The influence of subjective sleep quality on the association between eveningness and depressive symptoms.

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Abstract

Increasing evidence suggests that eveningness is associated with increased risk for depression. Eveningness, however, is also associated with poor sleep quality and the unique role of eveningness in depressive symptomatology remains to be elucidated. The goal of the current study, therefore, was to examine the inter-relationships between eveningness, subjective sleep quality and depressive symptoms in healthy participants free of current or previous depression and sleep disorder. Here, 167 healthy participants (mean age 24.16, 77/23 females/males) completed the reduced Morningness-Eveningness Questionnaire (rMEQ), the Pittsburgh Sleep Quality Index (PSQI) and the Centre for Epidemiological Studies Depression Scale (CES-D). Bootstrap mediation analysis for a simple mediation model including rMEQ, PSQI and CES-D was applied. Eveningness was associated with increased depressive symptoms and mediation analysis showed that this relationship was partly mediated by sleep quality. Our results suggest that indicators of impaired psychological function observed in evening-type individuals cannot be attributed exclusively to disturbed sleep. We suggest that interventions that target both sleep quality and dysfunctionl cognitive styles would be optimal to promote well-being in evening-type individuals.

Keywords: Chronotype; Depression; Sleep; Mediation

Introduction

The morningness-eveningness continuum refers to individual differences in sleep-wake behaviour, preferred phase of the sleep-wake cycle and time of day preference (Horne and Östberg, 1976). Morning-type individuals prefer to rise and retire early and optimal mental and physical performance is achieved in the earlier hours of the day. Evening-types, by contrast, rise late, prefer to retire to bed late and generally plan daily activities for later in the day/evening when they are feeling at their best.

In addition to differences in diurnal rhythmicity, morning- and evening-types also differ across a range psychological dimensions. Morning-types are reported to be more conscientious and less neurotic than evening-types (Duggan et al., 2014), more risk averse (Ponzi et al., 2014; Wang and Chartrand, 2015) and less impulsive (Hwang et al., 2016). Increasing research also suggests that evening-types are at increased risk of developing mental health problems – particularly depression (Fabbian et al., 2016). Across the general population late chronotype is associated with increased depressive symptoms (Levandovski et al., 2011; Merikanto et al., 2013, 2015; Togo et al., 2017), diagnosis of depression and use of antidepressant medication (Merikanto et al., 2013, 2015)

Eveningness is also associated with poor sleep quality and a range of sleep complaints. For example, Taillard *et al.* observed an association between eveningness and a number of markers of sleep quality and duration including greater need for sleep, less time in bed during the week compared to ideal sleep needs, more irregular sleep/wake habits and greater caffeine consumption (Taillard et al. 1999). Selvi and colleagues (2012) reported that later chronotype adolescents and young adults were significantly more likely to report poor sleep quality and daytime dysfunction (Selvi et al. 2012). Similar results were reported by Rique *et al.* (Rique et al. 2014) who observed reduced sleep quality in young adult later chronotypes as compared to age-matched individuals with a more morning profile, but no

between-group differences in daytime sleepiness. Eveningness is also associated with higher scores on the Insomnia Severity Index – a 7 item self-report instrument that includes measures of sleep onset, maintenance and sleep problem interference with daily functioning (Selvi et al. 2017).

Together, the above data suggest that eveningness is related to inadequate sleep patterns. In light of this, and the recognition that adequate sleep is essential for health and development (Patte et al. 2017) and that poor quality sleep is consistently related to impaired performance and adverse physical and mental health outcomes (Galinsky et al. 2017), it is not unreasonable to suggest that the relationship between eveningness and impaired psychological function and mental health may be mediated by sleep quality. Data on the influence of sleep quality on mood and emotional processing and its relation to chronotype are, however, equivocal. For example, Levandovski and colleagues observed a positive relationship between chronotype (estimated as the midpoint of sleep on work free days corrected for sleep debt accumulated during the working week) and scores on the Beck Depression Inventory - i.e. the more evening-type the individual the greater the depression symptoms, and also a relationship between social jetlag (the misalignment of biological and social time and calculated as the absolute difference in hours between the uncorrected midpoint of sleep free days and mid-sleep point on work days) and depression symptoms (Levandovski et al. 2011). More recently, Roeser *et al.* explored the relationship between chronotype, subjective sleep quality and acute stress (as measured by the arithmetic stress-induction task) in morning and evening-type females (Roeser et al. 2012a). Later chronotype individuals reported higher task-induced stress, but this effect was entirely mediated by subjective sleep quality. In both cases (Levandovski et al. 2011; Roeser et al. 2012a) the authors suggest that interventions that aim to reduce circadian misalignment or improve sleep quality may be useful strategies to prevent the onset of depression or stress-related

psychiatric disorder. In a novel approach, Tavernier and Wiloughby (2014) explored three aspects of psychosocial function (academic achievement, intrapersonal adjustment and alcohol consumption) in morning and evening chronotypes classified as either good or poor sleepers (Tavernier and Willoughby, 2014). Good sleepers (irrespective of chronotype) reported significantly better intrapersonal adjustment whereas alcohol consumption was higher in evening-types (irrespective of sleep quality). Together, these data (Levandovski et al. 2011; Roeser et al. 2012a; Tavernier and Willoughby, 2014) suggest that aspects of psychosocial function, response to acute stress and depressive symptoms appear to be more associated with sleep quality rather than eveningness *per se.*

By contrast, others have suggested that eveningness represents an independent risk factor, beyond other sleep characteristics, for psychosocial and emotional dysfunction. Simor *et al.* (2015) identified eveningness as an independent risk factor for greater negative emotionality, irrespective of age, gender, circadian misalignment or sleep complaints (Simor et al. 2015). Merikanto and colleagues observed, in a large population based study, that evening types were nearly 3 times more likely than morning types to report depression diagnosed or treated by a practitioner within the 12 months prior to completing their study after controlling for a number of potential confounds including subjective sleep duration (Merikanto et al. 2015). Similarly, Antypa *et al.* (2015) observed a clear association between eveningness and depression after adjusting for sociodemographic, somatic health, and sleep-related factors. (Antypa et al. 2015). Together, these findings (Antypa et al. 2015; Merikanto et al. 2015; Simor et al. 2015) suggest that psychological and emotional dysfunction and depression symptoms may be partially mediated by sleep quality and that eveningness should be considered an important factor for mental health problems.

Here we aim to examine the inter-relationship between eveningness, subjective sleep quality and depressive symptoms in healthy participants free of current or previous

depression and sleep disorder. Based on the weight of current evidence we make the guarded prediction that eveningness *per se* reflects an independent risk factor for depressive symptoms partially mediated by sleep quality.

Methods

Participants

All procedures were approved by the local Research Ethics Committee and all participants provided informed consent prior to completing the survey. A total of 286 participants completed an online survey (Qualtrics®, Provo, UT). Participants were subsequently excluded if they reported: 1) current or previous diagnosis of depression or anxiety, 2) current or previous diagnosis of sleep disorder, of if they failed to complete the entire survey. After application of these exclusion criteria 167 participants were included in the final analysis.

Questionnaires

Chronotype was assessed using the 5-item reduced Morningness-Eveningness Questionnaire (Adan and Almirall, 1991). The rMEQ consists of five items and participants are required to indicate their response on a 4-point scale (e.g "during the first half hour after you wake up in the morning, how do you feel?":"very tired", "fairly tired", "fairly refreshed", and "very refreshed"). This scale has good internal consistency ($\alpha = .86$) and higher scores indicate increased morningness. Sleep quality was determined using the Pittsburgh Sleep Quality Index (PSQI; Buysse et al. 1989). This scale produces a global sleep quality score, which is created by summing each of the subscales: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medication, and

daytime dysfunction. The PSQI has high internal consistency (α = .83). Items are answered either using a 4-point scale or by indicating time (e.g. ‘‘During the last month, how often have you had trouble sleeping because you wake up in the middle of the night or early morning?’’: “not during the last month”, “less than once a week”, “once or twice a week”, “more than three times a week”). Higher scores on the PSQI indicate worse sleep quality, with scores greater than 5 indicating clinically poor sleep quality. Neuroticism was assessed using the 12 neuroticism-related items taken from the revised Eysenck Personality Questionnaire (EPQ-R; Eysenck et al. 1984). Participants are required to make a binary (yes/no response) to each item and neuroticism is calculated as the sum of yes responses. Depressive symptoms were assessed using the Centre for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977). Participants were required to indicate how often (rarely, some of the time, a moderate amount of time, all of the time) they have felt a certain way in the last 7 days (e.g. “During the past week I felt that everything I did was an effort”). The CES-D has high internal consistency (α = .85). Participants were also asked to indicate current or previous diagnosis of depression or sleep disorder.

Statistical treatment

Simple Pearson’s correlations were used to examine associations between demographic characteristics, sleep quality, neuroticism, depressive symptoms, and moningness-eveningness. Mediation analyses included, respectively, depressive symptoms (CES-D), eveningness (rMEQ) and sleep quality (PSQI) as the dependent, predictor and mediator variables. Bootstrap mediation analysis was implemented through the PROCESS toolbox (Preacher and Hayes, 2004). Bootstrap mediation, a nonparametric sampling procedure, does not impose the assumption of normality of the sampling distribution of the indirect effect, and therefore is considered to be more powerful for hypothesis testing for mediation analysis than the Sobel’s test, which assumes a normal distribution of the indirect

effect. We utilised 5000 bootstrap samples for coefficient and indirect estimation. The indirect effect was statistically significant if the 95% bias-corrected confidence intervals (CIs) for the indirect effect did not include zero. The completely standardized effect size (CS) is reported as an index of effect size. All statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS) v21 (IBM, New York, USA).

Attrition analyses

Attrition analyses confirmed that excluded participants had higher depressive symptomatology (mean and standard deviation included; *M* = 15.74, *SD* 10.1, excluded; *M* = 26.01, *SD* 12.97, $t_{(238)}$ = -.6.65, $p < .001$) poorer sleep quality (*M* = 6.69, *SD* 3.62, *M* = 8.41, *SD* 4.09, $t_{(238)}$ = -.3.26, $p = .001$), and higher neuroticism (*M* = 6.09, *SD* 3.62, *M* = 9.03, *SD* 2.73, $t_{(238)}$ = -.6.20, $p < .001$). In addition, excluded participant were older in age as compared to included participants (*M* = 30.1, *SD* 13.45, *M* = 24.16, *SD* 10.44, $t_{(238)}$ = -.3.7, $p < .001$) but similar in terms of chronotype (*M* = 13.43, *SD* 4.82, *M* = 13.37, *SD* 4.47, $t_{(238)}$ = .093, $p = .926$).

Results

Basic demographics and sample characteristics are shown in Table 1. At the bivariate level chronotype, age, neuroticism and sleep quality, but not gender, were significantly correlated with depressive symptoms. Specifically, increasing depressive symptoms was inversely associated with chronotype and age and positively associated with neuroticism and poorer sleep quality (please see Table 2).

Table 1 & 2 near here please.

As age and neuroticism were significantly were correlated with depressive symptoms we included these variables as covariates in the mediation analysis. Eveningness had a significant effect on depressive symptoms via sleep quality (point estimate -.13, standard error (SE) = .06, 95% confidence interval (CI) [-.26, -.04]. The effect size for the indirect effect was CS = -.06.The effect of chronotype on sleep quality (path a) was significant (b = -.15, SE = .05, p < .004, CI [-.26, -.05] with eveningness associated with poor sleep quality. Lower sleep quality was associated with higher levels of depressive symptoms (path b: b = .83, SE = .18, p < .001, CI [.48, 1.17]). The total effect of chronotype on depressive symptoms (path c) was significant (b = -.48, SE = .13, p < .002, (CI) [-.73, -.23]) such that increasing eveningness was associated with higher depressive symptoms. With the addition of sleep quality to the model the direct effect of eveningness on depressive symptoms (path c′) was significant (b = -.35, SE = .12, p = .005, CI [-.59, -.11]. The results support the notion that sleep quality partially mediated the relationship between eveningness and depressive symptoms (see Figure 1).

Figure 1 near here please.

Discussion

The goal of the current work was to examine the influence of sleep quality on the association between eveningness and depressive symptoms in healthy participants free of current or previous depression and sleep disorder. A burgeoning corpus suggests that eveningness is associated with depression, antidepressant use and depressive symptoms (Levandovski et al. 2011; Merikanto et al. 2015, 2013; Togo et al. 2017). In line with

previous findings we observed that eveningness was associated with increased depressive symptoms.

Research has also demonstrated an association between eveningness and a number of sleep-related complaints, sleep duration and sleep quality (Rique et al. 2014; Selvi et al. 2017, 2012; Taillard et al. 1999). Few studies, however, have directly investigated the impact of sleep quality on the association between eveningness and psychological and emotional function. Sleep quality has been reported to completely mediate the effect of eveningness on acute stress in female participants (Roeser et al. 2012a) and better psychosocial function irrespective of chronotype (Tavernier and Willoughby, 2014). Moreover, social jetlag is associated with increased depressive symptoms (Levandovski et al. 2011). Based on this evidence, interventions that target sleep quality and work/study schedules that match individual circadian rhythms would be of benefit in improving emotional well-being. An exclusive focus on disturbed sleep characteristics as indicators of emotional well-being and mental health in later chronotype individuals, however, may be suboptimal as a number of previous studies have demonstrated that the association between eveningness and depression remains after controlling for a range of sleep-related factors (Antypa et al. 2015; Merikanto et al. 2015).

The putative unique role of eveningness in risk for depression and impaired psychological function remains to be fully understood although emerging evidence highlights a number of mechanisms whereby emotional dysfunction may emerge in evening-type individuals. For example, Antypa and colleagues found cognitive reactivity (the activation of negative thoughts in response to low mood) and rumination to be mediators of the association between eveningness and depression, independent of insomnia and neuroticism (Antypa et al. 2017). Rumination, which can be defined as repetitive and passive thoughts that focus an individual's depressive symptoms as well as the possible causes and consequences of those

symptoms is reported to be not only associated with more severe depressive symptoms but also increased vulnerability for depression (Aker et al. 2014; Liu et al. 2017). Related to the findings of Antypa and colleagues (2017) lower resting heart rate variability, which is an index of stress vulnerability, is inversely related to negative facets of rumination (e.g. brooding) (Williams et al. 2017) and eveningness is associated with lower resting heart rate variability (Roeser et al. 2012b). We have previously shown that eveningness is associated with increased emotion suppression (considered maladaptive) and reduced emotion reappraisal (adaptive) controlling for age, gender, depressive symptoms, neuroticism and sleep quality. Trait expressive suppression and reduced cognitive reappraisal are known to increase depression risk (Watts and Norbury, 2017). Furthermore, eveningness has been associated with increased recognition of sad facial expressions (Berdynaj et al. 2016; Horne et al. 2017) and reduced allocation of attentional resources to happy faces in evening-type individuals as compared to morning/intermediate-types similar in terms of age, gender, sleep quality, depressive symptoms, trait anxiety and neuroticism (Berdynaj et al. 2016).

Neuroimaging studies are also beginning to shed light on the neural substrates of eveningness. In a large voxel-based morphometry study Takeuchi and colleagues (2015) observed increased grey matter density in posterior parietal cortex and precuneus and reduced grey matter density in orbitofrontal regions (Takeuchi et al. 2015). Later chronotype has also been associated with an enhanced amygdala response to negative stimuli and reduced amygdala-cingulate connectivity (Horne and Norbury, 2018a) and localised atrophy in the subiculum region of the right hippocampus (Horne and Norbury, 2018b). Increased amygdala reactivity to negative stimuli and reduced amygdala-fronto connectivity are widely reported in acute depression (Disner et al. 2011). Similarly, depression is associated with reduced hippocampal volume (see Schmaal et al. 2015 for a recent meta-analysis) and both the amygdala and hippocampus are implicated in emotion processing and regulation. Using

Diffusion Tensor Imaging (DTI) Rosenberg *et al.* reported significantly lower fractional anisotropy (a measure of microstructural integrity) in the white matter underlying the left anterior cingulate cortex (ACC) and corpus callosum in evening-type healthy males free of current or previous psychiatric disorder (Rosenberg et al. 2014). Notably, white matter underlying the ACC and corpus callosum are reportedly affected by depression (Kempton et al. 2011; Matsuoka et al. 2017; Repple et al. 2017) and risk for depression (Huang et al. 2012). Together, these data (Antypa et al. 2017; Berdynaj et al. 2016; Watts and Norbury, 2017) demonstrate that eveningness is associated with a number of cognitive and physiological vulnerabilities and altered structural integrity (Rosenberg et al. 2014; Takeuchi et al. 2015) which may confer risk for future depression.

This study has a number of limitations that should be considered when interpreting the results. First, the cross-sectional study design precludes causal inference. Well-designed prospective studies are required to better understand the causal relationship between eveningness, sleep quality and psychological function. Second, we use the reduced morningness-eveningness questionnaire (Adan and Almirall, 1991) to determine chronotype, whereas a number of previous studies have used the Munich Chronotype Questionnaire (MCTQ, Roenneberg et al. 2003). The MCTQ correlates with rMEQ but the former includes additional metrics such as social jetlag which may be relevant to the current work. Third, we did not measure insomnia and previous research has demonstrated a mediating effect of insomniac symptoms on psychological function (Simor et al. 2015). Finally, current and previous depression or sleep disorder was determined via self-report rather than access to medical records and/or structured clinical interview which may have led to an underestimation of these conditions in the current sample.

The current findings suggest that indicators of impaired psychological function observed in healthy, never-depressed, evening-type individuals cannot be attributed

exclusively to disturbed sleep. We suggest that interventions that target both sleep quality and dysfunctionl cognitive styles would be optimal to promote well-being in evening-type individuals. Here, we limited our sample to participants free of current or previous depression and sleep disorder. If a similar mediation model as reported here applies to individuals with acute depression interventions that target both eveningness and sleep are warrented. Future work would benefit from including patient populations to test the efficacy of such interventions with the ultimate aim of developing more personalised medicine.

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Variable	*M* (SD)	Range (this sample)	Range (original scale)
Age	24.16 (10.44)	18-80	-
Gender	Female 129 (77%); Male 32 (23%)	-	-
Neuroticism	6.98 (3.63)	0 - 12	0 - 12
Depression symptoms	15.74 (11.97)	0 - 47	0 - 60
Sleep quality	6.69 (3.62)	0 - 15	0 - 21
Chronotype	13.43(4.81)	4 - 25	4 - 25

Table 1. Descriptive statistics: Basic demographics.Neuroticism as indexed by the EPQ-R, depression symptoms (CES-D), sleep quality (PSQI), chronotype (rMEQ). Values show mean (SD). Also included are questionnaire range (minimum-maximum) for the study sample and original scale.

	rMEQ	Age	Gender	PSQI	Neuroticism	CES_D
rMEQ	1	.244**	.290**	-.301**	-.230**	-.358**
Age		1	.336**	-.156*	-.251**	-.174*
Gender			1	-.139	-.132	-.080
PSQI				1	.461**	.559**
Neuroticism					1	.636**
CES_D						1

Table 2. Bivariate correlations between depression symptomatology, chronotype, age, neuroticism and sleep quality (**p <.01,* p <.05)

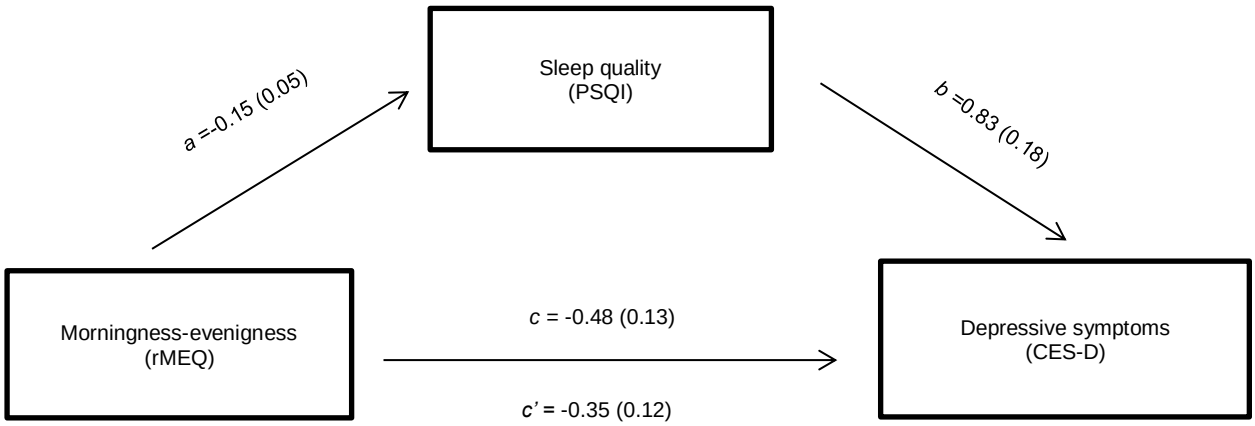

Figure 1. Simple mediation model for morningness/eveningnesss and depressive symptoms via sleep quality. Shown are unstandardized path coefficients and standard error (SE).