Decreased Psychological Well-Being in Late ‘Chronotypes’ Is Mediated by Smoking and Alcohol Consumption

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Individuals are different ‘chronotypes’ with early ‘larks’ and late ‘owls’ forming the limits of a normal distribution in the population. We recently described that late chronotypes who suffer from a conflict between internal and external time (‘social jetlag’) suffer from more mental distress and are more likely to smoke than early chronotypes (Wittmann, Dinich, Merrow, and Roenneberg, 2006. Social jetlag: mis-alignment of biological and social time. Chronobiology International, 23:497–509.). We performed a detailed analysis of the same database collected in 2002 comprising 134 daily smokers and 366 nonsmokers, scrutinizing the relationships between chronotype, smoking, and alcohol consumption as well as psychological well-being using a multiple mediation analysis. On average, smokers tend to be later chronotypes, report more sleep-associated psychosomatic symptoms, are more depressed, less balanced, and less vigilant. The mediation analysis suggests that only those late chronotypes who smoke and those who drink more suffer from increased psychological distress. We suggest that ‘chronotype’ is introduced as an additional factor in substance use, that is, when considering motives for smoking and drinking.

Keywords cigarette; smoking; alcohol; chronotype; sleep-wake cycle; mood

Introduction

Individual Differences in Chronotype

Phenotypic variations in the circadian clock of individuals result in a continuum of so-called chronotypes that ranges in a population from extreme early types (“larks”) to extreme

Acknowledgments: We thank Myriam Juda for her critical comments on the manuscript. Our work is supported by the Gottlieb Daimler- and Karl Benz-Stiftung as part of the CLOCKWORK consortium.

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late types (“owls”) (Roenneberg, Wirz-Justice, and Merrow, 2003). In a recent study on individual sleep-wake cycles (Wittmann et al., 2006), we showed that late chronotypes score lower on sleep-quality and emotional well-being than early chronotypes. The association with chronotype was most pronounced in smoking habits, with late chronotypes being significantly more often cigarette smokers than early types. We interpreted this correlation as being a consequence of attempts of late chronotypes to cope with ‘social jetlag’—defined as the misalignment of internal and external time (Wittmann et al., 2006). This misalignment is associated with accumulating a substantial sleep debt over the work week due to late sleep onsets—controlled by the internal, circadian clock—and forced wake-ups—controlled by the external clock (Gaina et al., 2006; Giannotti, Cortesi, Sebastiani, and Ottaviano, 2002; Roenneberg et al., 2003; Taillard, Philip, and Bioulac, 1999). Here, we further analyze the relationship between chronotype and psychological well-being by taking smoking behavior as a moderator variable into account and also controlling for alcohol consumption.

**Short-Term Effects of Smoking on Cognitive Performance and Psychological Well-Being**

Despite the increased awareness of the profound health risks due to smoking and an increasingly aggressive public antismoking attitude, many people still smoke, that is, about 22% in the United States (Strine et al., 2005) and about 33% in Germany (Lampert and Burger, 2004; Schmitz, Kruse, and Kugler, 2003). The short-term neuroregulatory effect of nicotine relieves smokers from withdrawal symptoms and, thus, reinforces tobacco use. The immediate cognitive and emotional effects of nicotine intake also contribute to the perpetuation of the habit. It is known that nicotine can improve cognitive performance on tasks that require attention and working memory (Sacco, Bannon, and George, 2004). In nicotine-addicted smokers who have stayed abstinent for a day, cigarette smoking can reverse withdrawal-related cognitive impairments (Jacobsen et al., 2005; Klein, Corwin, and Stine, 2003; Tong et al., 1978). Transdermal or subcutaneous nicotine produces short-term cognitive enhancement even in nonsmokers (Levin et al., 1998; Rezvani and Levin, 2001; Trimmel and Wittberger, 2004).

It is known that patients suffering from neuropsychiatric disorders (e.g., schizophrenia, attention deficit hyperactivity disorder, affective disorders) are significantly more likely to be smokers (Breslau, Novak, and Kessler, 2004; Lasser et al., 2000; Murphy et al., 2003). It has been suggested that smoking reflects a form of self-medication, transiently improving cognitive performance (e.g., Cattapan-Ludewig et al., 2005; Sacco et al., 2004). In nonsmoking adults with attention-deficit/hyperactivity disorder, nicotine consumption improves self-perceived vitality and shortens reaction times in computerized attention tasks (Levin et al., 1996). In addition to its cognitive effects, tobacco also acts on the emotional status. For example, clinically depressed individuals as well as patients with obsessive-compulsive disorder who are nonsmokers show an improvement in depression and anxiety after administration of transdermal nicotine patches (Salin-Pascual and Bassanez-Villa, 2003; Salin-Pascual, Rosas, Jiminez-Genchi, Rivera-Meza, and Delgado-Parra, 1996; for an overview on short-term nicotine effects on cognition and emotion, see Sacco et al., 2004).

**Long-Term Effects of Smoking on Psychological Well-Being**

Long-term chronic tobacco use affects the quality of life in smokers. Recent findings indicate poorer physical health, lower scores in vitality, mental health, social functioning,
and emotional well-being (Bellido-Casado et al., 2004; Martinez et al., 2004; Schmitz et al., 2003; Strine et al., 2005) in a dose-dependent manner (i.e., negative effects increase with number of cigarettes per day, Wilson, Parsons, and Wakefield, 1999). Cross-sectional data and longitudinal studies suggest that cigarette smoking is a predictor for developing depressive symptoms (Brook, Schuster, and Zhang, 2004; Korhonen et al., 2007). Two alternative hypotheses have been proposed for the relationship between psychological well-being and smoking (Brook et al., 2004): (1) Individuals with mood disorders are more likely to start and maintain the smoking habit as self-medication of their experienced symptoms (the self-medicating hypothesis). (2) Chronic smoking alters the mental state in the long run, resulting in symptoms of depressed mood by affecting neuroregulatory mechanisms (the neuroregulatory hypothesis). An interaction of these two scenarios is, of course, quite likely.

**Current Study**

Here, we focus on differences in psychological well-being between smokers and nonsmokers in the sample of healthy subjects ($n = 500$) ranging from adolescence to old age; former studies on the relation between psychological well-being and smoking used more global measures of quality of life (e.g., Bellido-Casado et al., 2004; Martinez et al., 2004, Strine et al., 2005) and rarely have distinguished individual chronotype. Specifically, we assessed sleep quality, ‘mood states at present,’ and ‘subjective well-being over the past week’. Since the short-term benefits of nicotine consumption are, on the long run, outweighed by negative effects on mood, we tested by multiple mediation analyses the possibility whether the lower psychological well-being scores in late chronotypes could be a consequence of smoking. Since alcohol can have an impact on mood in conjunction with smoking, we integrated alcohol consumption in the mediation analyses. Such combinatory effects are rarely investigated (Friend, Malloy, and Sindelar, 2005). It is known that smokers drink significantly more as measured by the number of drinks per drinking occasion and by the amount of drinks over a given period of time (Reed, Wang, Shillington, Clapp, and Lange, 2007). In addition, the relationship between mood states and drinking behavior is well established, where individuals with problematic drinking behavior have more mood disturbances than social drinkers (King, Bernardy, and Hauner, 2003; Rodgers et al., 2000). Thus, to sum up the aim of this investigation, we wanted to find out whether tobacco use together with alcohol consumption could have an aggravating effect on the relationship between chronotype and psychological well-being, that is, whether smoking and drinking worsen the mental distress late chronotypes experience as a result of their social jetlag.

**Methods**

**Participants**

Five hundred participants (198 men and 302 women) from Munich, Bad Töhlz (both Germany), and Innsbruck (Austria), were included in this study by using a database of volunteers, posting flyers, and by the word of mouth. Ages ranged between 14 and 94 (14–19 years: 13.6%; 20–29 years: 20.8%; 30–39 years: 16.4%; 40–49 years: 11.8%; 50–59 years: 12.0%; 60–69 years: 14.4%; 70–79 years: 7.6%; >80 years: 3.4%). Education levels: 1 = elementary (9 years of primary school; Hauptschule): 21%; 2 = secondary (4 years of primary school, 6 years of secondary modern school; Realschule): 22.2%; 3 = higher secondary (4 years of primary school, 9 years of grammar school, Gymnasium): 24%; 4
= tertiary, university/college degree as highest level of education: 28.2%; 0 = no school qualification yet (participants still went to school): 4.8%; in analyzing education level, category “0” was omitted since participants still had to reach their final education level.

**Measures**

Individual chronotype was assessed with the Munich ChronoType Questionnaire (MCTQ) which documents sleep (and activity) times separately for work and free days (Roenneberg et al., 2003). Using sleep onset and wake up, the midpoint of sleep (midsleep) was calculated as circadian phase reference point. Midsleep on free days (MSF) is a useful indicator for chronotype but should still be corrected for potential sleep debt. Especially late chronotypes get far too little sleep during the work-week and compensate for the accumulated sleep debt by extending sleep duration on free days (SIDuF, typically weekends). This recovery sleep confounds the estimation of chronotype because MSF is later than in people without sleep debt (Roenneberg et al., 2003). The difference between SIDuF and the average weekly sleep duration (SIDuØ) was, therefore, calculated to adjust MSF accordingly. MSFsc (sleep-corrected MSF) is a quantitative assessment for chronotype based on a person’s daily behavior without sleep debt: MSFsc = MSF − (SIDuF − SIDuØ)/2.

Sleep quality was assessed using the sleep questionnaire SF-A (Goertelmeyer, 1985) which contains 23 questions about the prior night. It refers to events of the day before, to subjective well-being on the evening before, the quality of sleep during the night, and subjective well-being in the morning. Fifteen of the twenty-three questions are grouped into different factors, (1) **sleep quality**, (2) the feeling of *recovery after sleep*, (3) the feeling of *mental balance* in the evening, (4) the feeling of *mental exhaustion* in the evening, (5) **psychosomatic symptoms** during sleep (such as sweating at night, waking up too early, and not being able to fall asleep again). The remaining questions address sleep-related aspects of the prior night not used in our study.

‘Psychological well-being at present’ was assessed by the Basler rating scale (Basler Befindlichkeits-Skala; Hobi, 1985) consisting of 16 word pairs (items); participants are asked to choose which word of each pair describes their current situation most accurately. Items are grouped into four factors representing the sums of the scores over all items within the factor (Petru, Wittmann, Nowak, Birkholz, and Angerer, 2005). The four factors are (1) **vitality**, referring to mental and physical vigor, (2) **intrapsychic balance**, describing mental balance, (3) degree of **social extraversion**, referring to the ability and willingness to form social contacts, and (4) **vigilance**, referring to the ability to direct one’s attention to something new.

‘Psychological well-being over the past week’ was rated with the Profile of Mood State (POMS). A German short version of the POMS (Bullinger, Heinisch, Ludwig, and Geier, 1990) consisting of 35 items with mood adjectives that have to be rated as how accurately they apply to the subject’s current state of well-being. The items are categorized in four subscales, i.e., **depression**, **fatigue**, **vigor**, and **anger**.

With an extended standard sociodemographic questionnaire, we assessed whether the participant is a cigarette smoker and, if yes, the number of cigarettes smoked per day, as well as the age at which the participant started to smoke. We did not incorporate other smoking habits such as cigar or pipe smoking, since cigarette smoking represents 95% of German smokers (Lampert and Burger, 2004). We also assessed average daily alcohol consumption quantified by ‘restaurant unit’: one unit of alcohol (approximately 14 g) equals a bottle of beer, a glass of wine, or a drink of hard liquor (Strandberg, Strandberg, Salomaa, Pitkälä, and Miettinen, 2004).
Mediation Effects of Nicotine and Alcohol

Figure 1. Model of multiple mediation effects: the independent variable $X$ affects the dependent variable $Y$ either directly ($c'$ path) or indirectly via $M_1$ or $M_2$ (a,b paths). The factor age ($C$) is controlled for.

Data Analysis

Independent-sample $t$-tests were performed to assess the differences between smokers and nonsmokers as well as between regular drinkers and nondrinkers of alcoholic beverages. Since multiple comparisons were applied, the risk of Type I error increases (incorrect rejection of null hypothesis). One solution of this problem is to correct the alpha level according to Bonferroni. This, however, increases the possibility of Type II error (false acceptance of null hypothesis). We, therefore, decided on a conservative alpha level of 0.01 to define variables affected by smoking or drinking. Only those variables showing a significant difference between smokers and nonsmokers or drinkers and nondrinkers were processed in the subsequent mediation analysis. Significance testing was adjusted when according to the Levene’s test equality of variances could not be assumed.

A variable can be considered a mediator $M$ if it carries the influence of a given independent variable $X$ (in our case: chronotype) to a given dependent variable $Y$ (e.g., psychological well-being) (Preacher and Hayes, 2004). We tested whether the recently discovered relationship between individual chronotype and psychological well-being reflected a direct influence or an indirect one, via a mediating effect of smoking or drinking alcohol (see Figure 1). Based on effect analyses between the three components in question, $X$ (chronotype), $Y$ (psychological well-being, sleep quality), and $M$ ($M_1$: cigarette smoking, $M_2$: drinking alcohol) we tested whether $X$ directly affects $Y$ or whether $M$ carries the effects of $X$ on $Y$ (for more details concerning this analysis, see Preacher and Hayes, 2008). In this model of multiple mediation effects (see Figure 1), $a$, $b$, and $c'$ represent the path coefficients for the effects of $X \rightarrow M$, $M \rightarrow Y$, and $X \rightarrow Y$, respectively. The path coefficient $c'$ represents the direct path, whereas $a$ and $b$ represent the indirect paths. The total effect $c$, that is, the initial effect of $X$ on $Y$ when mediators are not introduced in the model, is the sum of the indirect ($a$, $b$) and direct effect ($c'$).

A bootstrapping method was part of the procedure to analyze indirect effects since we had two possible mediators that had to be accounted for in the model ($n = 5,000$, confidence intervals set at 95%; SPSS and SAS macros available at: http://www.quantpsy.org). Bootstrapping methods offer a powerful method for obtaining confidence limits for specific
indirect effects (MacKinnon, Fairchild, and Fritz, 2007). There are three possible outcomes of a mediation analysis. When the effect of $X$ on $Y$ reaches zero after the inclusion of $M$, complete mediation has occurred. When the effect of $X$ on $Y$ decreases by a certain amount but is still existent, partial mediation has occurred. In case that no decrease of the effect of $X$ on $Y$ is registered by including $M$ into the model, no mediation at all has occurred (MacKinnon et al., 2007; Preacher and Hayes, 2004). The variable of age which in mean was significantly lower in smokers than in nonsmokers as well as the variable of education which was significantly lower in nondrinkers (see results) were included as covariates in the mediation models.

Results

Effects of Smoking and Drinking

Regular smokers comprised slightly over a quarter of the participants (26.8%; 30.3% of the males and 24.4% of the females) consuming on average 12.5 cigarettes per day ($SD = 9.2$; 42.4% smoked less than 10 cigarettes per day, 28.0% smoked 10 to 19 cigarettes per day, and 29.6% smoked at least 20 cigarettes per day), and had, on average, smoked for 13.6 years ($SD = 11.7$). Their mean starting age was 20.2 years ($SD = 9.1$). The percentage of smokers separated by age group is as follows: 14–19 years: 33.8%, 20–29 years: 43.8%, 30–39 years: 24.4%, 40–49 years: 32.2%, 50–59 years: 21.7%, 60–69 years: 15.3%, >70 years: 3.6%. Regular drinkers comprise 56.7% of the study population. Of those, 20.4% drink on average less than half a restaurant unit of alcohol per day, 54.6% drink between 0.5 and 1 drink per day, 19.5% drink more than 1 to 2 drinks per day, and 5.3% report drinking on average more than 2 drinks per day.

Table 1 shows the comparison between smokers and nonsmokers. Smokers and nonsmokers also significantly differ in chronotype, that is, smokers show substantially later mid-sleep times on free days. On average, smokers report lower psychological well-being (decreased vitality, intrapsychic balance, and vigilance), decreased mood (increased depression and fatigue), as well as more sleep problems (decreased feelings of recovery after sleep, increased psychosomatic symptoms during sleep, and overall shorter sleep duration on work and free days). Table 2 shows the comparison between regular drinkers of alcohol and nondrinkers. On average, drinkers are later chronotypes. They have more psychosomatic symptoms during sleep, report of having less vitality and inner balance, and are more depressed and have less vigor.

Smoking and Drinking as Mediators Between Chronotype and Psychological Well-Being

We used the mediation test to investigate the hypothesis that psychological well-being is not directly related to chronotype but rather indirectly mediated by smoking and/or drinking behavior (see results in Table 3). The combination of smoking and drinking mediates the effect of chronotype on psychosomatic sleep symptoms (SF-A), depression and fatigue (POMS). Later chronotypes who smoke and also drink more alcohol show more signs of depressed mood, fatigue, and have more psychosomatic sleep symptoms. Only smoking mediates the effects of chronotype on vigilance (Basler). Only drinking mediates the effect chronotype has on intrapsychic balance and vigilance (Basler) as well as on vigor (POMS).
Table 1
Independent-samples t tests on assessed variables between smokers and nonsmokers. Group differences are significant at an alpha-level of 0.01. A Bonferroni-adjusted alpha-level for \( n = 17 \) comparisons would have resulted in a \( p \) value of .0029

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Nonsmokers Mean</th>
<th>Smokers Mean</th>
<th>( T (df = 498) )</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>45.7</td>
<td>34.0</td>
<td>6.87</td>
<td>.001</td>
</tr>
<tr>
<td>Education</td>
<td>2.5</td>
<td>2.6</td>
<td>-0.69</td>
<td>.487</td>
</tr>
<tr>
<td>Alcohol (Drinks/day)</td>
<td>0.47</td>
<td>0.98</td>
<td>-4.47</td>
<td>.001</td>
</tr>
<tr>
<td>Chronotype (MCTQ)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-sleep time free days (MSFsc) (hrs)</td>
<td>3:40</td>
<td>4:42</td>
<td>-7.75</td>
<td>.001</td>
</tr>
<tr>
<td>Sleep questionnaire(SF-A)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality of sleep</td>
<td>3.44</td>
<td>3.34</td>
<td>1.66</td>
<td>.080</td>
</tr>
<tr>
<td>Feeling of recovery after sleep</td>
<td>3.42</td>
<td>3.21</td>
<td>2.79</td>
<td>.004</td>
</tr>
<tr>
<td>Feeling of mental balance in the evening</td>
<td>3.37</td>
<td>3.31</td>
<td>1.03</td>
<td>.306</td>
</tr>
<tr>
<td>Feeling of mental exhaustion in the evening</td>
<td>3.16</td>
<td>3.21</td>
<td>-0.86</td>
<td>.388</td>
</tr>
<tr>
<td>Psychosomatic symptoms during sleep</td>
<td>1.69</td>
<td>1.85</td>
<td>-3.08</td>
<td>.002</td>
</tr>
<tr>
<td>Basler subjective well-being rating scale (Basler)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitality</td>
<td>20.30</td>
<td>18.79</td>
<td>3.02</td>
<td>.003</td>
</tr>
<tr>
<td>Intrapsychic balance</td>
<td>22.36</td>
<td>20.91</td>
<td>3.51</td>
<td>.001</td>
</tr>
<tr>
<td>Social extraversion</td>
<td>19.59</td>
<td>19.28</td>
<td>0.58</td>
<td>.563</td>
</tr>
<tr>
<td>Vigilance</td>
<td>21.16</td>
<td>18.90</td>
<td>4.69</td>
<td>.001</td>
</tr>
<tr>
<td>Profile of mood state (POMS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>6.13</td>
<td>10.56</td>
<td>-4.54</td>
<td>.001</td>
</tr>
<tr>
<td>Fatigue</td>
<td>6.72</td>
<td>8.83</td>
<td>-3.68</td>
<td>.001</td>
</tr>
<tr>
<td>Vigor</td>
<td>16.25</td>
<td>15.39</td>
<td>1.85</td>
<td>.087</td>
</tr>
<tr>
<td>Anger</td>
<td>5.73</td>
<td>6.99</td>
<td>-2.18</td>
<td>.030</td>
</tr>
</tbody>
</table>

In six out of eight mediation analyses the covariate of age shows a significant effect on the psychological variable when at the same time no direct effect of chronotype is revealed. It has to be mentioned that chronotype and age show significant collinearity: people up to their lower twenties are predominantly later chronotypes becoming gradually earlier types with increasing age (Roenneberg et al., 2004). In our analysis the age difference between smokers and nonsmokers (34.0 vs. 45.7 years, see Table 1) is sufficient to explain the differences in the mentioned well-being score between the two groups. Younger individuals in general have less recovery after sleep (Pearson’s correlation with age: \( r = 0.21, p < .001 \), feel less vitality (\( r = .143, p < .001 \)) and vigilance (\( r = 0.237, p < 0.001 \)), and also suffer from more fatigue (\( r = -0.246, p < .001 \)). Due to the collinearity between age and chronotype
Table 2
Independent-samples t tests on assessed variables between regular drinkers of alcohol and non-drinkers. Group differences are significant at an alpha-level of 0.01. A Bonferroni-adjusted alpha-level for n = 16 comparisons would have resulted in a p value of 0.0031

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Nondrinkers N = 217</th>
<th>Regular drinkers N = 283</th>
<th>T (df = 498)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>45.7</td>
<td>34.0</td>
<td>-1.55</td>
<td>.121</td>
</tr>
<tr>
<td>Education</td>
<td>2.36</td>
<td>2.67</td>
<td>-2.79</td>
<td>.006</td>
</tr>
<tr>
<td>Chronotype (MCTQ)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-sleep time free days (MSF&lt;sub&gt;sc&lt;/sub&gt;) (hrs)</td>
<td>3:55</td>
<td>4:16</td>
<td>-2.86</td>
<td>.004</td>
</tr>
<tr>
<td>Sleep questionnaire(SF-A)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality of sleep</td>
<td>3.43</td>
<td>3.40</td>
<td>0.56</td>
<td>.576</td>
</tr>
<tr>
<td>Feeling of recovery after sleep</td>
<td>3.36</td>
<td>3.36</td>
<td>-0.03</td>
<td>.975</td>
</tr>
<tr>
<td>Feeling of mental balance in the evening</td>
<td>3.37</td>
<td>3.33</td>
<td>0.86</td>
<td>.392</td>
</tr>
<tr>
<td>Feeling of mental exhaustion in the evening</td>
<td>3.18</td>
<td>3.15</td>
<td>0.47</td>
<td>.641</td>
</tr>
<tr>
<td>Psychosomatic symptoms during sleep</td>
<td>1.67</td>
<td>1.79</td>
<td>-2.75</td>
<td>.006</td>
</tr>
<tr>
<td>Basler subjective well-being rating scale (Basler)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitality</td>
<td>20.59</td>
<td>19.37</td>
<td>2.72</td>
<td>.007</td>
</tr>
<tr>
<td>Intrapsychic balance</td>
<td>22.77</td>
<td>21.36</td>
<td>3.82</td>
<td>.001</td>
</tr>
<tr>
<td>Social extraversion</td>
<td>19.92</td>
<td>19.21</td>
<td>1.48</td>
<td>.140</td>
</tr>
<tr>
<td>Vigilance</td>
<td>21.07</td>
<td>20.17</td>
<td>2.04</td>
<td>.041</td>
</tr>
<tr>
<td>Profile of mood state (POMS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Depression</td>
<td>6.12</td>
<td>8.20</td>
<td>-2.95</td>
<td>.003</td>
</tr>
<tr>
<td>Fatigue</td>
<td>6.65</td>
<td>7.76</td>
<td>-2.34</td>
<td>.019</td>
</tr>
<tr>
<td>Vigor</td>
<td>16.98</td>
<td>15.32</td>
<td>4.02</td>
<td>.001</td>
</tr>
<tr>
<td>Anger</td>
<td>5.57</td>
<td>6.43</td>
<td>-1.74</td>
<td>.082</td>
</tr>
</tbody>
</table>

it cannot be ruled out that chronotype has a direct effect on these variables, however, the effect is statistically less influential than the factor age.

Discussion

Effects of Smoking and Drinking on Psychological Well-Being
Our results show that smokers feel less inner mental balance, vigilance, and vitality, and show more symptoms of depressed mood. They complement previous findings of lower quality-of-life scores (Bellido-Casado et al., 2004; Martinez et al., 2004; Strine et al., 2005;
### Table 3

Mediation analyses presuming chronotype as the independent variable, the various items of psychological well-being as dependent variables, and smoking and drinking as mediator variables in addition to age, sex, and education as covariates. Note that the coefficients are not standardized.

<table>
<thead>
<tr>
<th>Independent variable X</th>
<th>Mediating variable M1–M2</th>
<th>Dependent variable Y</th>
<th>Effect X on M (a)</th>
<th>Effect M on Y (b)</th>
<th>Indirect effect (ab)</th>
<th>Total indirect effect (ab)</th>
<th>Direct effect (c’)</th>
<th>Total effect (c)</th>
<th>Effect of covariates on Y</th>
<th>Degree of mediation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronotype</td>
<td>Smoking</td>
<td>Feeling recovered after sleep (SF-A)</td>
<td>.10***</td>
<td>−.15</td>
<td>−0.02</td>
<td>−0.014</td>
<td>−.03</td>
<td>−.04</td>
<td>Age:.006**</td>
<td>None</td>
</tr>
<tr>
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<td>−0.0062</td>
<td>.016*</td>
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<td>Smoking Vitality (Basler)</td>
<td>.10***</td>
<td>−.70</td>
<td>−.07</td>
<td>−1.16*</td>
<td>−.04</td>
<td>−.20</td>
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<td>−.62</td>
<td>−.06</td>
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<td>−.29</td>
<td>−.45**</td>
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*significant coefficients: *p < .05.
**p < .01.
***p < .001.
Wilson et al., 1999) and a higher incident of depression (Schmitz et al., 2003) in smokers. We further show that smokers feel less recovered after sleep and show more psychosomatic symptoms during sleep supporting earlier findings for adolescents (Patten, Choi, Gillin, and Pierce, 2000) and adults (Htoo, Talwar, Feinsilver, and Greenberg, 2004; Ohida et al., 2004). In general, smokers suffer from a complex of complaints comprising sleep problems and mood disturbances, which are probably interrelated (Giannotti et al., 2002; Taillard et al., 1999). Yet, not only sleep quality but also its quantity and timing differ: smokers sleep significantly shorter (30 min on workdays and 19 min on average) and at later times (with a delay of about 1 hr). This latter finding is backed by a body of evidence suggesting that smokers have more difficulty initiating and maintaining sleep as well as report of more daytime sleepiness (Wetter and Young, 1994). As a result of these sleep problems smokers have more minor accidents and also feel more depressed than nonsmokers (Phillips and Danner, 1995). Sleep disturbances in smokers are probably related to the stimulant effects of nicotine and nightly withdrawal symptoms, although some findings do not necessarily show linear effects as, for example, in one study, only light smokers (less than 15 cigarettes per day), and not heavier smokers, reported of insomnia and reduced sleep time (Riedel, Durrence, Lichstein, Taylor, and Bush, 2004).

On average, regular consumers of alcoholic beverages have more psychosomatic symptoms during sleep, they have less vitality and inner balance, report of being more depressed and having less vigor than nondrinkers. It is well established that high levels of alcohol abuse are related to psychological distress, that is, symptoms of anxiety and depression (Schucvit and Hesselbrock, 1994; Swendsen et al., 1998). However, the majority of alcohol drinking participants in our unselected study group drank moderately. Contrary to our study results, it has been reported that people with moderate drinking levels experience better mental and physical health as compared to noncurrent drinkers (Rodgers et al., 2000). However, other studies show a variety of factors to influence the relationship between alcohol intake and psychological well-being. For example, it has been shown that only noncurrent (or former) drinkers have lower physical and mental health scores than moderate drinkers but not life-time abstainers (Stranges et al., 2006). Moreover, the type of alcohol seems to influence health as only light to moderate wine intake was associated with better self-perceived health whereas beer and spirit drinkers did not differ to nondrinkers (Grønbaek et al., 1999). All the participants in our study group lived in southern Bavaria or northern Tyrol, regions well-known for beer and schnapps drinking habits. The drinkers of our study on average drank 0.305 drinks of beer, 0.148 drinks of wine, and 0.104 shots of spirits. This drinking behavior may at least account for the fact that low to moderate drinkers do not have better psychological well-being scores than nondrinkers as found in some other studies.

**Smoking and Alcohol Mediate the Influence of Chronotype on Psychological Well-Being**

Our mediation analysis determined that the association between chronotype and mental variables is predominantly mediated by smoking and drinking. Although in some mediation tests, age explained most of the variance of the dependent variables as a covariate, the results point to three psychological domains where smoking in combination with drinking alcohol carries the effects of chronotype on the psychological variable. Later chronotypes who smoke and drink more alcohol have more psychosomatic sleep problems, show less mental balance, and are more depressed. Our analysis, therefore, suggests that being a later chronotype (and consequently suffering from more sleep debt) does not necessarily directly
lead to mental imbalance and/or distress. Only later chronotypes who also smoke and drink show lower scores in psychological well-being and sleep disturbance. Social jetlag—similar to transmeridian travel jetlag—creates stress which some individuals compensate for by smoking. Smoking could be a form of coping with social jetlag, similar to the higher consumption of other stimulants such as alcohol or caffeinated beverages (Adan, 1994; Mecacci and Rochetti, 1998). Nicotine can produce short-term cognitive enhancement, that is, improving alertness. Larger quantities of alcohol, for example, may be used to enable an earlier sleep onset. That smoking habits correlate better with the absolute amount of social jetlag than with chronotype per se supports this possibility (Wittmann et al., 2006).

It could be argued that smoking and drinking are ‘evening habits’, so that late types just have more opportunity to smoke and drink (the pub hypothesis) rather than smoking and drinking being promoted by the symptoms of ‘social jetlag’. This argument is, to some extent, supported by our finding that smokers drink twice as much alcohol compared to nonsmokers (where drinking is definitely a strong evening habit). However, the average amount of cigarettes is similar over all chronotypes (Wittmann et al., 2006), thus weakening the pub hypothesis. It is the likelihood of being a smoker and not the amount of cigarettes consumed that is related to chronotype or even more stringently to social jetlag. In addition, daily profiles show that early chronotypes among the smokers just start and stop smoking earlier than late chronotypes (Till Roenneberg, unpublished results).

Limitations

There are some limiting factors of our study. Due to the cross-sectional design, we cannot offer a solution to the question whether smoking and drinking cause mood disorders (the neuroregulatory hypothesis) or mood disorders lead to smoking and drinking (the self-medication hypothesis) (Brook et al., 2004). Different subgroups of smokers and drinkers may match criteria for both hypotheses to varying degrees. Moreover, we did not control for nicotine or alcohol dependence. The status of being a smoker relied on the subject’s own categorization. It is known that nicotine-dependent subjects report of less quality of life than other smokers (Schmitz et al., 2003). In addition, the assessment of alcohol intake relied on the subject’s self-report of average consumption and did not include the assessment of problematic behaviors such as binge drinking or drinking alcohol outside of meals. Nevertheless, our approach to assess elementary variables of smoking and drinking behavior showed to be sensitive for pronounced effects in the mediational analysis.

Conclusions

Our study supports previous findings that chronic tobacco consumption in combination with alcohol alters psychological well-being and quality of sleep (Foster and Peters, 1999; Htoo et al., 2004; Schmitz et al., 2003; Strine et al., 2005). In addition, smoking as a habit, is strongly related to being a late chronotype or rather to suffering from social jetlag. As social constraints of school and work times interfere to a considerable amount with individual sleep preferences of late chronotypes which are dominant in adolescents, individuals suffering from sleep deprivation on work days may be more strongly inclined to take stimulants such as alcohol and nicotine. We hypothesize that social jetlag imposed on a late chronotype is one factor (among many others, see
Engels, Hale, Noom, and De Vries, 2005) for becoming a smoker and to increase drinking levels. Based on our results, we propose that future studies should incorporate individual chronotype as an important variable for understanding motivations for substance use.

Declaration of interest: The authors report no conflict of interest. The authors alone are responsible for the content and writing of this paper.

RÉSUMÉ

La réduction du bien-être psychologique chez les chronotypes tardifs est engendrée par la consommation d’alcool et de cigarettes

Chaque personne est un ‘chronotype’ qui se «lève tôt» ou se «couche tard», deux extrêmes qui forment les limites de la distribution normale d’une population. Nous avons récemment décrit que les chronotypes tardifs ont leur horloge interne en conflit avec le temps externe («social jetlag»): ces chronotypes souffrent de détresse mentale et sont plus enclins à fumer que les chronotypes matinales (Wittmann et al., 2006). Une analyse à médiation multiple de cette même base de donnée obtenue en 2002 et comprenant 134 fumeurs et 366 non-fumeurs est ici fournie afin de déterminer les relations entre chronotype, consommation d’alcool, consommation de cigarettes et bien-être psychologique. En moyenne, les fumeurs tendent à être des chronotypes tardifs. Ils reportent plus de symptomes psychosomatiques associés au sommeil, sont plus dépressifs, moins équilibrés et moins vigilant. Cette analyse suggère que seuls les chronotypes tardifs qui fument et consomment d’alcool souffrent d’une détresse mentale croissante. Par conséquent, nous suggérons de prendre en compte la chronotype comme facteur additionnel dans l’évaluation de l’usage de substances dans le cadre des motifs de consommation de cigarettes et d’alcool.

RESUMEN

La disminución del bienestar psicológico en cronotipos vespertinos es mediada por el consumo de alcohol y tabaco.

“Madrugadores” y “Transnochadores” forman los límites de la distribución normal en la población de cronotipos. Nuestro grupo ha descrito recientemente que los cronotipos que sufren un conflicto entre el tiempo interno y externo (‘social jetlag’) sufren más estrés mental y son más propensos a fumar que los cronotipos matutinos (Wittmann et al., 2006). En este artículo, llevamos a cabo un análisis detallado de la misma base de datos recogida en el año 2002, la cual constaba de 134 fumadores diarios y 366 no fumadores, examinando las relaciones entre el cronotipo y el consumo de alcohol y tabaco, así como el bienestar psicológico a través de un análisis de mediación múltiple. Como grupo, los fumadores tienden a ser cronotipos vespertinos, describen más síntomas psicosomáticos asociados con el sueño, están más deprimidos, menos equilibrados, y menos conscientes. El análisis de mediación sugiere que solo aquellos cronotipos vespertinos que fuman y beben más sufren un elevado nivel de estrés. Nosotros sugerimos que el cronotipo sea introducido como un factor adicional en el uso de sustancias, i.e., cuando se consideren los motivos por los cuales se fuma y se bebe.
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**Glossary**

**Chronotype**: Humans show large differences in the preferred timing of their sleep and activity. This so-called chronotype is largely regulated by the circadian clock. Both genetic variations in clock genes and environmental influences contribute to the distribution of chronotypes in a given population, ranging from extreme early types to extreme late types (the colloquial larks and owls) with the majority in between.

**Circadian clock**: Daily rhythms in fundamental aspects of physiology and behavior are controlled by an endogenous biological clock. They persist in temporal isolation experiments with a period of approximately 24 hr (hence circadian, about one day) and have been shown for many biological functions, ranging from the sleep/wake cycle and physiology, e.g., temperature, melatonin, and cortisol to gene expression.

**Social Jetlag**: Societal determination of work times interferes with individual sleep preferences. In late chronotypes, the constraints of early work schedules lead to an increasing sleep debt over the week that is compensated for on weekends. The fact that many people in our society shift their sleep and activity times several hours between the work week and the weekend (or other free days) is comparable to jetlag.

**References**


