleep impairments. It will be important to replicate our results with clinical samples of adults with ADHD before specific clinical assessment recommendations are made.

Previous research with children [3, 5, 6] and adults [9, 11] has demonstrated a significant association between ADHD inattention and daytime dysfunction or sleepiness. Given the strong association between inattention and SCT

[13], as well as SCT and daytime sleepiness [33], both inattention and SCT were included in the current study. Likewise, there is increasing interest in examining whether SCT predicts functioning even after controlling for *DSM-IV/DSM-5* ADHD inattention [19–31]. Inattention and SCT are distinct constructs in adulthood [14, 15], and results of the present study suggest that they evince similar associations with daytime sleepiness but differential relations to nighttime sleep functioning. Specifically, although all four psychopathology dimensions were significantly correlated with daytime dysfunction at the bivariate level, the correlations were stronger for inattention and SCT than for hyperactivity and impulsivity and only inattention and SCT remained significantly associated with daytime dysfunction in the path model. In the regression analyses, ADHD inattention and SCT both contributed unique variance above and beyond each other to daytime dysfunction, with SCT having a somewhat larger effect. It therefore appears that there is an additive effect of inattention and SCT in relation to daytime dysfunction, and it will important for future research to further confirm this hypothesis by examining whether individuals with both ADHD and SCT experience higher rates of daytime dysfunction than individuals with either ADHD or SCT in isolation.

In contrast, in the path model, SCT symptoms alone were significantly associated with higher rates of nighttime sleep disturbance (e.g., having bad dreams, waking up in the middle of the night, difficulty breathing comfortably, feeling too cold or too hot) and SCT symptoms (and not inattentive symptoms) were also significantly associated with poorer sleep quality. Since this is the first study to examine associations between SCT and nighttime sleep functioning domains, these results should be considered preliminary in nature and in need of replication before conclusions can be drawn. Nonetheless, our findings underscore the need for additional research investigating the interrelations of SCT and sleep functioning. In particular, given research demonstrating an association between ADHD and sleep-related movement disorders, parasomnias, hypersomnias, and circadian rhythm disorders [63], it is likewise important for research to examine SCT in relation to organic sleep disorder symptoms. Thus, there is a clear need for future studies to examine SCT in relation to objective measures of sleep (e.g., actigraphy, polysomnography).

Transactional Nature of Sleep and ADHD/SCT

It is important to acknowledge that, as described above, nighttime sleep quality and daytime dysfunction are themselves associated and likely bi-directional in nature, with evidence particularly compelling for poor sleep quality affecting daytime cognitive functioning including daytime dysfunction/sleepiness [35, 64]. As noted by Stein and colleagues [65], "inadequate duration of sleep will contribute to 'sleep debt,' making it difficult to wake up in the morning and increasing reports of tiredness during the day" (p. 514). We therefore conducted regression analyses to control for the association between nighttime sleep quality and daytime dysfunction, and found that hyperactivity and inattention/SCT added unique variance to the prediction of sleep quality and daytime dysfunction, respectively, above and beyond the relationship between sleep quality and daytime dysfunction. These results are important in that they demonstrate that the associations between inattentive and SCT symptoms and daytime dysfunction are not wholly accounted for by poor nighttime sleep quality. Nonetheless, it is clear that ADHD, sleep quantity/quality, and daytime dysfunction are intertwined and complex in their associations [7, 64–66]. ADHD symptoms may contribute to sleep problems and increased daytime dysfunction, but sleep deprivation may also lead to cognitive changes and behaviors that mimic ADHD symptoms [35, 64]. Given the cross-sectional nature of the present study, conclusions regarding directionality and causality cannot be made, and this is a critical area for future research. In particular, carefully designed studies are needed that can help tease apart the transactional nature of sleep problems and daytime dysfunction, as well as the interrelations of sleep functioning, ADHD/SCT symptoms, and functional impairment. A prospective association between daytime sleepiness and academic impairment in college students with ADHD has recently been documented [67], and as noted by Langberg et al. [68], it is likewise possible that ADHD symptoms and other behavioral problems mediate the association between sleep and academic difficulties. Further, ADHD may contribute to sleep problems, in turn contributing to more daytime dysfunction and associated functional impairments in a reciprocal manner.

Limitations

The sample included in this study consisted of college students, most of whom had not received a clinical diagnosis of ADHD, and the findings may not generalize to young adults not attending college or college students diagnosed with ADHD. In addition, we were unable to independently confirm the presence of an ADHD diagnosis (or methods for diagnosis) among those participants who self-reported having a professional diagnosis of ADHD, and so grouping analyses based on the presence or absence of diagnostic ADHD were not conducted. It would be interesting for future research to compare college students with and without ADHD to determine if relations are similar across these groups or whether ADHD diagnostic status moderates the associations reported in the present study. In

addition, although including distinct ADHD dimensions and SCT symptoms is a strength of the present study, it will be important for these results to be replicated using a multimethod research design that incorporates clinician assessments of psychopathology and objective measures of sleep. Although we controlled for psychiatric medication use in our path model analysis, there is some concern that stimulant medications in particular may adversely affect sleep functioning [see [69] for a review], and future research with larger samples should examine specific medications as well as other drug use (including caffeine, alcohol, and illicit drug use). Finally, our study did not include measures of other psychopathology symptoms that have been shown to exacerbate sleep impairments, including depressive and anxious symptoms [3], nor did we have a measure of organic sleep problems (e.g., obstructive sleep apnea, parasomnias, restless leg syndrome, circadian rhythm disorders) that not only affect sleep quantity/quality but may also be elevated in ADHD samples [63] and as-of-yet unstudied SCT samples. It will be important for future research to examine whether these internalizing and/or organic sleep symptoms have an additive or multiplicative role when considering the interrelations of ADHD, SCT, and nighttime and daytime sleep dysfunction.

Summary

In line with factor analytic studies demonstrating the distinctiveness of hyperactivity and impulsivity in adults, results of the present study suggest that hyperactive symptoms are particularly detrimental for young adults' nighttime sleep functioning, whereas impulsive symptoms do not appear to contribute to sleep quality or daytime dysfunction. In contrast to hyperactivity, inattentive and SCT symptoms appear related to daytime dysfunction. Importantly, these associations are not accounted for by the relationship between nighttime sleep quality and daytime dysfunction. This study also provides preliminary evidence suggesting that SCT may also impair nighttime sleep functioning and operate somewhat differently than inattentive symptoms in terms of sleep functioning. Specifically, although both SCT and inattention were significantly associated with daytime sleepiness, SCT symptoms (but not inattentive symptoms) were also significantly associated in the path model with poorer sleep quality and increased nighttime sleep disturbance (e.g., having bad dreams, waking up in the middle of the night, feeling too cold or too hot). Further studies are needed to shed light on the interrelations of nighttime sleep functioning, ADHD/SCT symptoms, and daytime sleepiness, as well to elucidate mechanisms that contribute to related functional impairments.

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