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SHORT COMMUNICATION

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 with morningness preference. In the current study, female morning (n = 27) and evening (n = 28) types completed the Pittsburgh Sleep Quality Index (PSQI) and were additionally challenged with an arithmetic 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 than 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. (Author correspondence: karolin.roeser@uni-wuerzburg.de)

Keywords: Chronotype, Mediation analysis, Morningness-Eveningness Questionnaire, Pittsburgh Sleep Quality Index, Sleep, Stress induction

INTRODUCTION

Individuals differ in the circadian phase position of their 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 & Östberg, 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 and wake/rise times, whereas M-types prefer early rise 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 lack of sleep on workdays, which they try to compensate for on weekends (Brown et al., 2001). These irregularities can reinforce and cause sleep problems (Buboltz et al., 2001; Soehner et al., 2011; Tzischinsky & Shochat, 2011). Hence, most E-types experience a *social jetlag*, i.e., discrepancy between their social and biological times and, as a result, they feel more tired and report poorer sleep quality than M-types (Wittmann et al., 2006; Tzischinsky & Shochat, 2011). 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 (Beşoluk et al., 2011; Engle-Friedman et al., 2003; Gomes et al., 2011; Taylor et al., 2011) and psychological and physical health (Adan et al., 2010; Borisenkov et al., 2010; Buysse et al., 2008; Knutson et al., 2009; Levandovski et al., 2011).

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 nonspecific arousal. Additionally, Vollmer and colleagues (2011) reported higher school-, parent-, and self-related

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problems in adolescent E- than M-types. Besides those studies that suggest lower psychosocial functioning in E-types as compared with 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 of 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 with 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

The study protocol met the ethical principles set forth for biological rhythm research on human beings (Portaluppi et al., 2011). We screened online 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 ≤44 for E-type and ≥56 for M-type) were selected for laboratory testing sessions. None of them reported psychiatric health problems. To also ensure 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 heart rate (HR) >100 bpm (n = 2), leaving a final sample of 55 subjects (aged $M \pm SD$: 23.04 ± 2.37 yrs).

Questionnaires

Morningness-Eveningness Questionnaire (MEQ)

The MEQ (Griefahn et al., 2001; Horne & Östberg, 1976) identifies morningness-eveningness preference and consists of 19 items (Cronbach's α = .82; Smith et al., 1989). Subjects can be classified in five categories: definite and moderate E-type, neutral type, and moderate and 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-wk-retrospective questionnaire for the assessment of several sleep characteristics (Cronbach's α = .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 5 min 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 min, 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.

Study 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 08:00 and 11:00 h and between 16:00 and 19:00 h. 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 again rate their perceived stress. Finally, subjects were debriefed.

Statistical Analysis

Differences between chronotypes in age, MEQ, and PSQI scores (hypothesis 1) were tested with univariate analysis of variance (ANOVA). 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 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. For this purpose, we calculated regression analyses of which we report explained variance (adjusted R^2) and standardized beta coefficients (β). The mediation analysis was then evaluated with the Sobel test (Sobel, 1982). As we had directional hypotheses, all *p* values are reported one-tailed. For the univariate ANOVAs, effect sizes (partial eta-squared, η_p^2) are reported in addition to *p* values.

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 >30 min and poor sleep quality, were existent in three participants, all classified as E-types.

Stress Response

A significant main effect of trial confirmed successful stress manipulation (before: $M \pm SD$: 2.11 ± 1.29; after: $M \pm SD$: 8.29 ± 1.81; $F_{1,51} = 459.30$, $p < .001$, $\eta_p^2 = .90$). A significant main effect of chronotype indicated differential stress levels in M- and E-types ($F_{1,51} = 4.81$, $p < .05$, $\eta_p^2 = .09$). Post hoc *t* tests showed that E-types reported higher stress levels after stress induction ($M \pm SD$: 8.79 ± 1.87) compared with M-types ($M \pm SD$: 7.78 ± 1.63, $t_{53} = -2.13$, $p < .05$). Those differences were not present before stress induction ($t_{53} = -.83$, nonsignificant [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 nonsignificant (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, whereas 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 $z = -1.81$, $p < .05$). 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 (Table 2). The overall regression model including MEQ and subjective sleep quality as predictors of stress response was significant ($F_{2,52} = 3.36$, $p < .05$, adj. $R^2 = .08$). Again, whereas subjective sleep quality was still a significant predictor of stress response ($\beta = .26$, $p < .05$), the influence of MEQ was no longer significant ($\beta = -.15$, 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 ($F_{2,52} = 5.84$, $p < .01$, adj. $R^2 = .15$). Daytime dysfunction was still a significant predictor of stress response ($\beta = .37$, $p < .01$), whereas MEQ was not ($\beta = -.15$, ns). However, daytime dysfunction did not

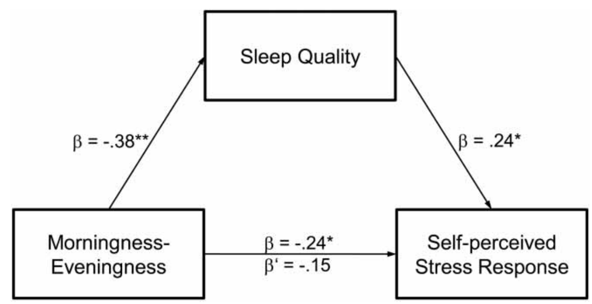

FIGURE 1. Mediation model for the influence of sleep quality (PSQI) on the relationship between M/E (MEQ) and stress response (self-perceived stress after stress induction). Standardized β coefficients are depicted for the relation between M/E and sleep quality, sleep quality and stress response (adjusted 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**.

TABLE 1. Group differences between morning types and evening types

	M-types (n = 27) *M* (*SD*)	E-types (n = 28) *M* (*SD*)	$F_{1,53}$	*p*	η_p^2
Age	22.96 (2.19)	23.11 (3.20)	.04	ns	.00
Morningness-Eveningness Questionnaire	59.74 (2.74)	40.93 (4.70)	325.92	<.001	.86
Pittsburgh Sleep Quality Index	4.52 (1.87)	6.86 (3.00)	11.92	<.01	.18
Subjective sleep quality	.70 (.47)	1.18 (.67)	9.26	<.01	.15
Sleep latency	.96 (.85)	2.18 (1.61)	12.09	<.01	.19
Sleep duration	.30 (.72)	.36 (.73)	.10	ns	.00
Habitual sleep efficiency	.19 (.62)	.46 (.79)	2.10	ns	.04
Sleep disturbances	1.07 (.27)	1.11 (.32)	.18	ns	.00
Use of sleeping medication*	na	na	na	na	na
Daytime dysfunction	1.30 (.61)	1.57 (.69)	2.45	ns	.04

*None of the participants reported taking sleeping medication.

TABLE 2. Regression analyses between PSQI components, MEQ, and stress response

PSQI component	β	p
Subjective sleep quality		
MEQ to subjective sleep quality	−.38	<.01
Subjective sleep quality to stress response	.31	<.05
Sleep latency		
MEQ to sleep latency	−.34	<.01
Sleep latency to stress response	.10	ns
Sleep duration		
MEQ to sleep duration	−.04	ns
Sleep duration to stress response	.07	ns
Habitual sleep efficiency		
MEQ to habitual sleep efficiency	−.14	ns
Habitual sleep efficiency to stress response	.15	ns
Sleep disturbances		
MEQ to sleep disturbances	−.09	ns
Sleep disturbances to stress response	.23	<.05
Use of sleeping medication*		
MEQ to use of sleeping medication	na	na
Use of sleeping medication to stress response	na	na
Daytime dysfunction		
MEQ to daytime dysfunction	−.25	<.05
Daytime dysfunction to stress response	.40	<.01

*None of the participants reported taking sleeping medication.

mediate the relationship between MEQ and stress response (Sobel $z = -1.56$, 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 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 (Levandovski et al., 2011; Ong et al., 2008) and psychosomatic conditions (Mecacci & Rocchetti, 1998) in E-types than 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 jetlag, i.e., the incompatibility between chronotype and work schedule (Wittmann et al., 2006). Consequently, E-types were more susceptible to experience stress in the current study, which could also be seen in physiological indicators of stress and emotional regulation (Roeser et al., 2012). In addition to previous findings about the association between 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 for 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, introduction of flexible working hours might also help E-types 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 & Sharma, 2011; Lone et al., 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), who 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. Although our results support this view, they further highlight the importance of subjective sleep quality, rather than more objective parameters, such as sleep duration or latency, as an underlying condition for successful stress coping. Notably, 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 not be 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) that successfully induced stress and, therefore, can be considered less susceptible to subjective bias compared with 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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