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Chronotype is associated with psychological well-being depending on the composition of the study sample

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Abstract

Past studies examining the effect of chronotype and social jetlag on psychological well-being have been inconsistent so far. Here, we recruited participants from the general population and enquired about their natural sleeping behavior, sleep quality, depressive symptoms, and perceived stress. Partial correlations were computed between sleep variables and indicators of psychological well-being, controlling for age and sex. Less sleep during work days was found a good indicator for impairments in psychological well-being. In exploratory follow-up analyses, the same correlations were calculated within groups of early, intermediate, and late chronotype. We observed that the composition of the sample in terms of chronotype influenced whether associations between sleep variables and psychological well-being could be observed, a finding that is advised to be taken into account in future studies.

Keywords

chronotype, depression, sleep, stress, well-being

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Introduction

The biological clock synchronizes to signals from the environment, which are also known as Zeitgebers, in an active process that has been termed entrainment (Roenneberg et al., 2007b). A group of people who share the same phase of entrainment have a certain chronotype (Roenneberg, 2015). Epidemiological studies revealed that chronotype follows a normal distribution across the population. Furthermore, chronotypes change over the life span: until the age of about 20 years, one's chronotype typically becomes later, while this reverses again when growing older. Finally, women reach their latest chronotype at the age of 19.5 years on average, for men this is 21 years (Roenneberg et al., 2007a). The later one's chronotype is, the more misalignment there will often be between the biological (inner) and social (outer) clock, a phenomenon referred to as social jetlag (SJL) (Wittmann et al., 2006).

Multiple tools exist to assess chronotype (Adan et al., 2012). The first scale developed for this specific purpose was the Morningness-Eveningness-Questionnaire (MEQ; Horne and Ostberg, 1976), which enquires about preferred sleep and wake times, with higher scores indicating a greater tendency toward morningness. A more recently developed scale is the Munich Chronotype Questionnaire (MCTQ; Roenneberg et al., 2003), which enquires about one's actual sleep and wake times. Additionally, it distinguishes between work and free days, thus determining both chronotype and SJL within one and the same questionnaire. Whereas the MEQ has been used extensively in previous studies, for example to reveal associations of evening preference with depressive symptomatology (Hidalgo et al., 2009; Kitamura et al., 2010) and impaired sleep quality (Vardar et al., 2008), only few studies assessed chronotype and SJL with the MCTQ to examine their relation with depressive symptoms in the general population (Keller et al., 2016).

Whereas one study found that later chronotypes are more likely to have increased SJL and more depressive symptoms (Levandovski et al., 2011), another study described a positive correlation between chronotype and the risk for psychiatric symptomatology, but SJL did not increase this risk (Sheaves et al., 2016). Also, late chronotypes seem to experience more disturbed sleeping patterns than earlier types. For example, Wittmann et al. (2006) found that later chronotypes were more likely to show lower sleep quality and stronger depressed mood over the past week. Önder et al. (2014) reported significant, but small positive correlations of both chronotype and SJL with sleep quality. However, neither Rutters et al. (2014) nor Polugrudov et al. (2016) found associations between SJL and sleep quality.

In sum, there is currently no conclusive evidence linking MCTQ constructs to other sleep-related variables or depression. In this study, we therefore aimed to further clarify the associations by assessing sleep quality and depressive symptoms. As depressive symptomatology often occurs alongside sleep disruptions (Grandner et al., 2006; Hayashino et al., 2010), we expected both to be higher in later chronotypes and with increasing SJL. We furthermore added a third questionnaire enquiring about perceived stress, following up on preliminary evidence that reported an association of subjectively reported stress with chronotype (Kantermann et al., 2012), as well as with depression and sleep quality (Felder et al., 2017; Lemma et al., 2012).

Materials and methods

Study sample

Recruitment of participants was carried out with posters and online advertisements between July 2015 and July 2016. Except for excluding people performing shift work, there were no further criteria to participate in the online survey. Upon inclusion in the study, participants filled out the MCTQ via an online portal run by the Ludwig-Maximilians-Universität München. If participants provided their email address, they were invited to participate in a second survey via the online tool LimeSurvey. Here, sociodemographic data, information about depressive symptoms, sleep quality, and subjectively perceived stress were assessed. All questionnaires were administered in German. From the initial 1781 participants (1294 females; mean age=36.14, standard deviation (*SD*)=13.35) that filled in the MCTQ, 835 participants completed all questionnaires of the second survey (640 females; mean age=37.15, *SD*=13.41). The final sample for analysis included 1111 participants from the MCTQ and 588 participants from the second survey (sociodemographic data in Table 1).

The study was approved by the Medical Ethics Committee of the Charité—Universitätsmedizin Berlin. Informed consent was obtained from all participants.

Instruments

Chronotype and SJL. Chronotype and SJL were assessed with the MCTQ (Roenneberg et al., 2003). Among other features, it asks participants to estimate their sleep onset and wake-up time for work and free days separately. This allows a differential estimation of sleep duration (SDw = work days; SDf = free days) and also establishes the midpoint of sleep on work days (MSW) and on free days (MSF), the latter reflecting chronotype. Because sleep during work days is often shortened by social obligations, such as having to get up early for work, people accumulate a sleep debt that is mostly compensated for on free days by sleeping in for a longer time. As this delays the MSF, it must be accounted for in calculating an individual's chronotype by correcting the MSF for sleep debt (MSFsc: MSF sleep corrected). The difference between MSF and MSW determines the amount of SJL, indicating the misalignment of social and biological time (Wittmann et al., 2006). As sleep loss often accompanies SJL, we evaluated its relationship with variables reflecting psychological well-being as well. For exact calculations of MCTQ variables, see Table 2 (Roenneberg et al., 2004).

Patient Health Questionnaire 9. To assess depressive mood, we used the depression section of the German version of the Patient Health Questionnaire 9 (PHQ9) (Löwe et al., 2002). It contains nine items that span the criteria of Major Depression in the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-V). Item scores range from 0 to 3, which are then summed to determine depressive symptom severity (Kroenke et al., 2001).

Pittsburgh Sleep Quality Index. The Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989) assesses sleep patterns, quality of sleep, and sleep disturbances over a period of 4 weeks. Responses are sorted into seven components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, sleep medication, and daytime sleepiness. Each component can be scored between 0 and 3, thus allowing a general PSQI score with a maximum of 21 points, with higher scores indicating worse sleep quality.

Perceived Stress Scale. The 10-item-version of the Perceived Stress Scale (PSS) (Cohen and Williamson, 1988) was used, which assesses subjectively perceived stress over the past 4 weeks. Individual item scores range from 0 to 4, which are added up to a total score with a maximum of 40. Higher scores indicate higher levels of perceived stress.

Statistical analyses

Replication of epidemiological results. To confirm that our sample is comparable to the samples used in previous studies employing the MCTQ for chronotype assessment, we first examined the 1781 participants included in the first survey and compared the MCTQ scores to the epidemiological results from Roenneberg et al. (2007a). Individuals who did not provide information on sleep onsets or offsets, number of work days, use of sleep medication, engagement in shift work, and/or use of an alarm clock on free days were excluded (see Figure 1). Additionally, we excluded people who slept longer on work than on free days to enable more direct interpretation of results. With a proportion of 15 percent, participants with lost sleep

Table 1. Sociodemographic data for the first and second survey.

		First survey			Second survey		
		Male	Female	All	Male	Female	All
	n	305	806	1111	138	450	588
Age	*M* (*SD*)	38.38 (14.00)	37.10 (12.82)	37.45 (13.16)	38.49 (13.73)	38.44 (13.05)	38.45 (13.20)
Nicotine use	n	71	158	229	31	86	117
Cigarettes (n/day)	*M* (*SD*)	6.38 (6.14)	6.44 (6.89)	6.42 (6.65)	7.89 (6.84)	6.48 (7.28)	6.86 (7.17)
Alcohol use	n	230	527	757	101	299	400
Beer (glasses/day)	*M* (*SD*)	0.47 (0.60)	0.16 (0.31)	0.26 (0.44)	0.45 (0.60)	0.18 (0.36)	0.25 (0.45)
Wine (glasses/day)	*M* (*SD*)	0.24 (0.36)	0.28 (0.32)	0.27 (0.34)	0.23 (0.33)	0.29 (0.35)	0.27 (0.34)
Liquor (glasses/day)	*M* (*SD*)	0.07 (0.17)	0.03 (0.08)	0.04 (0.12)	0.08 (0.17)	0.03 (0.08)	0.04 (0.11)
Caffeine use	n	274	753	1027	123	422	545
Coffee (cups/day)	*M* (*SD*)	2.02 (1.57)	1.55 (1.25)	1.67 (1.36)	2.05 (1.71)	1.58 (1.26)	1.69 (1.38)
Caffeinated drinks (n/day)	*M* (*SD*)	0.27 (0.69)	0.19 (0.61)	0.21 (0.63)	0.24 (0.62)	0.21 (0.74)	0.21 (0.71)
Black Tea (n/day)	*M* (*SD*)	0.55 (1.21)	0.39 (0.88)	0.43 (0.98)	0.58 (1.22)	0.41 (0.92)	0.45 (1.00)

M = mean; *SD* = standard deviation; n = number.

Table 2. MCTQ variables with their abbreviations and computations.

Variable	Abbreviation	Computation
Sleep duration on work days/on free days	SDw/SDf	Sleep offset–sleep onset
Average sleep duration	aveSD	(SDw × amount of work days + SDf × amount of free days)/7
Midpoint of sleep on work days/on free days	MSW/MSF	Sleep onset + sleep duration/2
Midpoint of sleep on free days sleep corrected (chronotype)	MSFsc	If SDf ≤ SDw: MSF If SDf > SDw: MSF - (SDf - aveSD)/2
Social jetlag	SJL	MSF − MSW
Sleep loss	SLoss	(aveSD − SDw) × amount of work days

MCTQ: Munich Chronotype Questionnaire.

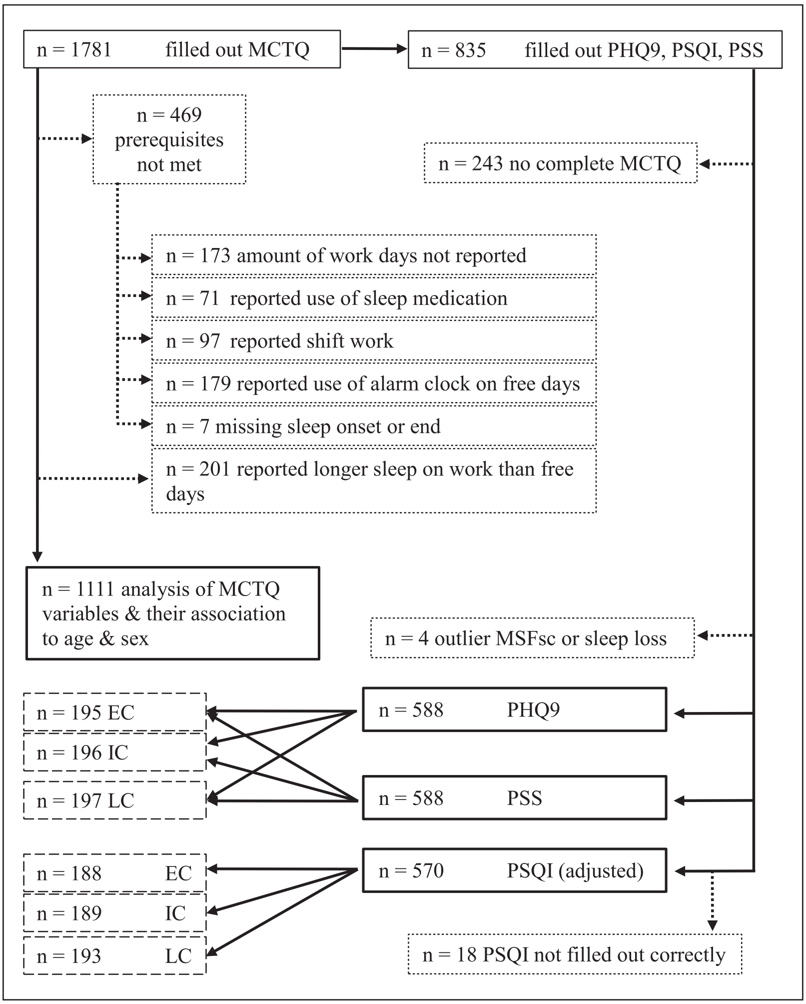

Figure 1. Flowchart describing amount of excluded participants (demarcated by dotted lines) and resulting composition of sample sizes for main analysis (demarcated by continuous lines) and exploratory analysis (demarcated by dashed lines).
EC: early chronotype; IC: intermediate chronotype; LC: late chronotype.

Table 3. Descriptive and statistical results for sex differences for MCTQ variables.

	All, *M* (*SD*)	Women, *M* (*SD*)	Men, *M* (*SD*)	*t*/*U* (*p*)
n	1111	806	305	–
Age	37.45 (13.16)	37.10 (12.82)	38.38 (14.01)	−1.07[a] (.285)
SDw (hours)	6.88 (0.97)	6.92 (0.99)	6.75 (0.89)	3.07[a] (.002)
SDf (hours)	8.22 (1.14)	8.29 (1.15)	8.04 (1.10)	−3.31[b] (.001)
MSFsc (hours:minutes)	4:02 (1:16)	3:56 (1:11)	4:18 (1:25)	−4.10[a] (<.001)
SJL (hours)	1.55 (0.93)	1.54 (0.90)	1.60 (1.01)	−0.96[a] (.336)
SLoss (hours)	1.87 (1.48)	1.90 (1.47)	1.79 (1.52)	−1.136[b] (.256)

MCTQ: Munich Chronotype Questionnaire; M: mean; SD: standard deviation; SDw: sleep duration during work days; SDf: sleep duration during free days; MSFsc: midpoint of sleep during free days sleep corrected; SJL: Social Jetlag; SLoss: sleep loss; *p*: significance value; *n*: sample size; *t*: *t*-test for independent samples; *U*: Mann–Whitney *U* test.
[a]Mann–Whitney *U* standardized statistics.
[b]Degress of freedom (*df*) = 1109.

on free days constitute a small but clearly defined subgroup in our sample. We acknowledge that this subgroup deserves separate attention. However, due to small proportion of participants in this study, we lack power to properly assess specific effects for this subgroup. Due to our cross-sectional design, we calculated correlations between MCTQ variables (SDw, SDf, MSF, MSFsc, SJL, and sleep loss) and age for the remaining 1111 participants and assessed the distributions of these variables in our sample. Sex differences were tested by means of a two-sample *t*-test.

Associations with psychological well-being. Before assessment of associations between MCTQ variables and psychological well-being, four participants were excluded from the second sample due to being outliers (>3 *SD*) on the MSFsc or sleep loss variables. The final samples for analysis comprised 588 participants for the PHQ9 and PSS, but 570 participants for the PSQI. As PHQ9 and PSQI values were not normally distributed, associations with MCTQ variables were calculated using nonparametric partial correlations (De Winter et al., 2016), controlling for age and sex. As PSS values were normally distributed, parametric partial correlation analysis was applied, again controlling for age and sex. Due to high collinearity between variables of the MCTQ, we refrained from applying multiple regression analysis.

As previous reports indicate that late chronotypes are especially vulnerable to reduced psychological well-being (Adan et al., 2012; Fabbian et al., 2016), associations may only appear in a subsample of our participants. We, therefore, divided the sample into equal thirds according to the MSFsc scores (early, intermediate, and late) and repeated nonparametric partial correlation analysis within each chronotype group as exploratory follow-up analyses.

All statistical analyses were performed with IBM SPSS Statistics for Windows, Version 22 (IBM Corp., Armonk, NY, USA). The significance threshold for all tests was set at $p < .05$. Multiple comparison correction was applied by controlling the false discovery rate (FDR) at $q = .05$, that is, we accepted a maximum of 5 percent false positives among the total number of tests (Benjamini and Hochberg, 1995).

Results

Replication of epidemiological findings

In the initial sample, which considered the MCTQ only, 77.9 percent of the participants stated that they worked 5 days a week, while 8.9 percent indicated to work more, and 13.2 percent to work less. Descriptive values and statistical results for sex differences are displayed in Table 3. Variable distributions (Figures S-1 to S-6) and correlational results (Table S-1) are provided as Online Resource.

Table 4. Descriptive and statistical results on sex differences for PHQ9, PSQI, and PSS.

	All, *M* (*SD*)	Women, *M* (*SD*)	Men, *M* (*SD*)	*t*/*U* (*p*)
PHQ9 ($n=588$)	5.48 (3.98)	5.68 (4.00)	4.85 (3.86)	−2.15[a] (.032)
PSQI ($n=570$)	4.03 (2.31)	4.10 (2.36)	3.80 (2.13)	−1.31[b] (.191)
PSS ($n=588$)	15.03 (6.84)	15.39 (6.96)	13.85 (6.34)	2.26[c] (.024)

M: mean; SD: standard deviation; PHQ9: Patient Health Questionannire 9; PSQI: Pittsburgh Sleep Quality Index; PSS: Perceived Stress Scale; *p*: significance value; *n*: sample size; *t*: *t*-test for independent samples; *U*: Mann–Whitney *U* test.
[a]Degrees of freedom = 586.
[b]Degrees of freedom = 568.
[c]Mann–Whitney *U* standardized statistics.

SDw, SDf, MSFsc, and SJL resembled normal distributions, whereas sleep loss was strongly right-skewed. Participants from the current sample were similar to Roenneberg's sample in terms of sleep timing (time one falls asleep, wakes up, and has their midpoint of sleep) and associations with age (all *r* between −.15 and −.38; $p<.001$), indicating that the higher the age, the lower SDw, SDf, MSFsc, SJL, and sleep loss tended to be. Women on average slept longer than men and had an earlier MSFsc (all $p\leq.002$). There were no sex differences for SJL or sleep loss. Whereas the MSFsc value was corrected for sleep duration, both SJL and sleep loss were associated negatively with SDw ($r=-.19$ and −.33, respectively; $p<.001$) and positively with SDf ($r=.27$ and .59, respectively; $p<.001$). We confirmed a positive association between MSFsc and SJL (r = .57; $p<.001$); thus, the later the MSFsc, the higher the amount of SJL. Sleep loss, however, showed no correlation with MSFsc ($p=.10$), but did show a strong positive association with SJL ($r=.48$; $p<.001$), illustrating a close connection between SJL and sleep loss.

Associations between MCTQ and psychological well-being

General distributions of the sum scores of the PSS resembled a normal distribution, whereas the distributions of PHQ9 and PSQI scores were right-skewed and steep (Online Resource: Figures S-7 to S-9). As peaks of the distributions were shifted to the left, the data illustrated that our sample mainly included participants experiencing higher levels of psychological well-being.

Not surprisingly, the three psychometric scales were strongly correlated among each other (all $r>.42$, $p<.001$). The PHQ9 and PSS showed significant differences between women and men (Table 4), with women scoring higher than men on both scales. For PHQ9 scores, we found a negative association with age ($r=-.13$; $p=.002$), indicating that men tended to show less depressive symptoms with increasing age. For PSS scores, there was a weak association with age ($r=-.09$; $p=.022$). There was no association between age and PSQI ($p=.332$).

After controlling for possible age and sex effects, PHQ9 values were negatively associated with SDw ($r=-.15$; $p<.001$). We did not observe any associations with other variables. For PSQI scores, we detected a negative association with SDw ($r=-.32$; $p<.001$), a weak negative association with SDf ($r=-.12$; $p=.005$), and a weak positive association with sleep loss ($r=.11$; $p=.007$). This indicated that impairments in sleep quality were stronger when sleep durations were shorter and the amount of sleep loss was higher. No associations were found for MSFsc or SJL. As the global score of the PSQI already incorporated sleep duration as a subscale, this might have introduced a bias in the associations. Therefore, we rebuilt sum scores of the PSQI, this time excluding sleep duration. As a result, the associations with SDf ($p=.063$) and sleep loss ($p=.419$) disappeared, whereas the association

Table 5. Partial correlations (controlled for age and sex) between PHQ9, PSQI, PSS, and MCTQ variables.

		PHQ9[a] (*df* = 584)	PSQI[a] (*df* = 566)	Adjusted PSQI[a] (*df* = 566)	PSS[b] (*df* = 584)
SDw	*r*	−.146***	−.317***	−.159***	−.064
	p (2-*tailed*)	.000	.000	.000	.122
SDf	*r*	−.012	−.117**	−.078	.012
	p (2-*tailed*)	.778	.005	.063	.770
MSFsc	*r*	.031	.029	.008	.005
	p (2-*tailed*)	.447	.496	.842	.910
SJL	*r*	.059	.050	−.018	.045
	p (2-*tailed*)	.153	.233	.676	.280
SLoss	*r*	.073	.113**	.034	.054
	p (2-*tailed*)	.077	.007	.419	.188

PHQ9: Patient Health Questionannire 9; PSQI: Pittsburgh Sleep Quality Index; adjusted PSQI: Pittsburgh Sleep Quality Index (without subscale sleep duration); PSS: Perceived Stress Scale; MCTQ: Munich Chronotype Questionnaire; SDw: sleep duration during work days; SDf: sleep duration during free days; MSFsc: midpoint of sleep during free days sleep corrected; SJL: Social Jetlag; SLoss: sleep loss; *r*: correlation coefficient; *p*: significance value; *df*: degrees of freedom.
[a]Nonparametric partial correlation.
[b]Parametric partial correlation.
**$p < .01$; ***$p < .001$

with SDw remained significant, although a bit weaker ($r = -.16$; $p < .001$). For the PSS score, we did not observe any association with the MCTQ variables (all $p > .05$). All results remained significant after FDR correction (Table 5).

Exploratory follow-up analysis with chronotype groups

For the PHQ9, early chronotypes displayed a negative association with SDw ($r = -.18$; $p = .014$) and with MSFsc ($r = -.15$; $p = .040$), whereas intermediate chronotypes only showed negative associations with SDw ($r = -.17$; $p = .017$). In the group of late chronotypes, PHQ9 was positively associated with MSFsc ($r = .19$; $p = .006$).

For the PSQI (taking the score without the subscale sleep duration, as discussed above), early chronotypes displayed a negative association with SDw ($r = -.23$; $p = .002$) and with MSFsc ($r = -.18$; $p = .014$), whereas intermediate chronotypes only showed negative associations with SDw ($r = -.21$; $p = .005$) and SDf ($r = -.17$; $p = .020$). In the group of late chronotypes, adjusted PSQI scores were positively associated with MSFsc ($r = .20$; $p = .005$).

For the PSS, early chronotypes displayed a negative association with SDw only ($r = -.16$; $p = .025$), whereas intermediate chronotypes and late chronotypes showed no associations at all. All results are listed in Table 6. Results of the exploratory analyses did not survive FDR correction.

Discussion

The aim of our study was to explore the relationship between chronotype-associated sleep variables and depression, sleep quality, and perceived stress in healthy individuals. We demonstrated that our sample corresponded well to Roenneberg's sample (Roenneberg et al., 2007a) in terms of sleep timing (i.e. onset, offset, duration, and midpoints of sleep). Also, we confirmed a negative association between chronotype and age, as well as sex-specific differences for chronotype. Women, on average, had an earlier chronotype than men. However, we did not find sex differences for SJL, but results largely have been inconsistent across

Table 6. Nonparametric partial correlations (controlled for age and sex) between PHQ9, adjusted PSQI, PSS, and MCTQ variables within chronotype groups.

		PHQ9			Adjusted PSQI			PSS		
		EC	IC	LC	EC	IC	LC	EC	IC	LC
df		191	192	193	184	185	189	191	192	193
SDw	*r*	−.177*	−.172*	−.083	−.230**	−.206**	−.041	−.161*	−.124	.040
	p (2-*tailed*)	.014	.017	.251	.002	.005	.571	.025	.084	.575
SDf	*r*	.034	−.080	.030	−.070	−.170*	.020	−.038	−.049	.104
	p (2-*tailed*)	.642	.268	.680	.344	.020	.779	.604	.498	.149
MSFsc	*r*	−.148*	−.124	.195**	−.180*	−.021	.204**	−.101	−.006	.138
	p (2-*tailed*)	.040	.085	.006	.014	.775	.005	.164	.929	.055
SJL	*r*	.030	.061	.031	−.056	−.092	.094	−.041	.064	.068
	p (2-*tailed*)	.681	.395	.663	.449	.212	.196	.569	.377	.348
SLoss	*r*	.138	.022	.063	.073	.010	.019	.067	−.010	.086
	p (2-*tailed*)	.055	.763	.378	.319	.895	.794	.356	.890	.233

PHQ: Patient Health Questionannire; adjusted PSQI: Pittsburgh Sleep Quality Index (without subscale sleep duration); PSS: Perceived Stress Scale; MCTQ: Munich Chronotype Questionnaire; EC: early Chrontype; IC: intermediate chronotype; LC: late chronotype; SDw: sleep duration during work days; SDf: sleep duration during free days; MSFsc: midpoint of sleep during free days sleep corrected; SJL: Social Jetlag; SLoss = sleep loss; *r*: correlation coefficient; *p*: significance value; *df*: degrees of freedom.
*$p < .05$; **$p < .01$.

previous studies so far (Haraszti et al., 2014; Roenneberg et al., 2012; Rutters et al., 2014).

We did not detect any association of chronotype or SJL with depressive symptoms, sleep quality, or perceived stress in the analysis of the total sample. Yet, when we divided our total sample into an early, intermediate, and late chronotype group, we found that MSFc had opposing associations with the PHQ9 and adjusted PSQI scores within the early and late chronotype groups: In the early chronotype group, depression scores and sleep impairment tended to be higher when MSFsc values were lower. In contrast, in late chronotypes, higher average depression scores and sleep impairment were associated with higher MSFsc values, suggesting that psychological well-being is lower in more extreme chronotypes on both ends of the spectrum. This is an important observation for two reasons: (1) depending on the composition of the total sample (i.e., with respect to their MSFsc) and on how accurately the sample represents chronotype distributions of the general population, associations with mental-health-related outcomes might vary, and (2) associations between psychological well-being and chronotype might follow a u-shaped function and therefore cannot be detected when examined across the entire sample.

Results concerning the association between chronotype and health- or performance-related variables have been inconsistent in previous research. Some studies have found no associations (Haraszti et al., 2014; Wittmann et al., 2006; Yong et al., 2016), whereas Levandovski et al. (2011), for example, found positive correlations between depressive symptoms and both chronotype and SJL. It should be mentioned that this particular sample had a mean chronotype earlier than 3 a.m., which would have qualified as early chronotype in other studies. In contrast, Önder et al. (2014) found positive correlations between PSQI scores and both chronotype and SJL, although this sample had a mean chronotype of 6 a.m., which would have qualified as late chronotype in other studies. One major shortcoming of chronotype studies is that groups are often created from continuous scores, yet justification for cut-off criteria or comparability to the distribution in the general population are mostly not reported, which hampers comparability of results across studies.

Besides chronotype and SJL, we included sleep duration and sleep loss in our analyses, as sleep disturbances are strongly related to almost all psychiatric disorders (Gruber and Cassoff, 2014). Most consistent results across the total sample were obtained for sleep duration on work days: Respondents reported higher depressive symptoms and a stronger reduction of sleep quality when sleep durations were shorter. This observation is in line with Grandner et al. (2006), who found a negative correlation between the global score of PSQI and total sleep time reported in a sleep diary.

Although we did not find associations of SJL or sleep loss with psychological well-being, it is important to emphasize that SJL and sleep loss are strongly intertwined. In this study, this was illustrated by the strong positive associations between SJL and sleep loss. This issue has been discussed recently by Jankowski (2017), who introduced a sleep-corrected formula to calculate SJL. However, even when implementing the sleep-corrected SJL scores, this did not change our results with respect to psychological well-being.

Another open question is to what extent people can temporarily adjust their sleeping behavior without any physical or psychological consequences. Specifically, in our sample, sleep duration on work days was 6.86 hours, whereas sleep duration on free days was 8.22 hours. It has been proposed that humans can adapt to shorter or longer sleep durations within a range of approximately 6–9 hours without increased daytime sleepiness or negative health consequences (Horne, 2011). Recently, Jankowski (2015) also questioned the feasibility of correcting the MSF, considering that sleep recovery is not necessarily a linear process and can only be achieved to a certain extent.

Limitations

One limitation for our study is that only few participants among our respondents reported severely reduced psychological well-being, while associations may only emerge in samples with more pronounced symptoms (Antypa et al., 2016; Kantermann et al., 2012). Second, using a cross-sectional design, it is impossible to draw conclusions about causal mechanisms. As Kantermann et al. (2012) have pointed out, it is important to disentangle whether a specific chronotype is more vulnerable to psychological impairment, or whether sleep disturbances that co-occur with psychiatric disorders artificially induce late chronotypes. Third, all psychological assessments were based on self-report. Future studies could benefit from including more objective measures, such as actimetry, or dim light melatonin onset (Roenneberg, 2015) to validate sleep variables. Fourth, the time period between filling out the MCTQ and the other questionnaires varied considerably between participants. Therefore, the change of seasons may have had an impact on our results (Allebrandt et al., 2014). Although 52.3 percent responded within 7 days and 90.4 percent within 30 days, the longest response period took as much as 161 days. However, when taking differences in response time into account, this did not change our results. In addition, when comparing respondents who filled out the MCTQ during summer to those who did so in autumn, a delay in chronotype and an increase in SJL were found for individuals participating in autumn, but still no significant differences in their associations with the PHQ9, PSQI, or PSS. Fifth, as the MCTQ only needs one value for each sleep onset and offset on both work and free days, we were not able to assess sleep time variability within participants. It is possible that sleep timing is more variable in some participants than in others due to alternating working hours and social obligations, which implies that the assessment of a general chronotype is less diagnostically conclusive in these cases.

Conclusion

Depending on sample composition in terms of chronotype, associations between chronotype and psychological well-being varied in extent and direction, which should be kept in mind when conducting future studies.

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