Subjective sleep quality exclusively mediates the relationship between morningness-eveningness preference and self-perceived stress response

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Eveningness preference has been associated with lower sleep quality and higher stress response compared to morningness preference. In the current study, female morning- ($n = 27$) and evening-types ($n = 28$) completed the Pittsburgh Sleep Quality Index (PSQI) and were additionally challenged with an arithmetical stress induction task. Evening-types reported lower subjective sleep quality and longer sleep latency than morning-types. Furthermore, evening-types reported higher self-perceived stress after the task as compared to morning types. Subjective sleep quality fully mediated the relationship between morningness-eveningness preference and stress response. Poor sleep quality may therefore contribute to the elevated health risk in evening-types.

Keywords

Pittsburgh Sleep Quality Index, chronotype, Morningness-Eveningness Questionnaire, stress induction, mediation analysis
Introduction

Individuals differ in the circadian phase position of biological and psychological rhythms. The concept of morningness/eveningness (M/E) maps this phenomenon on a scale from early to late chronotypes (Natale & Cicogna, 2002). Early chronotypes are referred to as morning-types (M-types) and present with significantly earlier peak times for body temperature (Horne & Ostberg, 1976), cortisol (Bailey & Heitkemper, 2001) and melatonin (Mongrain et al., 2004) than evening types (E-types). Furthermore, M-types and E-types differ in their sleep behavior. E-types prefer later bed times and later wake/rise times whereas M-types prefer early rise times and early bed times (Taillard et al., 1999). Due to educational and occupational demands, evening-orientated adolescents and adults often enforce rising before the circadian and homeostatic optimum, resulting in a lack of sleep on workdays, which they try to compensate at weekends (Brown et al., 2001). These irregularities can reinforce and cause sleep problems (Buboltz et al., 2001). Hence, most E-types experience a social jetlag, i.e. a discrepancy between their social and biological time and, as a result, they feel more tired and report less sleep quality than M-types (Wittmann et al., 2006). M-types, in contrast, show more regular sleep-patterns across work- and leisure days (Bailey & Heitkemper, 2001).

Sleep quality and duration are closely related to daytime functioning. Chronically disturbed sleep may result in daytime fatigue, mood changes, performance decrements, irritability, and memory difficulties (Buysse et al., 2005). Thus, sleep problems may affect academic effort (Engle-Friedman et al., 2003) and psychological and physical health (Buysse et al., 2008; Knutson et al., 2009).

Previous studies showed that E-Types are less emotionally, socially and motivationally stable than M-types (Cavallera & Giudici, 2008; DeYoung et al., 2007), and display lower heart rate variability (Roeser et al., 2012), a psychophysiological index of emotion regulation abilities (Appelhans & Luecken, 2006). Buschkens and colleagues (2010) found a positive relationship between eveningness and stress characterized by chronic non-
specific arousal. Additionally, Vollmer and colleagues (2011) reported higher school-, parent-
and self-related problems in adolescent E- than in M-types. Besides those studies which
suggest lower psychosocial functioning in E-types as compared to M-types, it has also been
found that susceptibility to stress varies during daytime as a function of chronotype (Willis et
al., 2005).

Taken together, these findings suggest associations between the three parameters M/E, sleep quality, and perceived stress. To further elucidate these relationships, we recruited M- and E-types, assessed their sleep quality and exposed them to a stress inducing task. We expected (1) better sleep quality and (2) lower perceived stress in M- compared to E-types. We further hypothesized that (3) sleep quality and perceived stress would be negatively related, and we assumed that (4) sleep quality may mediate the expected relation between M/E and elevated stress response.

Methods

Participants

We screened online $N = 471$ students of the University of Würzburg with the Morningness-Eveningness Questionnaire (MEQ, see below). Female participants ($n = 362$, 76.9%) reported significantly higher MEQ scores than males ($t_{469} = 2.45, p < .05$). Due to the high proportion of women and the confounding influence of sex, we recruited only females for the experimental sample. Women ($n = 63$) from the upper and lower 20% of the distribution (MEQ scores $\leq 44$ for E-type and $\geq 56$ for M-type) were selected for testing sessions in the laboratory. None of them reported psychiatric health problems.

To ensure also physical health, eight subjects were excluded because of taking medication other than contraceptives ($n = 3$), body-mass-index (BMI) $> 30$ kg/m$^2$ ($n = 3$), or baseline HR $> 100$ bpm ($n = 2$), leaving a final sample of $n = 55$ subjects (aged $M = 23.04$ years, $SD \pm 2.37$).

Questionnaires
Morningness-Eveningness Questionnaire (MEQ). The MEQ (Horne & Ostberg, 1976; Griefahn et al., 2001) identifies morningness-eveningness preference and consists of 19 items (Cronbach's $\alpha = .82$; Smith et al., 1989). Subjects can be classified in five categories: definite or moderate E-type, neutral type, moderate or definite M-type. MEQ scores and melatonin onset as a physiological marker of the circadian period correlate significantly, supporting the validity of the questionnaire (Griefhahn et al., 2001). Higher values indicate higher morningness preference.

Pittsburgh Sleep Quality Index (PSQI). The PSQI (Buysse et al., 1989) is a 4-week-retrospective questionnaire for the assessment of several sleep characteristics (Cronbach’s $\alpha = .83$, Buysse et al., 1989). Subjective ratings are provided for seven sleep-related components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Higher PSQI scores indicate lower sleep quality and higher sleep disturbance.

Subjective Stress Rating. To assess subjective stress, before and after stress induction, subjects indicated how stressful they experienced the past five minutes on a scale from 0 (not stressful at all) to 10 (very stressful).

Stress Induction

Stress was induced by a mental arithmetic task. The task was adapted from the Trier Social Stress Test (Kirschbaum et al., 1993). For 5 minutes, subjects had to subtract 13 from a four digit number as quickly as possible. After every wrong answer the observer told the participant to start again from the beginning. During the task a second observer was present and subjects were instructed to look straight into a video camera placed next to the experimenter and her colleague.

Procedure

Subjects were assigned randomly to the following experimental conditions: (a) M-types tested in the morning ($n = 14$), (b) M-types tested in the evening ($n = 13$), (c) E-types
tested in the morning \((n = 14)\) and \(d)\) E-types tested in the evening \((n = 14)\). Testing was conducted between 8-11 a.m. in the morning and between 4-7 p.m. in the evening. Each experimental session began with the assessment of demographic and control variables and completion of the PSQI, followed by baseline recording of heart rate and blood pressure (physiological data are reported in Roeser et al., 2012). Then, participants indicated their subjective stress level. After the stress induction, participants had to rate again their perceived stress. Finally, subjects were debriefed.

Statistical analysis

Differences between chronotypes in age, MEQ and PSQI scores (hypothesis 1) were tested with univariate ANOVAs. To check for successful stress manipulation and to test hypothesis 2, we calculated a repeated measures ANOVA with chronotype (M- vs. E-type) and time of day (morning vs. evening) as between-subject factors and trial (before vs. after stress induction) as within-subject factor.

To elucidate the relationship between M/E, sleep quality and perceived stress (hypotheses 3 and 4), we performed a mediation analysis whereby we followed the methodical guidelines as described by Baron and Kenny (1986). More precisely, we tested if PSQI components mediated the relationship between M/E preference and stress response, i.e. self-perceived stress after stress induction. We evaluated the mediation analysis with the Sobel test (Sobel, 1982). As we had directional hypotheses, all \(p\)-values are reported one-tailed.

Results

Participant characteristics

E-Types and M-Types did not differ in age. E-types had higher scores on the total PSQI and on its components sleep quality and sleep latency, indicating lower sleep quality and longer sleep latency (see Table 1 for all univariate ANOVAs). Indications of insomnia
(i.e. sleep latencies longer than 30 minutes and poor sleep quality) were existent in $n = 3$
participants, all classified as E-types.

**Stress response**

A significant main effect of trial confirmed successful stress manipulation (before: $M = 2.11$, $SD \pm 1.29$; after: $M = 8.29$, $SD \pm 1.81$; $F_{(1,51)} = 459.30, p < .001, \eta^2_p = .90$). A significant main effect of chronotype indicated differential stress levels in M- and E-types ($F_{(1,51)} = 4.81, p < .05, \eta^2_p = .09$). Post-hoc t-tests showed that E-types reported higher stress levels after stress induction ($M = 8.79, SD \pm 1.87$) compared to M-types ($M = 7.78, SD \pm 1.63$, $t_{(53)} = -2.13, p < .05$). Those differences were not present before stress induction ($t_{(53)} = -.83, ns$). The main effect of time of day, all two-way interactions between time of day (morning vs. evening), chronotype (M- vs. E-type) and trial (before vs. after stress induction), and the three-way interaction were non-significant (all $F's < 2.18, ns$).

**Mediation analysis**

MEQ was a significant predictor of PSQI total score ($F_{(1,53)} = 8.70, p < .01$, adj. $R^2 = .13, \beta = -.38$) and stress response ($F_{(1,53)} = 3.28, p < .05$, adj. $R^2 = .04, \beta = -.24$). PSQI also predicted the stress response ($F_{(1,53)} = 5.22, p < .05$, adj. $R^2 = .07, \beta = .30$). The overall regression model including MEQ and PSQI as predictors was also significant. ($F_{(2,52)} = 3.18, p < .05$, adj. $R^2 = .08$). However, while PSQI was still a significant predictor of the stress response ($\beta = .24, p < .05$), MEQ was not ($\beta = -.15, ns$). PSQI mediated the relationship between MEQ and stress response (Sobel $z = -1.81, p < .05$). A graphical illustration of the mediation model is depicted in Figure 1.

Testing relationships of PSQI-components and both MEQ and stress response led to significant results for subjective sleep quality and daytime dysfunction (Tab. 2).
regression model including MEQ and subjective sleep quality as predictors of stress response was significant ($F_{(2,52)} = 3.36, p < .05, \text{adj. } R^2 = .08$). Again, while subjective sleep quality was still a significant predictor of stress response ($\beta = .26, p < .05$), the influence of MEQ was no longer significant ($\beta = -.15, \text{ns}$). Subjective sleep quality mediated the relationship between MEQ and stress response (Sobel $z = -1.83, p < .05$).

The overall regression model including MEQ and daytime dysfunction as predictors of stress response was also significant ($F_{(2,52)} = 5.84, p < .01, \text{adj. } R^2 = .15$). Daytime dysfunction was still a significant predictor of stress response ($\beta = .37, p < .01$), whereas MEQ was not ($\beta = -.15, \text{ns}$). However, daytime dysfunction did not mediate the relationship between MEQ and stress response (Sobel $z = -1.56, \text{ns}$).

Discussion

The results of the present study indicate that E-types experienced lower overall sleep quality and specifically, lower subjective sleep quality and longer sleep latency. Both chronotypes responded to stress induction, but E-types presented with an elevated stress response. The difference was independent of testing time. Lower sleep quality was related to higher experienced stress independent of chronotype, and the relation between chronotype and self-perceived stress response was mediated by overall sleep quality, and specifically by subjective sleep quality.

Eveningness preference appears to be a risk factor for a widespread set of difficulties and mental problems. For instance, previous studies reported more symptoms of depression (Ong et al., 2008) and psychosomatic conditions (Mecacci & Rocchetti, 1998) in E-types as compared to the other chronotypes. Stress and emotional problems (Riemann et al., 2001), as well as chronic pain (Ohayon, 2005), and other psychosomatic health complaints (Motohashi & Takano, 1995) are known to be associated with impaired sleep. In line with these findings, E-types reported less restorative sleep in the present study. This might result from their social
Consequently, E-types were more susceptible to experience stress in the current study, which could also be seen in physiological indicators of stress and emotion regulation (Roeser et al., 2012). In addition to previous findings about the association of M/E, sleep and stress sensitivity, we investigated the structure of these interrelations in detail: Our results suggest that it is the poor sleep quality experienced by E-types that makes them more susceptible to perceiving stress. Poor sleep quality might also mediate the relationship between eveningness preference and emotional dysregulation as a risk factor to mental problems. A therapeutic implication of these findings is that an improvement of sleep quality should be especially targeted when psychiatric or psychosomatic patients present with an evening preference. Thereby, emotional problems might also be attenuated. Apart from psychotherapeutic sleep treatment, the introduction of flexible working hours might also help E-types to minimize their social jetlag and improve their sleep (Costa et al., 2006). Besides, results from recent animal studies suggest that synchronization of the circadian clock can be promoted by social interactions (Lone et al., 2011; Lone & Sharma, 2011). Interventions targeting social jetlag and sleep problems in E-types should therefore additionally consider their social environment.

A similar assumption about the link between M/E, sleep and stress was made by Gau and colleagues (2007). They found that eveningness preference in adolescents may be an indicator of underlying emotional or behavioral problems or of health risk behaviors such as substance abuse or suicidality. They claimed that early detection of disturbed sleep-wake patterns may enhance further assessment of any eventual psychopathology. While our results support this view, they further highlight the importance of subjective sleep quality, rather than more objective parameters like sleep duration or latency, as an underlying condition for successful stress coping. Notably, the difference in subjective sleep quality accounted for differences in the levels of perceived stress although it was not reflected in impaired daytime functioning.
However, generalization of our findings is limited. Firstly, we examined a sample of young female students. Future replications in representative samples would be desirable. Secondly, we cannot conclude that reduced sleep quality and elevated stress perception in E-types were due to social jetlag resulting from incompatible schedule demands. Additional information about the fit between chronotype and work schedule would have been necessary. Thirdly, our stress induction task may be not as externally valid as real-life stress, for example daily hassles. However, we used a standardized and well-evaluated stress induction (Kirschbaum et al., 1993), which successfully induced stress and therefore, can be considered less susceptible to subjective bias compared to retrospective questionnaire data.

To conclude, we found sleep quality to be the mediating mechanism between M/E and self-perceived stress response. Experiencing good sleep quality can therefore be considered an important precondition for coping with stress. Future investigations may consider this aspect when studying psychosocial functioning in chronotypes.

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Declaration of Interests

Conflict of Interests: Neither author has any conflict of interest.

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References


Table 1

Group differences between morning- and evening-types

<table>
<thead>
<tr>
<th></th>
<th>M-types (n = 27)</th>
<th>E-types (n = 28)</th>
<th>F(1,53)</th>
<th>p</th>
<th>ηp²</th>
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</thead>
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<td>Age</td>
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<td>23.11 (3.20)</td>
<td>.04</td>
<td>ns</td>
<td>.00</td>
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<td>Morningness-Eveningness Questionnaire</td>
<td>59.74 (2.74)</td>
<td>40.93 (4.70)</td>
<td>325.92</td>
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<td>.86</td>
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<td>6.86 (3.00)</td>
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<td>.18</td>
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<td>Subjective sleep quality</td>
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<td>1.18 (.67)</td>
<td>9.26</td>
<td>&lt; .01</td>
<td>.15</td>
</tr>
<tr>
<td>Sleep latency</td>
<td>.96 (.85)</td>
<td>2.18 (1.61)</td>
<td>12.09</td>
<td>&lt; .01</td>
<td>.19</td>
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<td>Sleep duration</td>
<td>.30 (.72)</td>
<td>.36 (.73)</td>
<td>.10</td>
<td>ns</td>
<td>.00</td>
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<tr>
<td>Habitual sleep efficiency</td>
<td>.19 (.62)</td>
<td>.46 (.79)</td>
<td>2.10</td>
<td>ns</td>
<td>.04</td>
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<td>Sleep disturbances</td>
<td>1.07 (.27)</td>
<td>1.11 (.32)</td>
<td>.18</td>
<td>ns</td>
<td>.00</td>
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<td>Use of sleeping medication*</td>
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<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
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<tr>
<td>Daytime dysfunction</td>
<td>1.30 (.61)</td>
<td>1.57 (.69)</td>
<td>2.45</td>
<td>ns</td>
<td>.04</td>
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</table>

*None of the participants reported to take sleeping medication.
Table 2
Regression analyses between PSQI-components, MEQ, and stress response

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<td>quality to stress response</td>
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<td></td>
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<td>Sleep latency to stress</td>
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<tr>
<td>response</td>
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<tr>
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<td>efficiency to stress</td>
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<td><strong>Sleep disturbances</strong></td>
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<td>MEQ to sleep disturbances</td>
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<td>stress response</td>
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*None of the participants reported to take sleeping medication.
Figure caption

Figure 1. Mediation model for the influence of sleep quality (PSQI) on the relationship between M/E (MEQ) and stress response (self-perceived stress after stress induction).

Standardized β-coefficients are depicted for the relation between M/E and sleep quality, sleep quality and stress response (adjusted for M/E), and M/E and stress response. β’ indicates the relation after it is adjusted for the mediator. Note that higher scores on the MEQ indicate higher morningness preference and higher scores on the PSQI indicate lower sleep quality. Asterisks indicate a p-value < .05* or < .01**.
Sleep Quality

\[ \beta = -.38^{**} \]

\[ \beta = .24^{*} \]

Morningness-
Eveningness

\[ \beta = -.24^{*} \]

\[ \beta' = -.15 \]

Self-perceived
Stress Response