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Personality and Sleep: Neuroticism and Conscientiousness Predict Behaviourally Recorded Sleep Years Later

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Abstract: Sleep is one key feature of people's lives that defines their daily routine and reflects overall health and well-being. To test the relevance of personality for core aspects of sleep, we examined if personality traits across the five broad personality domains predicted behaviourally recorded, week-long sleep characteristics up to five years later (alongside subjective sleep quality). Data from 382 participants (63% female, aged 34–82 years) were drawn from the longitudinal study on Midlife in the United States Study—Biomarker project. In terms of mean tendencies, both neuroticism and conscientiousness signalled more sleep continuity (fewer interruptions) alongside better subjective quality. In terms of intra-individual sleep variability, neuroticism predicted more variability in sleep duration, continuity, and subjective sleep quality, while conscientiousness predicted less variability in sleep duration and sleep continuity. Extraversion, agreeableness, and openness traits did not generally foreshadow behaviourally recoded sleep, only higher ratings of subjective quality. These links were robust to the impact of demographic factors and were not moderated by the duration of time between personality and sleep assessments. The findings distinguish which personality traits foreshadow core aspects of sleep and also implicate multiple traits as predictors of variability, not just mean tendencies, in behaviourally recorded sleep. © 2019 European Association of Personality Psychology

Key words: personality traits; sleep; variability; neuroticism; conscientiousness

> "How blessed are some people, whose lives have no fears, no dreads; to whom sleep is a blessing that comes nightly, and brings nothing but sweet dreams."
> Bram Stoker, "Dracula" (1897, p. 110)

Who are the people to whom sleep is a nightly blessing, and who are the unfortunate ones to whom sleep is a nightly curse? In this paper, we address this important question. Sleep is a major part of individuals' everyday lives and both an indicator of physical health and a process necessary for stable behavioural and emotional functioning. The mystery of who sleeps well is important to tackle because answers may show novel consequences of personality for night-time behaviour and biological processes, as well as aid identification and treatment of individuals with sleep-related problems. To this end, in this paper, we describe a systematic analysis of how human personality traits predict actual sleep behaviour in the years ahead.

Sleep and how it works

People spend about one-third of their lives sleeping, typically sleeping once every night for about eight hours. Sleep is behaviourally defined as a reversible state of perceptual disengagement from—and unresponsiveness to—the environment. In a human adult, it proceeds in alternating cycles of slow-wave sleep (non-rapid eye movement) and rapid eye movement (REM) sleep, which is associated with dreams (Carskadon & Dement, 2011). Although the full purpose of sleep remains a mystery, it plays a vital role in key physiological functions such as toxin disposal from the brain, thermoregulation, and physiological growth and repair (Xie et al., 2013). Moreover, sleep is essential for optimal psychological functions as it facilitates encoding of information, use of newly learned skills, and integration of emotional experiences (Walker, 2010).

Core features of sleep

Although everyone sleeps, how long and how well people sleep varies substantially, as illustrated by the opening quote. Although there are multiple aspects of sleep–wake processes (Buysse, 2014), there are four critical aspects of sleep episodes, namely, sleep duration (length of sleep), sleep continuity (ease in initiation and maintenance of sleep), subjective sleep quality (perceptions of sleep as uninterrupted and refreshing), and sleep architecture (patterning of sleep stages and biological activity; Hall, 2013; Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). According to large-scale surveys, sleep *duration* for most human adults is around seven to nine hours a night, although there are individual differences in sleep need (Bixler, 2009). Note that homeostatic processes produce mounting sleep pressure once sleep is significantly curtailed, resulting in the average

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amount of sleep that is relatively constant for any given individual (as shortened sleep on one night tends to produce elongated sleep on subsequent nights). How long an individual sleeps is ultimately a joint function of his or her chronic sleep need, current sleep debt, personal preferences, and environmental constraints on sleep (e.g. work schedules; Carskadon & Dement, 2011).

Sleep *continuity* refers to integration and efficiency of nightly sleep (Keklund & Åkerstedt, 1997; Hall, 2013). Ideally, sleep ensues quickly and easily as the person lays to rest, proceeds without any interruptions, and then concludes with a smooth awakening (Carskadon & Dement, 2011). However, how 'orderly' the process of falling and staying asleep is for any individual varies, with many individuals reporting insomnia, namely, complaints and struggling with initiation or maintenance of sleep (Espie, 2002). Behaviourally, poor sleep continuity and insomnia are evident in elongated sleep onset latencies (e.g. long time to fall asleep), undesirable night-time activity (e.g. waking up in the middle of the night), and unwanted wakefulness while in bed (e.g. waking up too early in the morning; Hall, 2013). As with sleep of insufficient duration, interrupted or discontinuous sleep also impairs vigilance, arousal, cognitive control, and emotional functioning (Bonnet & Arand, 2003; Janackova & Sforza, 2008; Reynolds & Banks, 2010).

Although perceptions of poor or disrupted sleep often follow objectively measured sleep discontinuity (Åkerstedt, Hume, Minors, & Waterhouse, 1994; Keklund & Åkerstedt, 1997; Palermo, Fonareva, & Janosy, 2008), sleep complaints may involve exaggerated or even confabulated perceptions of sleep disruption, such as overestimates of sleep onset latency, wakefulness during the night, or underestimates of sleep duration (Baker, Maloney, & Driver, 1999; Fernandez-Mendoza et al., 2011; Kay, Buysse, Germain, Hall, & Monk, 2015). As a result, *subjective sleep quality* is distinguished as a distinct aspect of sleep, reflecting overall perceptions of one's sleep. Self-reports of poor sleep are associated with numerous physical and psychiatric health conditions, often resulting from illness (Jennings, Muldoon, Hall, Buysse, & Manuck, 2007; Liu et al., 2009; Sabbatini et al., 2007). Reported sleep problems are also a marker of numerous psychiatric conditions including depression, anxiety, post-traumatic stress disorder, bi-polar disorder, and psychosis (Harvey, 2008). Chronic complaints of poor sleep themselves constitute *insomnia*, a disorder characterized by reported difficulties in initiating or maintaining sleep (or of nonrestorative sleep). Although insomnia involves subjective (mis)perceptions of disturbed sleep, it may also involve sleep of objectively insufficient duration or continuity (Fernandez-Mendoza et al., 2011; Kay et al., 2015; Vgontzas, Fernandez-Mendoza, Liao, & Bixler, 2013). Subjective sleep quality is thus a broad construct that is sensitive to a variety of behavioural and experiential sleep processes reflecting both the integrity and restorative value of sleep (Buysee et al., 1989; Harvey, Stinson, Whitaker, Moskovitz, & Virk, 2008).

Finally, *sleep architecture* refers to the pattern of individual sleep stages and neurobiological activity throughout the night. A typical sleep episode proceeds through alternating sleep stages with increasing amounts of REM sleep towards the morning (Hall, 2013; Jones, 2005). Sleep architecture is also flexible; individuals spend more time in non-rapid eye movement stages following sleep deprivation (Carskadon & Dement, 2011), while people with depression have earlier and longer REM episodes (Palagini, Baglioni, Ciapparelli, Gemignani, & Riemann, 2013). As sleep architecture was not examined in this research, it will not be considered in detail.

Individual differences in sleep

Although sleep is a flexible homeostatic process that is sensitive to a variety of external (e.g. stimulation) and internal (e.g. motivation) factors, it nevertheless shows stable individual differences. Alongside developmental changes in sleep that affect all individuals (e.g. adults sleep less and less well than children), there are nevertheless very stable rank-order differences in sleep characteristics, revealing sleep itself to be a meaningful individual difference dimension. Behavioural studies of sleep via polysomnography (the 'gold standard' for sleep measurement that involves full physiological assessment) or actigraphy (utilization of natural movement to infer sleep–wake patterns) reveal that despite sleep on any given night being unpredictable, even three-day aggregates of sleep variables are reasonably reliable approximations of individuals' average sleep (Rowe et al., 2008). Critically, individual differences in these tendencies are stable over time. Gaines et al. (2015) documented that three-night averages of polysomnographically recorded sleep variables (e.g. sleep duration and sleep onset latency) in a large group of men showed significant stability over two and a half years.

As mentioned earlier, nightly sleep also considerably varies from one day to the next. As a result, there are considerable individual differences in night-to-night *variability* of sleep, regardless of that individuals' typical sleep (Bei, Wiley, Trinder, & Manber, 2016; Dillon, Lichstein, Dautovich, Taylor, Riedel, & Bush, 2014). To what extent these intra-individual variabilities are themselves stable over time is not clear, though it is recommended to at least use a seven-day period to estimate them (Rowe et al., 2008). Variability in sleep is associated with increased stress, mood disorder symptoms, evening orientation, and poorer physical health (Bei et al., 2016; Mezick et al., 2009). This suggests that not only do individuals exhibit stable individual differences in *typical* sleep propensities but that individuals' *variability* in sleep may also reflect stable and important aspects of personality.

Personality traits

Human personality as a whole is complex and involves phenomena at multiple levels, from dispositional traits, motivational and emotional adaptations, to conscious life narratives (McAdams & Pals, 2006). At a general level, personality is effectively described by *traits*, namely, stable patterns of thought, emotion, and behaviour that characterize individual's typical functioning (Fleeson, 2001; McCrae & Costa, 1997). Despite the fact that the number of ways in which individuals differ from one another is virtually limitless, research on personality traits has converged on an empirically supported structure of personality, centred on the Big Five personality domains. Based on analyses of natural

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language and drawing on self, informant, and behavioural sources of data, human personality can be effectively described as a combination of individual differences in extraversion, neuroticism, agreeableness, conscientiousness, and openness to experience (Digman, 1990; John, Naumann, & Soto, 2008). This structure of the five core traits is genetically based, persistent across the life course, common to normal and abnormal personality expression, and relatively universal across cultures (DeYoung, 2010; Markon, Krueger, & Watson, 2005; McCrae & Costa, 1997; Yamagata et al., 2006).

Whereas the Big Five traits describe personality at a relatively broad level, they also subsume a variety of more specific personality features. Most inventories assessing the Big Five traits also assess their aspects or facets, which are more concrete personality features nestled within each of the Big Five domains (DeYoung, 2010; Markon, 2009; Yamagata et al., 2006). For example, facets of extraversion frequently assessed are social dominance, gregariousness, positive affect, and excitement seeking (McCrae & Costa, 1997). Because structure of personality is complex and intertwined, finer-grained features sometimes lay at the borders of the Big Five domains. As a result, considering more specific facets of personality is also important, as it may provide insights into how specific personality attributes that are not straightforward indicators of broader personality domains relate to sleep.

For example, trait anger and hostility are considered a facet of neuroticism (given anger is a negative emotion) yet often relate more closely to (dis)trust features of agreeableness than to depression features of neuroticism (Costa & McCrae, 1995). Considering features like aggressiveness directly may thus reveal associations with sleep not as identifiable when focusing on broader domains. Alternatively, specific features within a given broad domain could be linked to sleep in opposing ways (e.g. in the case of extraversion, dominance could mean worse sleep while gregariousness could mean better sleep), masking any connection at a broader level of personality description.

Personality and sleep

Are personality traits connected to sleep among adults? Most evidence on this score comes from studies on insomnia. Difficulties initiating or maintaining sleep are reported by up to a third of the US population, with 5–10% reporting chronic insomnia in need of medical help (Roth, 2007). Insomnia is also a common feature of both physical and psychiatric conditions; it is a common consequence of chronic illness and a diagnostic symptom for mood disorders such as anxiety and depression (Katz & McHorney, 1998; McCall, 2001). Critically, personality traits are consistently associated with insomnia. Contrasting pathological personality profiles of individuals with insomnia with those of good sleepers on the Minnesota Multiphasic Personality Inventory (Butcher, Dahlstrom, Graham, Tellegen, & Kreammer, 1989) reveals considerable elevations on depression, hysteria, and hypochondriasis, indicating that these individuals report more severe mood, anxiety, and psychosomatizing problems (for review, see Van de Laar, Verbeek, Pevernagie, Aldenkamp, & Overeem, 2010). These 'neurotic' personality features also serve as risk factors for developing future insomnia (e.g. Singareddy et al., 2012).

Similarly, studies that have more generally focused on normal personality traits and sleep complaints also find neuroticism to predict reports of poor sleep quality or interrupted sleep, regardless of demographic factors (Cellini, Duggan, & Sarlo, 2017; Duggan, Friedman, McDevitt, & Mednick, 2014; Gray & Watson, 2002; Hintsanen et al., 2014; Soehner, Kennedy, & Monk, 2007; Williams & Moroz, 2009). Low conscientiousness (and high impulsivity) has also been linked to reports of poor sleep, although its ties are weaker and less consistent than those of neuroticism and depression (Cellini et al., 2017; Granö et al., 2007; Huang, Peck, Mallya, Lupien, & Fiocco, 2016; Kim et al., 2015). Regarding other traits, extraversion and especially positive affectivity have been linked to reports of somewhat better sleep, while agreeableness and openness show weak or inconsistent relations (Cellini et al., 2017; Duggan et al., 2014; Gray & Watson, 2002; Williams & Moroz, 2009). In this vein, a recent large-scale investigation of more than 22 000 individuals confirmed neuroticism to be the strongest and most robust predictor of reported poor-quality sleep, followed by (low) conscientiousness and extraversion, with no role for agreeableness and openness (Stephan, Sutin, Bayard, Krizan, & Terracciano, 2017). In contrast to sleep quality, personality traits have not been found to robustly predict sleep duration, although some survey evidence finds higher neuroticism linked to reports of shorter sleep (Butkovic, Vukasovic, & Bratko, 2014; Soehner et al., 2007; Vincent, Cox, & Clara, 2009).

Do core aspects of sleep reflect personality?

On one hand, these findings clearly implicate personality as important for sleep; more neurotic individuals are at a greater risk for developing insomnia, report worse and declining sleep quality as do less conscientious individuals, and may be at an increased risk for depression due to distress about their sleep (Huang et al., 2016; Singareddy et al., 2012; Stephan et al., 2017). On the other hand, existing evidence does not speak to important questions about how core features of sleep link to personality.

First, even larger population studies are confined to self-reports of sleep problems, which provide only limited information about core aspects of individuals' sleep. Although experiencing distress about one's sleep is important in its own right, it does not necessarily indicate that actual sleep is curtailed or interrupted. Insomnia complaints do *not always* follow actually disrupted sleep; individuals who complain of chronic sleep problems may not exhibit objectively short sleep nor actual sleep discontinuity (Carskadon et al., 1976; Coleman et al., 1982; Lichtenstein, 2017). Similarly, individuals vary widely in the extent to which they accurately perceive features of their sleep, frequently over-reporting or under-reporting sleep latency, and awakenings (Baker et al., 1999; Kay et al., 2015; Williams, Kay, Rowe, & McCrae, 2013).

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As a result, no simple inference about other core aspects of sleep can be made solely from reports of poor sleep or insomnia dominating the existing literature. Interpreting their links to personality is further complicated because neuroticism is also linked to *over-reporting* of sleep problems, such as unwanted wakefulness in bed (Jackowska, Dockray, Hendrickx, & Steptoe, 2011; Williams et al., 2013). Similarly, elevated neuroticism seems most indicative of insomnia *without* objectively short sleep (Fernandez-Mendoza et al., 2011). The few investigations utilizing behaviourally or physiologically assessed sleep used limited personality assessment (e.g. only neuroticism) or focused exclusively on discrepancies between subjectively and objectively measured sleep characteristics, signalling a need for a comprehensive account of how core sleep aspects themselves co-vary with personality (Vanable, Aikens, Tadimeti, Caruana-Montaldo, & Mendelson, 2000; Vgontzas et al., 2013; Williams et al., 2013).

Second, existing research is typically limited to average or typical self-reports of sleep (e.g. average duration of sleep and average number of awakenings) and largely ignores day-to-day variability in sleep characteristics (Bei et al., 2016). As with other behavioural states indicative of personality, alongside stable mean tendencies sleep also shows substantial variability over time (He et al., 2015). Importantly, the extent of nightly variability in sleep (e.g. duration) may itself be a stable individual difference connected to personality, as has been observed for variability in personality states (Fleeson, 2001; Fleeson & Gallagher, 2009). Existing evidence suggests reliable differences in within-person sleep fluctuations and implicates neuroticism and negative affect in more variability over time (Mezick et al., 2009). Although variability in sleep has been assessed objectively (e.g. via actigraphy) in several studies and implicated in psychiatric symptoms (Cheek, Shaver, & Lentz, 2004; Signal et al., 2007; Waters et al., 2011), to our knowledge, no analysis has yet systematically related personality to variability in nightly sleep behaviour.

Study purpose and hypotheses

To address these gaps and comprehensively examine the predictive power of personality for core aspects of sleep, we employed data from the longitudinal Midlife in the United States Study (MIDUS; Ryff, Seeman, & Weinstein, 2013). Critically, this study included (i) rich assessment of basic personality traits at an initial time point and (ii) behaviourally (i.e. actigraphically) recorded week-long sleep patterns years later (at a subsequent time point). Drawing on these data allowed us to examine the predictive power of personality both in terms of the Big Five adjective scales and available specific features of personality via Multidimensional Personality Questionnaire (MPQ) facets (although not their change over time, due to a single assessment of each). Moreover, it enabled us to simultaneously examine the link of personality with sleep duration and sleep continuity (not addressed in analyses by Stephan et al., 2017), in addition to subjective sleep quality.

First, to examine sleep *duration*, we derived estimates of typical sleep duration (i.e. average nightly sleep across the week of actigraphic assessment), as well as variability in the duration of sleep (i.e. standard deviations of nightly sleep across the week). Second, to examine sleep *continuity*, we first created a composite index of overall continuity for each night of sleep within an individual (i.e. aggregated sleep onset latency, wake after sleep onset, and number of awakenings). We then examined typical sleep continuity (i.e. weekly average) and daily variation in continuity (i.e. standard deviation of the continuity composite across the week). Third, to examine subjective sleep *quality*, we derived estimates of typical quality (i.e. average of sleep quality ratings taken each morning) and variation in subjective quality (i.e. standard deviations of daily quality across the week). This approach enabled us not only to comprehensively test theoretically derived propositions but also to explore novel possibilities about the relevance of personality for yet-unexamined aspects of sleep (e.g. nightly variation in sleep).

Typical sleep

In terms of the average sleep tendencies, we anticipated that low neuroticism, conscientiousness, and extraversion will predict better average subjective sleep quality, replicating prior work (e.g. Stephan et al., 2017). More critically, we expected neuroticism to predict less sleep continuity given that stress and mood disturbances play an important role in development and perpetuation of insomnia and have been linked to objectively measured sleep disruption (Benca, Obermeyer, Thisted, & Gillin, 1992; Espie, 2002; Fuller, Waters, Binks, & Anderson, 1997; Roth, 2007). We additionally hypothesized that conscientiousness will predict better sleep continuity given that conscientious individuals often adopt better sleep hygiene practices (e.g. avoid substances and engage in exercise) that may reduce longer sleep latencies or unwanted behavioural arousals during the night (Bogg & Roberts, 2004; Duggan et al., 2014). Finally, we hypothesized that neuroticism may predict shorter sleep duration (in accord with survey research; Butkovic et al., 2014; Soehner et al., 2007), although we were sceptical of strong relations given homeostatic and environmental pressures on sleep duration discussed earlier.

In contrast, we expected that agreeableness, extraversion, and openness will *not* be substantial predictors of sleep continuity given the relative absence of both theory and evidence that such traits links to sleep, with the exception of positive affectivity (Duggan et al., 2014; Gray & Watson, 2002; Stephan et al., 2017). Even with analyses regarding other traits being necessarily exploratory given the novelty of the research, we did expect that traits such as aggressiveness and hostility will predict poorer sleep continuity and worse subjective sleep given they engender anger, arousal, and social conflicts that undermine sleep (Hisler & Krizan, 2017; Krizan & Herlache, 2016).

Variability of sleep

In terms of *variation* in nightly sleep, we hypothesized that because neuroticism is associated with instability in mood and emotional reactions, more neurotic individuals should

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have more variation in sleep to the extent the emotions and stresses that interfere with sleep themselves vacillate. Along these lines, Mezick et al. (2009) observed that individuals reporting more anxiety and depression had more variability in actigraphically recorded sleep duration and continuity. We also expected that anger and hostility aspects of neuroticism may predict more variable sleep (Hisler & Krizan, 2017). Second, because conscientious individuals live healthier lives and deviate less from personally important routines (Bogg & Roberts, 2004; Turiano, Whiteman, Hampson, Roberts, & Mroczek, 2012), such individuals may also have less day-to-day variability in sleep continuity, duration, and sleep quality. We did not have firm expectations about the role of agreeableness, extraversion, and openness in sleep variability.

METHOD

Sample and timeline

In order to examine behavioural and psychosocial factors underlying age-related differences in physical and mental health, MIDUS recruited 7108 adults across the nation from 1995 to 1996 to complete a survey. A longitudinal follow-up to this initial study (MIDUS II) occurred from 2004 to 2005 (N = 3485) in which participants again completed a survey. In addition, MIDUS II also used subsamples of its participants to conduct projects with more targeted assessments. One such project, the Biomarker project (N = 1255), conducted additional bio-indicator and health assessments from 2004 to 2009. The Biomarker sample is highly similar to the MIDUS II sample in terms of demographics and health characteristics (e.g. subjective health, chronic health conditions, exercise, and alcohol use; Love, Seeman, Weinstein, & Ryff, 2010). One data collection site of the Biomarker project (University of Wisconsin—Clinical and Translational Core) also collected one week of behavioural sleep data using Actiwatch-64 activity monitors, alongside sleep diary (N = 436). We thus used data from participants who both completed personality assessments during the MIDUS II national survey and who wore actigraphs to behaviourally measure sleep during the Biomarker project (N = 382; 63% female, M_{age} = 53.11, range: 34–82 years, 66% Caucasian, 31% African-American, 3% other). These participants, on average, completed 6.80 out of seven days of daily actigraphic recordings (i.e. completed 2509 out of 2583 recordings) and completed, on average, 6.92 out of seven days of self-reported sleep quality recordings (i.e. completed 2553 out of 2583 recordings). The participation times between the MIDUS II national survey and actigraphic sleep assessment ranged from zero to six years (M_{time} = 2.75 years, SD = 1.34 years). Means on personality dimensions did not practically differ between our selected sample and the MIDUS II sample. Only alienation and control were significantly greater in the subsample than in the MIDUS II full sample (M_{diff} = 0.10 and 0.06, respectively, p's $< .05$).

Data used in this study are protected by a restricted data use agreement and are therefore not openly accessible. Full information on MIDUS study design, measures, participant samples, and data can be found at http://midus.wisc.edu after obtaining approval for data access.

Personality measures

The MIDUS II wave involved two main forms of personality assessment. First, the Big Five traits were assessed via four to seven adjective markers for each domain in which respondents indicated the extent to which the adjective 'describe you' from 'not at all' (1) to 'a lot' (4). Specifically, neuroticism was assessed via 'moody', 'worrying', 'nervous', and 'calm' (reverse scored) (α = .76), conscientiousness via 'organized', 'responsible', 'hardworking', 'careless' (reverse scored), and 'thorough' (α = .65), agreeableness via 'helpful', 'warm', 'caring', 'softhearted', and 'sympathetic' (α = .77), extraversion via 'outgoing', 'friendly', 'lively', 'active', and 'talkative' (α = .78), and openness via 'creative', 'imaginative', 'intelligent', 'curious', 'broad-minded', 'sophisticated', and 'adventurous' (α = .80). Such adjective-based measures have been extensively used and show good convergence with sentence-based measures of personality traits (Goldberg, 1992; John et al., 2008).

Second, more specific traits were assessed with an adapted form of the MPQ (based on Patrick, Curtin, & Tellegen, 2002). Each trait was assessed with three statements to which respondents indicated how well the statement described them from 'false' (1) to 'true of you' (4). These specific traits included stress reactivity (e.g. 'My mood often goes up and down.', α = .77), alienation (e.g. 'People often try to take advantage of me.', α = .70), aggression (e.g. 'When people insult me, I try to get even.', α = .60), achievement (e.g. 'I like to try difficult things.', α = .65), control (e.g. 'I like to stop and think things over before I do them.', α = .60), well-being (e.g. 'I usually find ways to liven up my day.', α = .69), social closeness (e.g. 'I usually like to spend my leisure time with friends rather than alone.', α = .66), social potency (e.g. 'I am very good at influencing people.', α = .69), harm avoidance (e.g. 'It might be fun learning to walk a tightrope.', α = .56), and traditionalism (e.g. 'People should observe moral laws more strictly than they do.', α = .60). Although some of these measures resemble measures of psychological adjustment or preferences, they have been developed and validated as measures of stable individual differences. Note that the specific personality features do not provide a representative nor exhaustive coverage of facets underlying the Big Five domains, as they have been developed through a theoretical approach focused on temperament. However, they still enabled a more targeted look at how more specific facets of personality link to future sleep behaviour, including some not directly assessed by the Big Five markers available (e.g. aggression and social potency). Moreover, these additional descriptors enabled us to conduct profile analyses, contrasting personality signatures of distinct sleep features.

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Core sleep measures

In the Biomarker project, sleep was assessed over one week, from Tuesday morning to the following Tuesday morning, with the Mini Mitter Actiwatch-64. Participants continuously wore the watch on their non-dominant wrist to evaluate sleep–wake state at every 30-second epoch through measurement of wrist movement. Each epoch is scored as either 'wake' or 'sleep' depending on whether the recorded activity count during the epoch breaches a threshold value of 40. Activity epochs with values of greater than 40 were scored as wake. During the week of actigraphy recording, participants also kept a sleep diary in which they indicated bed and rise times, the quality of their sleep, alongside other information about nightly disturbances (e.g. awakenings), daytime behaviour (e.g. caffeine consumption), and unusual circumstances (e.g. travelled to a different time zone). Information from this sleep diary was used to enhance the accuracy of Actiwatch recordings of sleep and wake states by using participant reported bed and rise times to help specify sleep intervals. Actiwatch software then used these specified sleep intervals and the scored sleep epochs within these interval in its sleep detection algorithm to determine sleep onset and sleep offset.

In cases of missing data for weekdays, values were imputed by using the mean of other available weekday values if data are available for at least three weekdays (for weekends, the other weekend-day was used; see Ryff et al., 2013, for detailed information). The Mini Mitter Actiwatch-64 has been validated against polysomnography to show that it reliably estimates sleep indices, though it does systematically underestimate sleep efficiency and sleep duration, while overestimating sleep fragmentation (Rupp & Balkin, 2011). As these misestimates are systematic across all participants, they should not produce confounds in our individual difference analyses between personality and sleep.

Sleep duration

Typical sleep duration was measured by the participant's nightly total minutes scored as asleep by the actigraph. This calculation of sleep duration does not overlap with sleep onset latency and wakefulness after sleep onset because sleep onset latency and wakefulness after sleep onset are not included in the number of minutes spent sleeping.

Sleep continuity

As sleep *continuity* involves multiple components such as sleep onset latency (minutes categorized as 'resting' before falling asleep), sleep fragmentation (number of nocturnal movements or awakenings during sleep), and wake after sleep onset (minutes categorized as 'wake' after falling asleep), we aimed to create a representative composite index of these features. Sleep efficiency is one oft-used composite metric of continuity as it represents time asleep relative to time in bed (i.e. time trying to sleep), mathematically combining these characteristics for each person (Reed & Sacco, 2016). However, it is not very sensitive to number of arousals from sleep unless these involve longer periods of wakefulness (e.g. two awakenings totalling 10 minutes reduce the sleep efficiency composite much more than 10 awakenings of 10 seconds each). Critically, sleep efficiency scores also reflect different combinations of sleep continuity components for each participant, potentially reducing personality-relevant contributions of distinct components (e.g. two individuals may share sleep efficiency of 80%, yet one person may have extended sleep onset latency without awakenings during the night, whereas the other person may fall asleep quickly yet awake frequently). Therefore, to create a more balanced and representative index that evenly incorporates contributions of individual differences in these sleep components, we created daily composites of actigraphically recorded daily sleep onset latency, fragmentation count, and wake after sleep onset (following standardization). We selected these characteristics based upon the National Sleep Foundations definition of continuity (Ohayon et al., 2017), and a principal components analysis revealed one factor with an eigenvalue larger than 1 that explains 60% of the variance.

Subjective sleep quality

To assess perceptions of sleep quality and disturbance, we aggregated participants' responses to four questions asked each morning: 'Overall quality of your sleep last night', rated on a 1 (very poor) to 5 (very good) scale, 'How deeply you slept last night', rated from 1 (very lightly) to 5 (very deeply), 'How well-rested you feel this morning', rated from 1 (poorly rested) to 5 (very rested), and 'How alert you feel this morning', rated from 1 (not alert at all) to 5 (very alert). The multilevel daily reliability of this scale was .82.

Covariates

To test the robustness of personality in predicting sleep, participants' age, gender, race (coded *European American* = 0 and *all other races* = 1), income, and education level were included as covariates in analyses. Income was measured through participants' self-reports of income from personal earnings, pension, and social security over the past year from *A* 'Less than $0 (Loss)' to *WW* '$1,000,000 or more'. Incomes from these three sources were then summed to create a total income index, which the MIDUS data capped at $200 000. Education level was measured by participants' responses to 'What is the highest grade of school or year of college you completed?' from 1 'No school or some grade school' to 12 'PH.D., ED.D., MD, DDS, LLB, LLD, JD, or other professional degree'.

Analytic plan

To examine the influence of personality on average sleep and its variability, our analysis occurred in two stages. To investigate raw relations between personality and sleep, we first computed bivariate correlations of personality traits with typical level (i.e. nightly average across assessment week) and variability (standard deviation across assessment week) in sleep characteristics. However, separately modelling the mean levels and variabilities as a function of a single predictor has notable limitations (see Wang, Hamaker, & Bergeman, 2012, for full discussion).

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First, variability estimated as the standard deviation of data obtained from repeated assessments within a person is longitudinal in nature. Given that the data source is longitudinal, systematic temporal trends may exist in the data (e.g. some people may have linear increases in sleep duration over the assessment week whereas others may not). If such trends exist, then the degree of intrapersonal variability associated with a predictor can be overestimated if temporal trends are not taken into account. Although it seems unlikely that there are systematic daily temporal trends in sleep characteristics across a week, there may be systematic temporal changes from the weekday to weekend characterizing many participants (i.e. longer sleep duration on weekends than weekdays). Thus, it helps to account for individual differences in temporal trends of sleep characteristics when estimating a person's degree of variability. Second, separately modelling the average and variability fails to take into account that mean levels and the degree of variability are often interrelated. For instance, as the average score for a person approaches the ceiling or floor of a scale, the variability of the scores comprising the average should shrink. Thus, to understand how personality uniquely predicts average sleep alongside its variability, it is necessary to account for the interdependence between the mean and variance for a given individual.

To circumvent these limitations, in the second stage, we conducted multilevel location-scale modelling, an extension of growth curve modelling (Hedeker, Mermelstein, & Demirtas, 2008). Similar to a growth curve model, the location-scale model can estimate a random intercept (i.e. average) and a growth curve (i.e. temporal trend) but relaxes the assumption of homoscedasticity (i.e. allows for the residual variance to vary across all participants). Importantly, this residual variance as the outcome variable reflects within-person differences not captured by the intercept and growth curve and therefore captures variability after accounting for mean levels and temporal trends. If the residual variance varies across people, this degree of variability can be then modelled by individual difference factors, such as personality traits. Thus, the location-scale model accounts for the interdependence among the mean, temporal trends, and the variance while simultaneously estimating how individual differences predict the mean and variance. Importantly for the current study, by accounting for the interdependence among the mean, temporal trends, and variance, location-scale modelling will allow for estimates of how personality is uniquely associated with the average and variability of sleep characteristics. Finally, covariates can be entered as predictors of the intercept and residual variance to account for the influence of additional factors (see Hedeker, Mermelstein, Berbaum, & Campbell, 2009, for an example).

Given the advantages of multilevel location-scale modelling in this context, we present results from this statistical technique after we present the results from the raw correlational analyses. Location-scale modelling was conducted via the standalone MIXWILD software freely available at https://reach-lab.github.io/MixWildGUI/ (Hedeker & Nordgren, 2013). Specifically, in our multilevel location-scale models, we first separately examined the effect of each personality variable on each sleep outcome (i.e. sleep duration, sleep continuity, and subjective sleep quality). The general equation for these models is as follows:

$$\text{Sleep characteristic}_{ij} = \beta_{1j} + \beta_{11}\,(\text{day}_i) + \beta_{12}\,(\text{weekday}_i) + e_{1j},$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}\,\left(\text{personality trait}_j\right) + u_{1j},$$

$$\text{Var of } e_{1j} = \exp\left(\beta_{2j} + \beta_{21}\,(\text{day}_i) + \beta_{22}\,(\text{weekday}_i) + e_{2j}\right),$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}\,\left(\text{personality trait}_j\right) + u_{2j}.$$

Note the use of the exponential function when predicting the variance of residuals across participants. This function is used because the variance, by definition, cannot be negative, which is achieved in a location-scale model by using the exponential function.

After evaluating how personality traits uniquely predicted the mean and variability in sleep tendencies, we then evaluated the ability of personality traits to predict sleep by reconducting these location-scale models after including important demographic predictors, namely, age, gender, race, income, and education level. If zero-order associations between personality and sleep characteristics remain after controlling for mutual confounding of means and variances, temporal trends, and demographic factors, they could be appraised as robust.

Profile analyses

Finally, we also generated correlational personality profiles for each sleep variable, namely, a vector of correlations across the 36 personality descriptors (single Big Five adjectives and 10 facet scores from the MPQ). We then correlated these vectors across distinct sleep characteristics, testing to what extent the personality signature of a given sleep characteristic is shared with that from another. High correlations between particular sleep characteristics suggest that similar personality features are involved.

Study power

To obtain an estimate of study power, we used G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) to estimate what the smallest correlation between personality and individual differences in sleep the study should detect. With a sample of 382 participants available here, alpha set at .05, and power set at .80, we should detect correlations between individual difference factors as small as .11. In terms of detecting mean level and variability effects within a location-scale model, estimates from Walters, Hoffman, and Templin (2018) suggest that using a sample of 382 participants, each with seven days of repeated assessments, should be adequately powered to detect even modest associations.

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RESULTS

Sleep and personality characteristics of the sample

Descriptive statistics for key sleep measures appear in Table 1. Overall, the sample exhibited sleep characteristics that are fairly typical for individuals that age, alongside substantial individual differences on all sleep and personality characteristics. Although we focus on the aggregate index of sleep continuity, inter-correlations among specific continuity measures (i.e. sleep onset latency, wake after sleep onset, and number of arousals), time in bed, overall sleep efficiency, and among all the personality measures are presented in Appendixes A and B. We consider links to subjective sleep quality first given those have been the most extensively researched. We focused our analysis on correlation effect sizes (larger than .10) and patterns of association, instead of binary significance testing (McShane, Gal, Gelman, Robert, & Tackett, 2017). To this end, we pay particular attention to patterns across measures and covariate control, alongside their practical differences (e.g. minutes of unwanted wakefulness). SPSS syntax used to conduct descriptive and correlational analyses and MIXWILD output from the multilevel location-scale modelling are available at https://osf.io/2nvup.

Personality and subjective sleep quality

Raw correlations

To what extent did personality traits predict future reports of sleep quality? The last two columns in Table 2 present zero-order correlations between average and variability in sleep quality and personality traits. Replicating prior work, personality traits were substantive predictors of future average sleep quality, with neuroticism [$r = -.32$, $p < .001$, 95% confidence interval (CI) = −0.41 to −0.22], conscientiousness ($r = .28$, $p < .001$, 95% CI = 0.17 to 0.37), and extraversion ($r = .25$, $p < .001$, 95% CI = 0.15 to 0.35) showing links above .20. Agreeableness ($r = .10$, $p = .05$, 95% CI = 0.00 to 0.20) and openness ($r = .12$, $p = .02$, 95% CI = 0.02 to 0.22) showed much smaller links. These links with poor sleep quality extended to more specific features associated with neuroticism, such as stress reactivity ($r = -.27$, $p < .001$, 95% CI = −0.37 to −0.17) and alienation ($r = -.20$, $p < .001$, 95% CI = −0.30 to −0.10), and to some features associated with extraversion that involved positive affectivity (i.e. well-being, $r = .32$, $p < .001$, 95% CI = 0.23 to 0.42).

In terms of variability in sleep quality, only neuroticism predicted more variability in sleep quality ($r = .22$, $p < .001$, 95% CI = 0.12 to 0.32), as neither conscientiousness nor agreeableness predicted less variability. In terms of more specific facets, only greater well-being (i.e. positive affectivity) had a substantive association with less variable sleep quality ($r = -.15$, $p = .004$, 95% CI = −0.25 to −0.05).

Multilevel location-scale model

Next, we used multilevel location-scale modelling to examine the unique contributions of personality to average sleep quality and its variability, as well as to examine the robustness of these relations to important demographic factors (Table 3). Results from the location-scale model largely replicated the findings from the correlational analysis with the exception that greater extraversion also predicted less variability in sleep quality over a week. While results were generally replicated, we did observe reductions in the magnitude of coefficients. To determine the source of this change, we investigated models in which we removed the day of assessment and weekday variables as predictors of sleep quality. Removing these predictors from the models did not change results. Given that these additional predictors in the location-scale models did not account for differences from the correlational analyses and that the average in sleep quality was moderately correlated with its variability ($r = -.43$; Appendix B), we concluded that these differences emerged because the location-scale model accounts for the correlation between the mean and variance. Finally, findings were overall robust to the impact of age, gender, race, income, and education level, though some effects further decreased in magnitude.

Table 1. Means and standard deviations for specific sleep characteristics ($N = 382$)

Variable	*M*	*SD*
Sleep duration in minutes (*M*)	370.12	67.48
Sleep duration in minutes (*SD*)	60.88	34.26
Sleep continuity (*M*)	0.00	0.78
Sleep continuity (*SD*)	0.00	0.86
Sleep onset latency in minutes (*M*)	31.17	32.55
Sleep onset latency in minutes (*SD*)	27.46	30.73
Number of sleep fragmentations (*M*)	32.46	10.73
Number of sleep fragmentations (*SD*)	9.67	6.04
Wake after sleep onset in minutes (*M*)	49.08	24.55
Wake after sleep onset in minutes (*SD*)	22.11	21.36
Subjective sleep quality (*M*)	2.34	0.72
Subjective sleep quality (*SD*)	0.75	0.30

Note: *M*, mean; *SD*, standard deviation.

Personality and sleep duration

Raw correlations

To what extent did personality traits predict sleep duration in the years ahead? The leftmost column in Table 2 presents zero-order relations between personality traits and average sleep duration as well as variability. Overall, how long individuals slept was *not* foreshadowed by their personality. Links between personality traits and typical sleep duration were generally trivial, although openness ($r = -.11$, $p = .04$, 95% CI = −0.21 to −0.01) and alienation ($r = -.16$, $p = .002$, 95% CI = −0.26 to −0.06) modestly predicted shorter sleep duration.

Although personality was generally unimportant for average sleep duration, more substantive relations did emerge with sleep duration *variability*. Neuroticism was the only Big Five trait that predicted future variability in sleep duration ($r = .19$, $p < .001$, 95% CI = 0.09 to 0.28). Relatedly, stress reaction ($r = .17$, $p = .001$, 95% CI = 0.07 to 0.27) and alienation ($r = .26$, $p < .001$, 95% CI = 0.16 to 0.36)

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Table 2. Correlations between personality and sleep tendencies (N = 358–379)

	Sleep duration		Sleep continuity		Subjective sleep quality	
Variable	Average	Variability	Average	Variability	Average	Variability
Neuroticism	.02	.19***	−.21***	.18***	−.32***	.22***
Conscientiousness	.09†	−.10†	.20***	−.22***	.28***	−.04
Agreeableness	−.01	−.01	.04	−.07	.10*	.01
Extraversion	−.05	−.05	.02	−.01	.25***	−.08
Openness	−.11*	.05	−.04	.06	.12*	−.06
Stress reaction	−.03	.17**	−.17**	.19***	−.27***	.18***
Alienation	−.16**	.26***	−.19***	.26***	−.20***	.09†
Aggression	.03	.07	−.09†	.08	−.14**	.04
Control	−.09†	.01	.02	.01	.08	−.04
Achievement	−.02	−.02	.06	−.04	.16**	−.03
Well-being	.00	−.08	.07	−.07	.32***	−.15**
Social closeness	.04	−.07	.09†	−.09	.16**	−.02
Social potency	−.01	−.02	.03	−.05	.12*	−.04
Harm avoidance	−.06	.00	−.10†	.07	.04	−.02
Traditionalism	.06	.04	.02	.00	.04	.06

Note:
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 3. Multilevel location-scale model with personality predicting sleep tendencies (person-level N = 358–379 and day-level N = 2435-2625)

	Sleep duration				Sleep continuity				Subjective sleep quality			
Variable	Average	With covariates	Variability	With covariates	Average	With covariates	Variability	With covariates	Average	With covariates	Variability	With covariates
Neuroticism	.01	.03	.18***	.11*	−.10***	−.09***	.18**	.09	−.24***	−.20***	.14**	.11*
Conscientiousness	.06†	.00	−.09†	−.02	.09***	.04	−.25***	−.10†	.21***	.19***	−.02	−.04
Agreeableness	−.02	−.07*	.00	.03	.02	.00	−.06	−.01	.08*	.08*	−.01	−.04
Extraversion	−.03	−.04	−.02	−.01	.01	.01	.06	.06	.19***	.18***	−.11*	−.09†
Openness	−.08*	−.07*	.06	.07	−.02	−.01	.07	.07	.10*	.09*	−.08	−.07
Stress reaction	−.02	.00	.17**	.11*	−.07**	.06*	.19**	.11†	−.20***	−.16***	.10*	.07
Alienation	−.12**	−.05	.25***	.15**	−.09***	−.04	.31***	.12*	−.15***	−.09*	.01	.00
Aggression	.01	.04	.04	.02	−.05†	−.04	.07	.04	−.10**	−.07†	.01	−.01
Control	−.06†	−.05	.00	.00	.01	.02	.03	.02	.06†	.04	−.09†	−.05
Achievement	−.03	−.03	−.04	.02	.04	.02	−.10	−.03	.12**	.08*	−.02	.01
Well-being	.01	.00	−.06	−.04	.04	.03	−.07	−.05	.24***	.22***	−.13*	−.12*
Social closeness	.03	.00	−.09	−.08	.05†	.02	−.09	−.05	.12**	.11**	−.02	−.04
Social potency	−.01	.02	.01	.01	.01	.01	−.06	−.03	.08*	.07†	−.05	−.04
Harm avoidance	−.04	−.03	.03	.00	−.05†	−.04†	.17**	.08	.03	.05	−.03	−.04
Traditionalism	.04	.05	.05	.02	.01	.02	.05	.00	.04	.05	.05	.04

Note:
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$. Coefficients are standardized betas (β).

were the only more specific features of personality that exhibited links with duration variability. Links between other Big Five traits or other more specific traits and sleep duration variability were generally trivial.

Multilevel location-scale model

The links between personality and average and duration in sleep duration did not exhibit any substantial changes in patterns of predictors nor magnitude of effects (Table 3). Likely, no differences emerged because the average sleep duration and its variability were minimally correlated ($r = -.14$). Additionally, links between personality and sleep duration tended to be diminished but not wholly eliminated when accounting for the demographic factors.

Personality and sleep continuity

Raw correlations

In contrast to sleep duration, personality showed clearer and stronger links with future sleep continuity (see middle of Table 2). Greater neuroticism ($r = -.21$, $p < .001$, 95% CI = −0.31 to −0.12) and conscientiousness ($r = .20$, $p < .001$, 95% CI = 0.10 to 0.30) foreshadowed worse and better average sleep continuity, respectively. Focusing on

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more specific personality features did not yield any further associations larger than .10, except that those higher in alienation ($r = -.19$, $p < .001$, 95% CI = −0.29 to −0.09) and stress reaction ($r = -.17$, $p = .001$, 95% CI = −0.27 to −0.07) were less likely to sleep continuously, in accordance with our hypotheses (aggression exhibited a similar, yet weaker, trend).

Personality traits also showed clear links with nightly variability in future sleep continuity. Alongside low neuroticism ($r = .18$, $p < .001$, 95% CI = 0.08 to 0.28), high conscientiousness predicted less variable continuity ($r = -.22$, $p < .001$, 95% CI = −0.32 to −0.12). The relevance of neuroticism is further strengthened by the fact that more variability in continuity was predicted by greater stress reaction ($r = .19$, $p < .001$, 95% CI = 0.09 to 0.29) and alienation ($r = .26$, $p < .001$, 95% CI = 0.16 to 0.35). Focusing on other specific personality traits or features did not yield any further associations larger than .10.

Multilevel location-scale model

Similar to findings about sleep quality, the location-scale models predicting sleep continuity showed almost no changes in patterns of predictors (greater harm avoidance became a predictor of more variability in sleep continuity) but did show reductions in effect size estimates. Again, this seemed to be due to a sizeable correlation between the mean and variability parameters ($r = -.75$). Interestingly, associations of personality with sleep continuity were not quite as robust as other sleep characteristics to the effects of demographic variables as several relations were reduced. Of import, the associations of alienation and conscientiousness with average sleep continuity and that of neuroticism with sleep continuity variability were only somewhat smaller yet estimated much less precisely (top middle of Table 3).

Scaling differences in sleep as a function of neuroticism and conscientiousness

Because the most novel and strongest findings were that neuroticism and conscientiousness predicted mean levels of sleep continuity and its variability over time, we sought to meaningfully scale the links between these traits and sleep continuity. Figure 1 presents the average sleep onset latency, the average number of nocturnal movements, and the length of time awake while in bed separately for individuals in the bottom and top quartiles of neuroticism and conscientiousness. In short, more neurotic individuals took about 10 minutes more to fall asleep, stirred around four more times, and spent around 10 more minutes awake while in bed, than did less neurotic individuals. Similarly, less conscientious people individuals took about nine minutes more to fall asleep, awoke around three more times, and spent around eight more minutes awake while in bed than their more conscientious counterparts.

Figure 2 presents the average standard deviation of sleep onset latency, the number of nightly arousals, and the length of time awake while in bed separately for these individuals. In terms of sleep variability, neurotic individuals' standard deviation in time to fall asleep across the week was about 10 more minutes, their deviation in their number of arousals was about three more arousals, and the deviation in time awake in bed was about seven more minutes, than for less neurotic individuals. In contrast, less conscientious individuals' standard deviation in time to fall asleep across the week was about 11 more minutes, their deviation in their number of arousals was about three more arousals, and the deviation in time awake in bed was about eight more minutes than conscientious individuals. These sleep disparities are among the first findings to speak about concrete difference in multiple aspects of sleep as a function of core personality traits.

Personality profiles of sleep characteristics

Next, we evaluated how similar are the profiles of correlations with personality traits across different sleep characteristics. To do this, we computed the correlations of each personality with each sleep outcome of interest and then correlated these vectors of correlations across each sleep characteristic (Table 4). This analysis revealed that personality

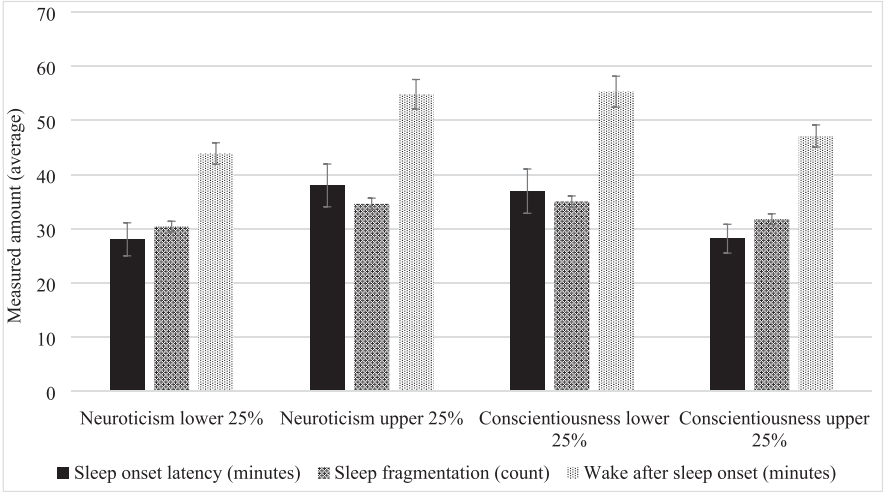

Figure 1. Average sleep continuity indices for the lower and upper quartiles (25%) of neuroticism and conscientiousness.

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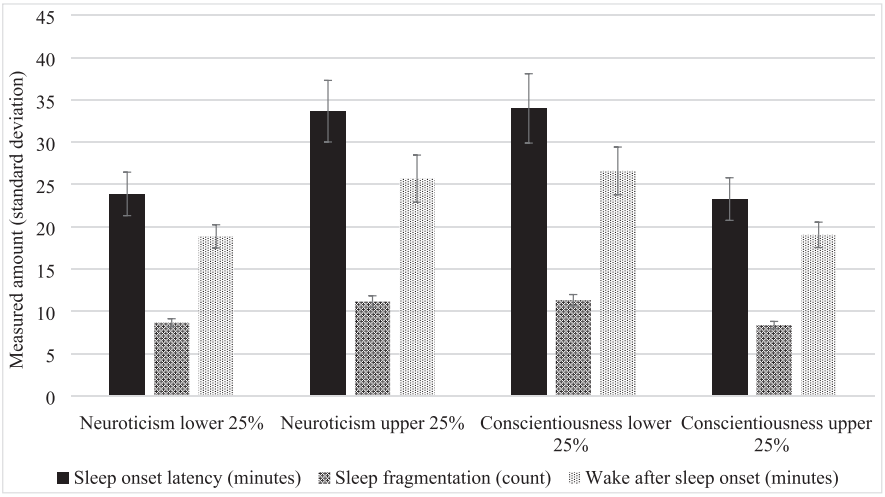

Figure 2. Standard deviation of sleep continuity indices for the lower and upper quartiles (25%) of neuroticism and conscientiousness.

Table 4. Correlations of personality profiles across sleep characteristics ($N = 36$ descriptors)

Variable	1	2	3	4	5	*M*	*SD*
1. Average sleep duration	—					0.00	0.06
2. Sleep duration variability	−.39*	—				0.01	0.09
3. Average sleep continuity	.41*	−.88*	—			−0.01	0.11
4. Sleep continuity variability	−.55*	.90*	−.95*	—		0.02	0.11
5. Average subjective sleep quality	.04	−.75*	.77*	−.75*	—	−0.04	0.17
6. Subjective sleep quality variability	.09	.70*	−.60*	.58*	−.85*	0.00	0.09

Note: *SD*, standard deviation. *$p < .05$. †$p < .10$.

traits related similarly to all sleep characteristics except average sleep duration. In other words, the relative ranking of importance of personality traits for predicting sleep was stable between variability in sleep duration, average and variability in sleep continuity, and average and variability in subjective sleep quality (all|*r*'s $> .58$|, though the profile correlations with variability in subjective sleep quality tended to be somewhat smaller. The personality profile of sleep duration likely exhibited smaller correlations with other personality traits because personality traits were relatively unimportant for sleep duration yielding range restriction.

Predicting sleep from personality as a function of time

Did the predictive power of personality persist over time? To test this possibility, we used linear regression to examine if the association of personality traits on average and variability in sleep characteristics was moderated by time elapsed between the assessments (after standardizing both variables). There was little evidence that the predictive ability of personality faded over time (Appendix D). Although interaction terms were generally in the expected direction, the few interactions crossing conventional standards of significance mostly involved traits not linked to sleep in these data (e.g. achievement and traditionalism), were small in magnitude, and likely to occur by chance given the large number of tests involved in this one analysis.

Summary of results

First, most traits were implicated in *typical* subjective sleep quality, with the strongest links to neuroticism, conscientiousness, and extraversion, replicating prior findings. However, only neuroticism, (low) conscientiousness, stress reaction, and alienation (i.e. hostility) predicted less behaviourally recorded typical sleep continuity. In contrast, typical sleep duration was generally independent of traits. Second, personality traits also predicted intra-individual *variability* in sleep characteristics. Neuroticism, alienation, and well-being all predicted variability in subjective perceptions of sleep quality. Neuroticism predicted more variable sleep duration, while neuroticism, stress reaction, alienation, and (low) conscientiousness predicted more variable sleep continuity. Extraversion and openness were not associated with objectively recorded sleep, although openness predicted slightly shorter sleep duration.

Importantly, the ability of neuroticism and conscientiousness to predict variability in sleep characteristics remained after accounting for average sleep tendencies, except when predicting subjective sleep quality variability. The strengths of all links were also generally robust to the impact of

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socio-demographic factors and time, although associations with sleep continuity were often halved following covariates. In this vein, the passage of time did little to weaken these links between personality and sleep; traits predicted sleep assessed more than five years later as well as sleep assessed only a few weeks later.

DISCUSSION

One key finding to emerge from this analysis is that traits were indicative of future sleep behaviour across multiple core aspects of sleep. This suggests that how one is sleeping is tied with the make-up of a given individual; in general, those who were better able to regulate unwanted emotions and control their behaviour also seemed to achieve healthier sleep and to do so more regularly. Although these findings do not isolate causal impact of personality on sleep, they point to systematic overlaps that carry implications for isolating processes operating in both causal and developmental directions.

Neuroticism and conscientiousness are critical to sleep and its variability

This evidence critically extends prior findings on subjective sleep quality (e.g. Stephan et al., 2017), showing that more neurotic and less conscientious individuals also show more behaviourally recorded disturbances during their sleep. Whereas the current data cannot provide definitive answers as to why neuroticism and conscientiousness were so important for sleep, prior findings offer hints as to the nature of their connection. Stress and emotional disturbances have been implicated as predisposing, precipitating, and perpetuating factors for insomnia (Espie, 2002). Because neuroticism constitutes a general propensity towards emotionally distressing (e.g. depression) and physiologically arousing (e.g. anxiety) states, these states may be responsible for why more neurotic individuals are at a higher risk for poorer sleep (Cellini et al., 2017; Van de Laar et al., 2010). Clinical research linking anxiety and depression to objectively assessed sleep discontinuity is consistent with these conclusions (Benca et al., 1992; Fuller et al., 1997).

More neurotic individuals also showed more nightly variability in future sleep duration and continuity, perhaps reflecting more unpredictable sleep displacement due to unexpected worries or unpredictable stressors (Tavernier, Choo, Grant, & Adam, 2016). Alternatively, unstable sleep may itself contribute to emotional instability. Because adequate sleep is itself crucial for regulating negative affect (Walker, 2010), unstable night-to-night sleep of those high in neuroticism documented here may play a hitherto neglected role in explaining why emotional lability persists over time among more neurotic individuals. For example, Bouwmans, Bos, Hoenders, Oldehinkel, and de Jonge (2017) documented that in both depressed and non-depressed individuals, nightly sleep quality foreshadowed adverse changes in next-day affect (but not vice versa).

Why did conscientiousness foreshadow better and more consistent sleep? The answer here may lie mostly in behavioural practices of those high on this trait. More conscientious individuals live healthier lives and engage less in behaviours known to undermine sleep, such as substance use and lack of exercise, while being more likely to have a regular bedtime routine (e.g. less sleep procrastination, Kroese, Evers, Adriaanse, & De Ridder, 2016; substance use, Turiano et al., 2012). The nature and regularity of such behavioural practices may help explain why these individuals not only show healthier sleep but also sleep that is more consistent from one night to another. In this vein, consistent sleep routine has itself been linked to more restorative sleep (Barber, Munz, Bagsby, & Powell, 2009). Moreover, consistent and relatively healthy sleep of more conscientious individuals could be a factor that supports consistent expression of this trait over time. Regularly achieving needed sleep enables consistent occupational and social performance, such as at work or in school (Barber & Munz, 2011). Because adequate itself sleep is important for maintaining self-control (Krizan & Hisler, 2016), it is also possible that irregular sleep may undermine expressions of conscientiousness, suggesting causal processes that may flow in both directions.

Taken together, these possibilities speak to potential bidirectional relations between sleep and personality that demand future investigation. For example, Stephan et al. (2017) found mutual prospective relations between personality traits (especially neuroticism, conscientiousness, and extraversion) and subjective sleep quality, suggesting operation of reciprocal long-term causal processes. Besides neuroticism and conscientiousness, the observed link between alienation (i.e. hostility) and poor sleep quality may be one good candidate for such a reciprocal relation. Not only do anger and hostility predict actigraphically recorded worse sleep but are themselves more likely to occur following disrupted sleep (Hisler & Krizan, 2017; Krizan & Hisler, 2018). Over time, such processes could produce intimate ties among individual differences in sleep on one hand and anger or hostility on the other.

Extraversion, agreeableness, and openness are less relevant to core aspects of sleep

In contrast to neuroticism and conscientiousness, extraversion, openness, and related features did not show notable links with either typical sleep or its variability (with the exception of better subjective quality alongside higher openness and extraversion). This dovetails with prior findings that generally do not find these aspects of personality linking to sleep features, although these relations deserve further scrutiny. Whereas extraversion (and some of its features) has been linked to better sleep quality, this evidence is exclusively based on self-reports of sleep (e.g. Stephan et al., 2017). Our findings replicated such associations between extraversion, openness, and subjective sleep quality, but raise the possibility that these relations reflect the importance of these traits for sleep *perceptions*, rather than actual sleep behaviour (see Hintsanen et al., 2014, for a similar finding).

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Our conclusion that extraversion is not linked to sleep duration or continuity is strengthened by the use of multiple measures (e.g. MPQ facets of social potency, closeness, and well-being), making it unlikely this lack of an association was driven by specific extraversion markers in the MIDUS. Nevertheless, future inquiries should more comprehensively test the potential role of these traits in sleep, especially the positive affect features of extraversion (Ong, Kim, Young, & Steptoe, 2017). Moreover, extraversion may confer increased risk to behavioural deficits following sleep deprivation due to lower arousability, even if it does not shape sleep behaviour directly (Killgore, Richards, Killgore, Kamimori, & Balkin, 2007).

Variability in sleep is a meaningful individual difference

Perhaps the most novel aspect of our findings involves linking personality to indices of behavioural variability in people's sleep. Importantly, by using location-scale modelling, we able to examine how personality is associated with variability in sleep after accounting for the association between variability and average sleep tendency. We began with an assumption that variability in sleep, just like variability in other behaviour indicative of personality, may itself be a somewhat stable and thus predictable parameter (Bei et al., 2016). In line with this assumption, more variability in sleep duration and continuity across the week of the study were consistently predicted by neuroticism (and some facets), as well as (low) conscientiousness, assessed years earlier and even after accounting for average duration and continuity. This suggests that vacillation of individuals' sleep is sufficiently stable and independent of mean sleep tendencies to merit more intense investigation as an individual difference. Moreover, it suggests novel pathways through which personality may impact sleep. Whereas past theorizing linking personality and sleep has typically focused on what individuals' qualities mean for how and how well people sleep *in general* (i.e. average sleep tendencies), our findings suggest that personality also impacts the regularity of people's sleep schedules and the consistency of the sleep integrity itself. Because sleep is a cyclical behaviour that occurs every day, personality factors that impinge on daily stability of individuals' environments, relationships, or proximal psychological factors should be a key focus of future investigations into the role that personality plays for sleep (e.g. rumination; Takano, Sakamoto, & Tanno, 2014).

The link of personality to sleep is robust

Personality traits also seem equally or more important for multiple aspects of sleep than do age, gender, income, or education; all factors extensively linked to sleep (Bixler, 2009). In fact, neuroticism was the single most powerful predictor of sleep across the entire set of sleep variables, with the exception of race (Appendix B). Moreover, these relations did not diminish as years between the assessments have passed. This suggests that relevant aspects of personality and sleep were either themselves relatively stable or that personality traits may have precipitated significant events which then shaped subsequent sleep (e.g. divorce and illness). Although environmental sources of stress (e.g. job loss), changes in one's social environment (e.g. marriage), and even physical changes (e.g. getting ill) can all impact sleep in ways not directly connected to an individual's personality, there are at least some aspects of sleep tied to personality in ways that transcend immediate context. Because stable components of personality are heavily based on genetic influence, this finding also calls for examining overlapping genetic bases between sleep and personality (Johnson, McGue, & Krueger, 2005). Furthermore, the make-up of the study sample may have also played a role; because the average age was 53 years and rank-order stability of personality (and environments) peaks at this age (Roberts & DelVecchio, 2000), older individuals may show less perturbation in these links because of passage of time. Future research should aim to directly identify what role developmental stage and life events of the individuals play in the predictive ability of specific personality traits for sleep.

Finally, the unique role that personality plays in shaping sleep relative to other aspects of health should be scrutinized. Neuroticism and conscientiousness are broadly relevant for physical and mental health (e.g. Bogg & Roberts, 2004; Turiano et al., 2012), so the specific implications of these traits for sleep relative to diet, exercise, or substance use need attention. As sleep has itself been linked to such behaviours (e.g. Wilckens, Erickson, & Wheeler, 2018), sophisticated multi-wave designs will be necessary to disentangle these influences.

Limitations and challenges

Despite important strengths, the present analysis also involves limitations important to consider. First, the nature of the sample and employed measures may have limited the robustness or generality of the findings. The sample employed in our analyses is relatively older; this should make it higher on conscientiousness, lower on neuroticism, and worse on sleep quality and continuity than a younger sample (Caspi, Roberts, & Shiner, 2005; Reyner, Horne, & Reyner, 1995). Although individual differences on some dimensions may have been narrowed as a result of who was in the sample, such restriction of range would only weaken our ability to detect any relationships.

Second, although sleep was assessed behaviourally, the actigraphic method itself has limitations. Of most relevance is the tendency for actigraphy to overestimate wakefulness and the number of awakenings; because this technology uses movement to infer wakefulness and people often move even while sleeping, absolute values of sleep onset latency and the number or nightly arousals are often too large in older adults (Marino et al., 2013). However, this bias is inherent to the measurement tool and should thus apply equally across all participants with ultimately little consequence for individual differences considered here. An additional constraint is that participants' sleep was only measured in one specific week —this week may have been unrepresentative of individuals' typical sleep, leading to biased associations. Because week-long aggregates of sleep variables have been shown to be

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adequately representative of individuals' sleep, including variability, this is likely not a great concern (Rowe et al., 2008). In fact, demonstrating that self-reported personality traits predicted actual sleep assessed via actigraphy throughout a 'random' week years later speaks to the importance of personality in this context.

Third, sole reliance on self-reports to assess personality and limited coverage of some personality domains limits the conclusions. Although this was dictated by the methodology of the original investigation, it is worth considering what impact the assessment may have had on the results. First, some important personality features were not adequately covered by the brief measures administered in MIDUS (e.g. organization and perseverance facets of conscientiousness and most facets of agreeableness), so they await further scrutiny regarding their relevance for sleep. In this vein, questions about the unique relevance of personality traits at different levels of the hierarchy remain open. For example, Hirsh, DeYoung, and Peterson (2009) found that subjective sleep complaints are uniquely associated with shared variance at the stability meta-trait level rather than just unique contributions of neuroticism, conscientiousness, or agreeableness. In this vein, future work should examine the level of personality description most important for understanding individual differences in sleep.

Second, traits for which others have little information are often better assessed through self-reports than informant-reports; for example, others are unlikely to have much insight into one's neuroticism barring extensive intimacy (Vazire, 2010). To this end, our findings linking neuroticism to sleep may not extend to personality perceptions of others, especially strangers. However, traits that are highly observable yet also highly evaluative (i.e. 'socially loaded'), such as hostility, may often be assessed more accurately by knowledgeable others. As a result, our study may have missed some connections between sleep and personality to the extent limits of self-knowledge undermined insight into aspects of one's own personality important for sleep (Vazire, 2010; Zell & Krizan, 2014). Finally, the data are cross-sectional and do not afford clear causal primary to either sleep or personality.

CONCLUSIONS

We began this paper by raising the question of who sleeps well. By drawing on links between personality and sleep behaviour from a large sample of adults, we provided important insights to this age-old question. Individuals who were emotionally stable and responsible slept better and did so for years following a query into their personality. Moreover, these individuals slept better more consistently, as their sleep vacillated less from one night to the next. At the same time, more extraverted and curious individuals did not sleep differently from their more timid counterparts, despite appraising their sleep as better. In the end, it is indeed those without fears and dreads that are more likely to receive the blessing of sleep, as opined by the famed author of Dracula. Moreover, our investigation revealed it is also those that are responsible, conscientious, and less angry that are more likely to receive that blessing and receive it regularly.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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APPENDIX

Table A1. Correlations among all personality variables, age, and gender (N = 359–382)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Neuroticism	—																		
2. Stress reaction	.72*	—																	
3. Alienation	.45*	.52*	—																
4. Aggression	.36*	.47*	.41*	—															
5. Conscientiousness	−.21*	−.32*	−.34*	−.19*	—														
6. Control	−.05	.00	.04	−.07	.28*	—													
7. Achievement	−.09†	−.07	−.02	−.04	.38*	.18*	—												
8. Agreeableness	−.09†	−.12*	−.07	−.22*	.31*	.08	.18*	—											
9. Extraversion	−.19*	−.22*	−.18*	−.20*	.28*	.03	.29*	.47*	—										
10. Well-being	−.31*	−.30*	−.21*	−.17*	.35*	.08	.36*	.31*	.56*	—									
11. Social closeness	−.17*	−.17*	−.16*	−.17*	.15*	.00	.06	.33*	.41*	.33*	—								
12. Social potency	−.11*	−.05	−.11*	−.01	.20*	.01	.39*	.07	.44*	.39*	.12*	—							
13. Harm avoidance	.02	−.15*	−.04	−.20*	.01	.03	−.19*	.04	.00	−.01	.11*	−.18*	—						
14. Openness	−.17*	−.17*	−.09†	−.06	.29*	.14*	.43*	.36*	.55*	.49*	.18*	.43*	−.17*	—					
15. Traditionalism	.02	.03	.12*	−.04	.04	.09†	−.15*	.12*	−.02	.02	.11*	−.13*	.17*	−.17*	—				
16. Age	−.25*	−.23*	−.13*	−.09†	.01	.09†	.00	.04	.08	.13*	.07	−.10†	.12*	.04	.08	—			
17. Gender	.08	.00	−.10†	−.14*	.11*	−.11*	−.12*	.24*	.02	.04	.13*	−.14*	.20*	−.04	.06	−.02	—`		
18. Race	.10*	.06	.26*	−.01	−.20*	.03	−.12*	−.02	.03	−.01	−.03	−.05	.24*	.02	.08	−.02	.13*		
19. Education level	−.18*	−.10*	−.26*	−.11*	.14*	−.01	.22*	.01	−.02	.08	−.07	.22*	−.10	.16	−.25*	−.11	−.06	−.23*	—
20. Income	−.13*	−.13*	−.22*	−.03	.13*	.00	.16*	−.04	.03	.06	.10	.20*	−.04	.02	−.13*	−.13*	−.18*	−.21*	.38*

Note: Gender was coded 0 for male and 1 for female. Race was coded 0 for White and 1 for non-White. *$p < .05$. †$p < .10$.

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Table B1. Correlations among all sleep variables and covariates (N = 371–382)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Sleep amount (*M*)	—																				
2. Sleep amount (*V*)	−.14*	—																			
3. Sleep continuity index (*M*)	−.11*	.34*	—																		
4. Sleep continuity index (*V*)	−.33*	.64*	−.75*	—																	
5. Sleep onset latency (*M*)	−.37*	.35*	−.66*	.69*	—																
6. Sleep onset latency (*V*)	−.36*	.41*	−.62*	.77*	.88*	—															
7. Sleep fragmentation (*M*)	.20*	.13*	−.77*	.37*	.13*	.13*	—														
8. Sleep fragmentation (*V*)	−.22*	.62*	−.63*	.85*	.39*	.43*	.50*	—													
9. Wake after sleep onset (*M*)	−.09†	.29*	−.89*	.68*	.39*	.41*	.67*	.58*	—												
10. Wake after sleep onset (*V*)	−.26*	.57*	−.65*	.89*	.49*	.53*	.29*	.72*	.72*	—											
11. Subjective sleep quality (*M*)	.07	−.15*	.17*	−.17*	−.10*	−.13*	−.10†	−.12*	−.19*	−.18*	—										
12. Subjective sleep quality (*V*)	.01	.15*	−.07	.07	.01	−.02	.04	.07	.10*	.11*	−.43*	—									
13. Sleep efficiency (*M*)	.60*	−.39*	.77*	−.78*	−.80*	−.74*	−.33*	−.58*	−.65*	−.63*	.15*	−.04	—								
14. Sleep efficiency (*V*)	−.49*	.59*	−.47*	.73*	.60*	.73*	.09†	.54*	.38*	.58*	−.14*	.08	−.72*	—							
15. Time in bed (*M*)	.64*	.21*	−.61*	.39*	.35*	.32*	.53*	.30*	.54*	.35*	−.07	.05	−.21*	.10*	—						
16. Time in bed (*V*)	−.14*	85*	−.31*	.60*	.25*	.31*	.15*	.61*	.31*	.60*	−.18*	.17*	−.33	.43*	.16*	—					
17. Age	.06	−.16*	.07	−.09†	−.02	−.01	−.08	−.12*	−.05	−.10†	.19*	−.19*	.07	−.07	.01	−.18*	—				
18. Gender	.20*	.01	.12*	−.08	−.13*	−.07	−.14*	−.12*	−.01	−.01	−.04	.14*	.17*	−.05	.10†	−.01	−.02	—			
19. Race	−.29*	.20*	−.30*	.39*	.31*	.36*	.06	.27*	.33*	.35*	−.18*	−.01	−.44*	.43*	.07	.24*	−.02	.13*	—		
20. Education level	.05	−.12*	.11*	−.16*	−.19*	−.21*	.01	−.08	−.06	−.12*	.09†	−.07	.17*	−.15*	−.11*	−.14*	−.11*	−.06	−.23*	—	
21. Income	−.02	−.16*	.14	−.18*	−.12*	−.17*	−.04	−.12*	−.15*	−.17*	.16*	−.06	.13*	−.21*	−.16*	−.14*	−.13*	−.18*	−.21*	.38*	—

Note: Gender was coded 0 for male and 1 for female. Race was coded 0 for White and 1 for non-White. *$p < .05$. $^{\dagger}p < .10$.

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Table C1. Inter-correlations between specific sleep and personality variables (N = 368–379)

Variable	Sleep amount (M)	Sleep amount (SD)	Sleep continuity (M)	Sleep continuity (SD)	Sleep onset latency (M)	Sleep onset latency (SD)	Sleep frag. (M)	Sleep frag. (SD)	Wake after sleep onset (M)	Wake after sleep onset (SD)	Subjective sleep quality (M)	Subjective sleep quality (SD)	Sleep efficiency (M)	Sleep efficiency (SD)	Time in bed (M)	Time in bed (SD)
1. Neuroticism	0.02	0.19*	−0.21*	0.18*	0.16*	0.14*	0.15*	0.17	0.19*	0.14*	−0.32*	0.22*	−0.17*	0.11*	0.18*	0.16*
2. Stress reaction	−0.03	0.17*	−0.17*	0.19*	0.14*	0.17*	0.09†	0.15	0.16*	0.15*	−0.27*	0.18*	−0.16*	−0.15*	0.13*	0.15*
3. Alienation	−0.16*	0.26*	−0.19*	0.26*	0.24*	0.25*	0.06	0.20	0.14*	0.20*	−0.20*	0.09†	−0.28*	−0.27*	0.06	0.25*
4. Aggression	0.03	0.07	−0.09†	0.08*	0.09†	0.08	0.06	0.08*	0.07	0.04	−0.14*	0.04	−0.09†	0.04	0.10*	0.09†
5. Conscientiousness	0.09†	−0.10†	0.20*	−0.22*	−0.16*	−0.18*	−0.12*	−0.21*	−0.17*	−0.17*	0.28*	−0.04	0.19*	−0.12*	−0.10*	−0.07
6. Control	−0.09†	0.01	0.02	0.01	0.02	0.00	−0.05	0.01	−0.02	0.01	0.08	−0.04	−0.05	0.07	−0.07	0.04
7. Achievement	−0.02	−0.02	0.06	−0.04	−0.05	−0.07	−0.06	−0.06	−0.03	0.02	0.17*	−0.03	0.06	−0.05	−0.07	−0.01
8. Agreeableness	−0.01	−0.01	0.04	−0.07	−0.04	−0.04	−0.04	−0.11*	−0.02	−0.02	0.10*	0.10	0.04	−0.02	−0.05	0.03
9. Extraversion	−0.05	−0.05	0.02	−0.01	0.00	0.03	−0.04	−0.05	−0.01	−0.01	0.25*	−0.08	−0.01	0.02	−0.05	0.03
10. Well-being	0.00	−0.08	0.07	−0.07	−0.04	−0.05	−0.07	−0.07	−0.04	−0.06	0.32*	−0.15*	0.04	−0.05	−0.03	−0.05
11. Social closeness	0.04	−0.07	0.09†	−0.09†	−0.06	−0.05	−0.10†	−0.11*	−0.06	−0.08	0.17*	−0.02	0.07	−0.05	−0.02	−0.01
12. Social potency	−0.01	−0.02	0.03	−0.05	0.00	−0.02	−0.04	−0.06	−0.03	−0.05	0.12	−0.04	0.02	−0.04	−0.03	0.03
13. Harm avoidance	−0.06	0.00	−0.10†	0.07	0.02	0.01	0.08	0.09	0.12*	0.08	0.04	−0.02	−0.11*	0.08	0.01	−0.03
14. Openness	−0.11*	0.05	−0.04	0.05	0.06	0.07	−0.01	0.02	0.05	0.07	0.12*	−0.06	−0.09†	0.10*	−0.04	0.11*
15. Traditionalism	0.06	0.04	0.02	0.00	0.04	0.03	−0.03	−0.03	−0.05	0.01	0.04	0.06	0.02	0.03	0.06	0.05

Note: M, average; V, variability. Gender was coded 1 for male and 2 for female. *$p < .05$. $^{\dagger}p < .10$.

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Table D1. Moderation of the personality–sleep relation by time elapsed between personality and sleep assessments (N = 369–379)

Variable	Average sleep duration	Sleep duration variability	Average sleep continuity	Sleep continuity variability	Average subjective sleep quality	Subjective sleep quality variability
Neuroticism × Time	.09	.02	.02	.01	.06	−.04
Conscientiousness × Time	.03	−.03	−.02	.02	−.00	−.01
Agreeableness × Time	.03	.00	−.06	.05	.01	.01
Extraversion × Time	−.07	−.04	−.04	.02	.01	−.02
Openness × Time	.02	−.05	.04	−.02	−.02	−.06
Stress reaction × *Time*	.05	.06	.07	−.04	.06	−.03
Alienation × *Time*	.10†	.06	.01	.04	.04	−.08
Aggression × *Time*	−.04	.06	.08†	.00	.07	−.06
Control × *Time*	−.06	−.02	−.03	.04	−.06	−.10†
Achievement × *Time*	.03	−.07	−.11*	.13*	−.01	−.08
Well-being × *Time*	.02	−.02	−.03	.00	.01	−.02
Social closeness × *Time*	−.01	.00	−.03	.02	−.02	−.04
Social potency × *Time*	−.02	.01	.01	.02	.05	−.02
Harm avoidance	.02	.01	−.05	.01	−.02	.06
Traditionalism × *Time*	−.05	.05	−.09†	.08	−.03	.13*

Note: *$p < .05$. $^{\dagger}p < .10$.

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