This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

Yawning while scrolling? Examining gender differences in the association between smartphone use and sleep quality

By Simon Amez,[i] Sunčica Vujić,[ii] Pieter Soffers,[iii] and Stijn Baert[iv]

Abstract

The negative consequences of deteriorated sleep have been widely acknowledged. Therefore, research on the determinants of poor sleep is crucial. A factor potentially contributing to poor sleep is the use of a smartphone. This study aims to measure the association between overall daily smartphone use and both sleep quality and sleep duration. To this end, we exploit data on 1,889 first-year university students. Compared with previous research we control for a large set of observed confounding factors. Higher overall smartphone use is associated with lower odds of experiencing a good sleep. In addition, we explore heterogeneous differences by socioeconomic factors not yet investigated. We find that the negative association between smartphone use and sleep quality is mainly driven by female participants.

Keywords: smartphone use; sleep quality; sleep duration

Number of references: 43

Word count: 8972

---

[i] Ghent University. **Corresponding author.** Postal address: Sint-Pietersplein 6, B-9000 Ghent, Belgium. Telephone number: 003292643481. Email address: Simon.Amez@UGent.be.

[ii] University of Antwerp and University of Bath.

[iii] University of Antwerp.

[iv] Ghent University, Research Foundation – Flanders, University of Antwerp, Université catholique de Louvain, IZA, GLO, and IMISCOE.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

1. Introduction

The importance of a proper night's sleep has been the subject of societal debates. Recently, The Guardian (2017) even suggested that physicians should prescribe sleep based on recent scientific research on the consequences of sleep deprivation. Indeed, poor sleep quality has also received scholarly attention for decades. As such, poor sleep quality has been associated with (a) an increased risk of physical health problems (see, e.g. Gallicchio & Kalesan, 2009), (b) a deteriorated mental health (Ben-Simon & Walker, 2018), (c) reduced cognitive performance (Baert, Verhaest, Vermeir & Omey, 2015; Hartmann & Prichard, 2018), and (d) lower workplace productivity (Nuckols, Bhattacharya, Wolman, Ulmer & Escarce, 2009; Brossoit et al., 2019). Moreover, these associations at the individual level may result in high economic costs of poor sleep quality on the macro-level (RAND Europe, 2016). These findings emphasize the importance of a more efficient approach to handling sleep deprivation. Therefore, it is crucial to investigate the determinants of poor sleep quality and reduced sleep duration.

Recently, the question was raised whether the (over)use of smartphones contributes to deteriorated sleep (see, e.g., Liu et al., 2019). In the growing literature on the association between sleep and technology use, multiple mechanisms underlying this association have been raised. Firstly, technology use may lead to time displacement (Cain & Gradisar, 2010). More time spent on the smartphone reduces the time left to sleep. In addition, the content of smartphone activity could induce psychological and physiological arousal, which may interfere with sleep (Exelmans & Van den Bulck, 2017). Next, the need to be continuously accessible and the desire not to miss out on what is happening online (nowadays labelled as 'FOMO', i.e. fear of missing out) may result in smartphone-related stress (Van der Schuur, Baumgartner & Sumter, 2018). As a result, stress hormones like cortisol, which have been linked to sleep difficulties (Zeiders, Doane & Adam, 2011), are produced (Sanford, Suchecki & Meerlo, 2014). Furthermore, the bright light from the phone screen suppresses production of the sleep-promoting hormone melatonin, which might cause difficulties with falling asleep (Cain & Gradisar, 2010; Higuchi, Motohashi, Liu & Maeda, 2005). Finally, the presence of the switched-on smartphone inside the bedroom implies the risk of being disturbed by phone calls, text messages, and push notifications (Adachi-Mejia, Edwards, Gilbert-Diamond, Greenough & Olson, 2014).

The growing literature on this association is in line with the theoretical mechanisms predicting a negative relationship. We distinguish two main empirical research lines. On the one hand, scholars have revealed a negative association between smartphone use just before bedtime and sleep quality. As such, Exelmans and Van den Bulck (2016) and Li, Lepp, and Barkley (2015) found a negative association between cell phone use at night and sleep quality in Belgium and the USA, respectively. On the other hand, multiple studies have concentrated on a potential negative association between smartphone addiction[1] and sleep. Specifically, Eyvazlou, Zarei, Rahimi, and Abazari (2016), Mohammadbeigi et al. (2016), Sahin, Ozdemir, Unsal, and Temiz (2013), and Demirci, Akgönul, and Aspinar (2015) used survey data to find a negative association between cell phone overuse and college students' sleep quality in Iran and Turkey.

In the literature to date, we identify a lack of studies investigating the association between smartphone use and sleep in an European university setting. Therefore, the primary research goal of the current study is to investigate the association between smartphone use and university students' sleep (Research question 1 – R1). We focus on the association between students' overall smartphone use and both their (a) sleep quality (R1a), and (b) sleep duration (R1b). In addition, we investigate the association between students' smartphone addiction and their (a) sleep quality (R1c), and (b) sleep duration (R1d). Based on the aforementioned reasoning, we hypothesize a significant negative association between smartphone use and university students' sleep (Hypothesis 1 – H1).

[1] Addiction is a phenomenon that manifests tolerance, withdrawal symptoms, and dependence, accompanied by social problems (O'Brien, 2011). The term was initially limited to drugs or substances but it is later also applied to gambling, internet, gaming, and smartphone use (Kwon et al., 2013).

Surprisingly, the impact of factors potentially moderating the association between smartphone use and sleep quality has only received limited scholarly attention. However, Valkenburg and Peter (2013) argued that it is important to examine individual differences in the susceptibility to media effects. Therefore, a secondary goal of this study is to explore the potential moderating role (see Figure 1) of socioeconomic factors in the association between smartphone use and both sleep quality and sleep duration (R2).

<Figure 1 about here>

There are crucial differences between males and females regarding smartphone-related stress. Females are more likely to report stress linked with their social media use (Beyens, Frison & Eggermont, 2016) and to inadequately cope with stress by ruminating (Nolen-Hoeksema, Larson & Grayson, 1999). In line with the latter, Van der Schuur, Baumgartner, Sumter, and Valkenburg (2018) found only for female teenagers an association between media multitasking and subsequent sleep latency. Thus, based on those findings, we expect the negative association between smartphone use and sleep to be stronger for female students (H2a). Next to gender, we explore other socioeconomic factors whose potential moderating role has yet to be investigated. Recent scholarship has associated feeling cared for, understood, and validated by a partner with better sleep quality (Selcuk, Stanton, Slatcher & Ong, 2017). Since being in a romantic relationship is positively related to lower stress (Feeney & Kirkpatrick, 1996), it can be argued that the potential behavioural association of smartphone-related stress and anxiety, in particular FOMO, is buffered by the relieving knowledge of being cared for and supported by a partner. As such, we hypothesize that the negative association between overall smartphone use and both sleep duration and sleep quality is smaller for students who are in a relationship (H2b). Next, we believe the association between students' smartphone use and their sleep may be heterogeneous by the student's residence situation. Belgian universities are divided geographically into multiple smaller campuses within the major cities. Therefore, students can opt to rent a student room in the university's city or to commute back and forth every day from their hometown. Commuting have been associated with poor sleep quality in Europe (Hansson, Mattisson, Björk, Östergen & Jakobsson, 2012). In terms of sleep duration, it could be argued that students commuting with public transport experience less problems of time displacement due to smartphone use since they might use their smartphone during the commute (Keseru & Macharis, 2017). Yet, with respect to sleep quality, it is possible that students who commute, and thus do not live near campus, face a higher level of FOMO since they are confronted with student activities they cannot attend, and thus use their smartphone as a means to stay current with what is happening on campus. As such, we investigate whether student's residence status does moderate the association between smartphone use and sleep (R2c). Finally, we explore the possibility of a moderating role of a migration background on the studied association. Having a migration background was recently associated with negative sleep outcomes (Schneeberger et al., 2019). Students with a migration background might suffer more in terms of sleep quality due to their smartphone use. Depending on the country of origin, differences in time zones may force them to contact their peers abroad late at night or early in the morning, which leads to the aforementioned time displacement. Moreover, being confronted–by means of news applications–with news facts about their home country can result in an increased psychological arousal. In addition, a feeling of homesickness may influence their desire to be accessible at any time to their peers abroad (Hack-Polay, 2012). Therefore, we hypothesize that the negative association between overall smartphone use and both sleep quality and sleep duration is stronger for students with a migration background (H2d).

To answer these research questions, we analyse a large dataset of 1,889 first-year university students, spread across two major Belgian universities and 11 academic programs. We collected data by paper-and-pencil questionnaires regarding those students' sleep quality–by means of the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman & Kupfer, 1989)–and their daily smartphone use–by means of the Smartphone Usage Subscale of Rosen, Whaling, Carrier, Cheever, and Rokkum (2013). In addition, we control for more confounding factors (e.g., relationship status, academic choices, and having a migration background) than previous studies. Our data is then analysed by means of an ordered logistic regression approach.

2. Methods

2.1 Research Population

Our dataset was constructed by surveying Belgian first-year university students on their sleep quality, smartphone use and further socioeconomic background characteristics. For two consecutive academic years, first-year students from two major Belgian universities–Ghent University and University of Antwerp–were surveyed by means of a paper-and-pencil questionnaire. In December 2016 and 2017, we surveyed first-year students enrolled in all 11 academic programs, taught at three different faculties in these two universities.

In total, 2,140 questionnaires were obtained, of which 1,117 were collected during a first-year course in December 2016 and 1,023 during the following academic year, i.e. in December 2017. Twenty students completed the questionnaire more than once in the same year.[2] Therefore, we randomly dropped one of the observations tin order to have only one completed questionnaire per student, resulting in a loss of ten observations. Next, 37 students reported on the question 'Do you own a smartphone (i.e. a mobile phone which enables more computer capabilities than sending text messages and making calls)?' that they did not own a smartphone. Subsequently, the data was cleaned of contradictory answers. Six respondents did provide nonsensical answers[3] and were consequently excluded from the data. Finally,

[2] Students could attend first-year courses of different academic programs as they could add courses included in another academic program to their personal curriculum as an elective course.

[3] All paper-and-pencil questionnaires were monitored for irregularities. Survey answers were categorised as 'nonsensical' In the case respondents (a) added 'funny' answer possibilities and (b) answered the scales by means of a clear and illogical pattern. For example, students providing non-existing cities as a place of residence were marked with the tag 'nonsensical answers'.

we removed from the dataset 198 largely incomplete questionnaires, thus only retaining those students who provided fully completed questionnaires. As a result, we obtained a final dataset with complete information for 1,889 first-year students which was used to perform our analyses.

2.2 Data

The questionnaire used to survey the participating students was comprised of three sections. The first section contained questions with respect to students' smartphone use. In the second section, students were asked about their general socioeconomic background. In the last section, students were requested to provide information about their sleep quality.

We surveyed smartphone use in two different ways. Firstly, students were asked to fill in the Smartphone Usage Subscale of Rosen et al. (2013). This scale includes nine items in which students indicate the frequency with which they use their smartphone for nine different activities (such as 'reading e-mails' and 'taking pictures'), rated on a 10-point frequency scale ranging from 'never' to 'all the time'. Answers on all nine items were averaged to derive a scale with higher scores indicating a higher frequency of smartphone use. The Cronbach's alpha of the Smartphone Usage Subscale in our sample was 0.748. In the remainder of this article, we refer to this scale as *overall smartphone use*. Secondly, the Smartphone Addiction Scale (SAS) of Kwon et al. (2013) was included in the questionnaire to assess the respondents' degree of smartphone addiction. The SAS contains ten statements with respect to the student's dependence on her/his smartphone, rated on a 5-point Likert scale. Students indicated whether they agreed with each statement (e.g., 'Having my smartphone in my mind even when I am not using it.'), ranging from 'strongly disagree' (score 1) to 'strongly agree' (score 5). Scores of the single items were averaged with a higher score indicating a higher degree of smartphone addiction. The Cronbach's alpha of this scale in our sample was 0.776. In the remainder of this article, we refer to this scale instrument as *smartphone addiction.* Panel A of Table 1 presents the average score of both measures of smartphone use in our sample as well as for the subsamples of students with a below-average versus above-average score on overall smartphone use. The average score with regard to overall smartphone use was 5.764 while the average score with respect to smartphone addiction was 2.424.

<Table 1 about here>

Next, we gathered information on control variables for our analyses. Therefore, students were surveyed on potential socioeconomic determinants of sleep quality: gender, age, migration background[4], language spoken at parental home, maternal and paternal education, household composition, relationship status and living in a student room[5] (versus living at home). Then, respondents completed the 28 items of the College Version of the Academic Motivation Scale of Vallerand et al. (1992), all rated on a 7-point Likert scale. The 28 answers were averaged, resulting in a motivation score between 1 and 7. The Cronbach's alpha of this scale in our sample was 0.884. Additionally, we constructed a dummy variable for the year in which the data was gathered.

Panel B of Table 1 shows the students' average scores on these control variables, for the full sample as well as for the subsamples of students, with a below-average versus above-average overall smartphone use. Our complete sample consisted of 1,889 students who were on average 18.785 (SD = 2.010) years old. Little more than half our sample (52.7%) was female. Next, 15.4% of participating students had a migration background, and 708 (37.5%) students indicated they were currently in a relationship. Finally, approximately one half (49.9%) of the questionnaires where gathered in December 2017, the other half (50.1%) one year earlier. Since we expect that students' sleep quality and sleep duration to be confounded by factors such as migratory background (Schneeberger et al., 2019), language spoken at

[4] Migration background was assessed by asking the respondents 'What is your nationality?'. Students with a non-Belgian nationality were considered as having a migration background.

[5] We captured student's residence status by asking them 'Do you rent a room in the university's city?' providing options 'yes' and 'no'. Therefore, we are not able to distinguish between students who rent a room provided by the university or on the private housing market.

home, academic motivation (Edens, 2006) as well as general time trends, it is necessary to control for these variables in our analyses.

Finally, sleep quality was measured by the means of two components of the validated Pittsburgh Sleep Quality Index (Buysse et al., 1989; henceforth referred to as PSQI). This question module measures sleep quality during the previous month. In the present study, we used (a) the PSQI subjective sleep quality component and (b) the PSQI sleep duration component. Firstly, the respondents were asked to answer the PSQI subjective sleep quality component, the most important measure in the context of the current study. Students were asked to rate their overall subjective sleep quality based on the question 'During the past month, how would you rate your sleep quality overall?'. Four different answer possibilities–each corresponding to a specific score–were given:[6] 'very bad' (score 0), 'fairly bad' (score 1), 'fairly good' (score 2), and 'very good' (score 3). As a result, higher scores indicate a better sleep quality. Next, students were asked to answer the PSQI sleep duration component, based on the question: 'During the past month, how many hours of actual sleep did you get a night? (This may be different than the number of hours spent in bed)'. Thereafter, the answer on this question was scored as follows:[7] score of 3 for an average sleep duration of at least seven hours; score of 2 for an average sleep duration of at least six (but lower than seven) hours; score of 1 for an average sleep duration between five and six hours; and score of 0 for an average sleep duration less than five hours. As such, higher scores indicate longer sleep durations.

As panel C of Table 1 shows, the students in our sample reported on average a subjective sleep quality score of 1.934 (i.e. close to a 'fairly good' sleep), while the average score for sleep duration was 2.826 (i.e. close to the maximum of 3). As expected, respondents with an above-average overall smartphone use reported on average a lower score for their subjective sleep quality compared with the below-

[6] Note that we used a reversed scoring of the original PSQI subjective sleep quality component for ease of interpretation.

[7] Note that we used a reversed scoring of the original PSQI sleep duration component for ease of interpretation.

average smartphone use subsample (p = 0.006). Furthermore, these high frequent smartphone users slept fewer hours than their peers (p < 0.001). However, this comparison did not consider confounding factors. The ordered logistic regression we apply in the current study controls for the observed (socioeconomic) characteristics panel B of Table 1 presents. Therefore, the regression results presented in the next section are better suited to answer our research questions.

3. Results

Ordered logistic regressions are used to estimate the association between overall smartphone use and sleep quality. We regress both our outcome variables, i.e. the PSQI subjective sleep quality component and the PSQI sleep duration component, on the students' overall smartphone use and the aforementioned control variables.[8] The standardised values of the Smartphone Usage Subscale of Rosen et al. (2013) are used.

In ordered logistic regression, an underlying score is estimated as a linear function of the independent variables and a set of cutpoints. The probability of observing outcome i corresponds to the probability that the estimated linear function, plus random error, is within the range of the cutpoints estimated for the outcome:

$$\Pr\left(outcome_j = i\right) = \Pr(\kappa_{i-1} < \beta_1 x_{1j} + \beta_2 x_{2j} + \cdots + \beta_k x_{kj} + u_j \leq \kappa_i)$$

u_j is assumed to be logistically distributed in ordered logit. We estimate the coefficients $\beta_1, \beta_{2,\ldots,} \beta_k$ together with the cutpoints $\kappa_1, \kappa_{2,\ldots,} \kappa_{k-1}$, where κ is the number of possible outcomes, where $\kappa_0 = -\infty$ and $\kappa_k = +\infty$. All of this is a direct generalization of the ordinary binary outcome logit model. Results of

[8] When we run ordered logistic regressions with only the significant control variables from our main analyses, we find similar empirical conclusions (which are available on request).

our benchmark analyses can be found in Table 2.[9] Table 2 includes four regressions in which our main outcome variable, i.e. the respondents' score on the PSQI subjective sleep quality component, is explained by the subjects' smartphone use and different sets of control variables. Firstly, in model (1), students' subjective sleep quality is directly regressed on overall smartphone use, without controlling for potential confounding variables. In model (2) we control for students' general socioeconomic background. In model (3), we introduce control variables for the academic choices that students made before the start of the academic year. Specifically, we introduce a variable which captures students' residence status. Finally, in model (4), students' academic motivation is additionally considered.

<Table 2 about here>

Irrespective of the set of control variables used, we find a negative association between students' overall smartphone use and their sleep quality. When we do not consider any confounders (column (1)), a one standard deviation increase in the overall smartphone use scale (this corresponds to a higher score of 0.930 on 10) is associated with 10.4% ($p = 0.017$) lower odds of experiencing a 'very good' sleep quality, compared with the three other categories of the PSQI sleep quality component. If we then consider the respondents' background characteristics, academic choices, and academic motivation in model (4), an increase of one standard deviation in the overall smartphone use is associated with odds of experiencing a very good sleep quality which are 10.3% ($p = 0.021$) lower.

Table 3 presents the results of our regression analysis with regard to the association between sleep duration and overall smartphone use. The construction of Table 3 is analogous to Table 2 with regard to the model's four different specifications. In line with the aforementioned negative association between overall smartphone use and subjective sleep quality, we find a highly significant negative association between overall smartphone use and students' sleep duration: a one standard deviation increase in the

[9] Linear models with White-corrected standard errors yield similar empirical conclusions (and are available on request).

smartphone use (i.e. a higher score of 0.930 on 10) is associated with 28.3% ($p < 0.001$) lower odds of sleeping at least seven hours a night, compared to sleeping fewer hours.

<Table 3 about here>

To further explore the mechanisms driving the negative association between smartphone use and (a) sleep quality and (b) sleep duration, we run ordered logistic regressions with an alternative set of independent variables. Instead of using the overall smartphone use scale, we include all nine items comprised by the scale separately. The main estimation results–presented in Table A1–indicate that listening to music on the smartphone is the activity that is most strongly associated with sleep quality and sleep duration.

<Table 4 about here>

To answer R1c and R1d, we used an ordered logistic regression approach, in analogy to the models in Table 2 and 3.[10] In these analyses, we rely on smartphone addiction as the independent variable instead of overall smartphone use. We present the detailed estimates of these regressions in Tables 4 and 5. Firstly, as Table 4 shows, we regress the PSQI subjective sleep quality scores on smartphone addiction. In accordance with the results that Table 2 presents, we find a strong significant and negative association between smartphone addiction and sleep quality. Indeed, an increase of one standard deviation of smartphone addiction (this corresponds to a score of 0.547 out of 5) is associated with 21.7% ($p < 0.001$) lower odds of experiencing very good sleep quality, when compared with the three other categories of the PSQI sleep quality component. In addition, we test the association between smartphone addiction and sleep duration. As Table 5 shows, we find a consistently negative association between smartphone addiction and sleep duration (OR = 0.776). In summary, with respect to H1, we find that smartphone use

[10] In addition, we test the sensitivity of the analyses we present in Table 3 by performing linear regressions–with White-corrected error terms–of the specific hours of sleep a night on overall smartphone use. Those analyses yield similar results as those based on the PSQI sleep duration component and are available on request.

is significantly negatively associated with both students' sleep quality and the length of their sleep.

<Table 5 about here>

To answer R2, we add several interactions between overall smartphone use and student's characteristics to the regression models of Tables 2 and 3. As Table 6 and Table 7 show, we separately add interactions of the overall smartphone use with a dummy that is '1' when the participant (1) is a woman, (2) is in a relationship, (3) is living in a student room, and (4) has a migration background. Model (5) integrates all four aforementioned interactions into one single regression. In these models, we control for the whole set of (potential) confounders included in model (4) of Table 2 and 3.

<Table 6 about here>

Table 6 presents the results of the regressions exploring moderating factors in the association between smartphone use and sleep quality. When students' smartphone use increases, we find that the odds of very good sleep quality of female students are significantly lower ($p = 0.001$) when compared with their male peers (OR = 0.785). The interactions we explore in model (2), model (3), and model (4) of Table 6 do not yield significant coefficients. In model (5), which integrates all interactions into one regression, the significant moderating role of gender ($p = 0.011$) remains consistent, both in significance and magnitude (OR = 0.788). In Table 7, we present the results of our regressions exploring these potential moderating factors in the association between smartphone use and sleep duration. Here, our empirical analyses do not yield any significant evidence for a moderating role of (i) gender, (ii) relationship status, (iii) residence status, and (iv) having a migration background. In summary, with respect to R2, we only find evidence for the moderating role of gender in the association between smartphone use and sleep quality.

<Table 7 about here>

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

4. Conclusion

With the current study, we add to the literature investigating the association between technology use and sleep outcomes. We investigated the association between overall smartphone use and both sleep duration and sleep quality exploiting data on 1,889 Flemish university students. We contribute to the literature in three ways. Firstly, we control for a very large set of confounding factors in our analyses. Secondly, we explore the moderation role in the association between smartphone use and sleep quality of socioeconomic factors not yet investigated in the previous literature. Next, we confirm our findings by using different constructs for sleep duration and smartphone use.

In conclusion, we find that a one standard deviation increase in students' overall smartphone use is associated with 10.3% lower odds of experiencing very good sleep quality when compared with the odds of experiencing poor sleep quality. This association seems to be the strongest for listening to music on the smartphone. Although listening to relaxing music has been associated with improved sleep (Cordi, Ackermann & Rasch, 2019), other music genres might induce arousal and/or emotional distress. The strong negative association found by Li, Lepp, and Barkley (2015) between smartphone use at night and sleep quality, might indicate that our results are driven by student's smartphone use at night. Furthermore, a similar increase in smartphone use is associated with 28.3% lower odds of sleeping at least seven hours a night rather than sleeping fewer hours. Although, this results do confirm our a priori expectation, this association is in contrast with Exelmans and Van den Bulck (2016) who do not find any association between smartphone use at night and sleep duration.[11]

[11] Justifications for different outcomes could be as follows: Exelmans and Van den Bulck (2016) measure only smartphone use just before bedtime whereas we measure overall smartphone use. Further, their respondents are 18-94 years old, while we focus on students who are on average 19 years old. Since the paper by Exelmans and Van den Bulck (2016) does not report the results for this age group separately, it is difficult to make direct comparison of the findings. Finally, Exelmans and Van den Bulck (2016) control for a smaller set of possible confounders than this paper.

With respect to the association between smartphone addiction and sleep quality, we find that an increase in the score for smartphone addiction is associated with 21.7% lower odds of experiencing good sleep quality and 22.4% lower odds of sleeping at least seven hours a night. Similar associations between problematic smartphone use and sleep quality were found by Eyvazlou, Zarei, Rahimi, and Abazari (2016), Mohammadbeigi et al. (2016), Sahin, Ozdemir, Unsal, and Temiz (2013), and Demirci, Akgönul, and Aspinar (2015) for students in Asia.

Comparing the magnitude of the association between (a) overall smartphone use and (b) smartphone addiction with sleep duration shows that an increase in the score of smartphone addiction is associated with higher odds of sleeping at least seven hours a night than an increase in overall smartphone use. In contrast, there is a substantial difference in the magnitude of the association with sleep quality. A higher score on the smartphone addiction scale is associated with much lower odds on a good sleep quality compared to an increase in overall smartphone use. This might indicate that in the case of smartphone addiction the time trade-off is less dominant since the association with sleep duration is less outspoken. In contrast, there is a stronger association with the sleep quality of the students which might point out that students with a higher level of smartphone addiction do experience higher levels of arousal and smartphone-related stress rather than only using the smartphone more.

We find a moderating role of gender in the association between smartphone use and sleep quality. This finding is supportive for the smartphone-related stress mechanism as females report more social media stress (Beyens, Frison & Eggermont, 2016) and are coping less effective with this stress (Nolen-Hoeksema, Larson & Grayson, 1999). In contrast, we do not find a significant moderating role of gender in the association of smartphone use with sleep duration. Our results indicate that feeling cared for in a relationship does not buffer the association between smartphone use and sleep. An alternative explanation is that being in a relationship leads to a higher need to be accessible for this partner. As such, the buffering mechanism might be neutralised by this additional stress.

We do not find any evidence for moderation of student's migration background on the association between smartphone use and both sleep quality and sleep duration. This could be result of our specific research population. Since the first-year courses at the university are taught in Dutch, students do need an adequate knowledge of the language. Therefore, our data collection might suffer from a selection bias since we might have captured only students who have been in Belgium for a long period. Students' residence status does not moderate the association of smartphone use with both sleep. This might be the result of a compensation of the extra smartphone use while commuting by waking earlier to be on time.

We end this article by acknowledging the main limitations of the current study and specific suggestions for further empirical research. Firstly, despite the fact that we do not claim any causality, we lack information on the chronology of the smartphone use and the sleep quality, which raises concerns about potential reversed causality (Tavernier & Willoughby, 2014). It is possible that high smartphone use is the outcome, rather than the cause of shorter nights and sleep quality (Hale & Guan, 2015). Moreover, although we collected data on a large variety of (socioeconomic) control variables, it is likely that we were not able to fully address potential bias from omitted variables. Therefore, in order to identify a causal relationship, following research could use different empirical approaches (e.g. fixed-effects estimations based on longitudinal data or instrumental variable techniques). If these studies confirm that the association measured in the present study reflect a causal impact of smartphone use on sleep quality, policy interventions (such as smartphone bans in schools) should be considered.

Secondly, our analyses were based on self-reported data collected by means of a paper-and-pencil questionnaire. We used the most common validated scales to date and introduced different constructs for both smartphone use and sleep quality into our analyses. However, only two subcomponents of the PSQI were integrated into our questionnaires. With respect to smartphone use, we only have data on overall smartphone use, lacking specific timing of the different activities. Furthermore, Boase and Ling

(2013) find only a limited correlation between actual, tracked smartphone use and that measured by self-reported instruments. Therefore, we look forward to future research confirming our empirical results based on actual smartphone usage statistics.

Thirdly, the construction of the paper-and-pen questionnaires implies that students are instructed to reflect on their smartphone use before answering questions about their sleep quality. This might trigger an order of question effect (McFarland, 1981) and potentially biased answers. Therefore, we encourage research based on randomly ordered online questionnaires to confirm our research results.

Fourthly, the current study demonstrates a strong negative association between smartphone use and sleep outcomes while previous research has repeatedly shown multiple consequences of deteriorated sleep. Therefore, it seems plausible that sleep quality might mediate the relationship between smartphone use and other outcomes. As such, it could be argued that sleep quality mediates the negative association between smartphone use and academic performance, which has been found by–amongst others–Lepp, Barkley and Karpinski (2014). Consequently, we encourage research that investigates the mediating effect of sleep quality in related associations with smartphone use.

Finally, although we do not have a priori reasons to believe that the association between smartphone use and sleep quality would be different for other groups of students, our research findings cannot automatically be generalised neither to other groups nor regions. Nevertheless, we encourage research confirming our conclusions based on comparable samples of another group of students or in other regions. And, we encourage the use of various constructs for both smartphone use and sleep quality.

Compliance with Ethical Standards

Simon Amez declares that he has no conflict of interest. Sunčica Vujić declares that she has no conflict of interest. Pieter Soffers declares that he has no conflict of interest. Stijn Baert declares that the has no conflict of interest. The authors received official approval of the Ethical Committee of the Faculty of Economics and Business Administration of Ghent University. Informed consent was obtained from all individual participants included in the study.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

References

Adachi-Mejia, A.M., Edwards, P.M., Gilbert-Diamond, D., Greenough, G.P., Olson, A.L. (2014). Txt me I'm only sleeping. Adolescents with mobile phones in their bedroom. *Family & Community Health, 37*(4), 252–257.

Baert, S., Verhaest, D., Vermeir, A., Omey, E. (2015). Mister Sandman, bring me good marks! On the relationship between sleep quality and academic achievement. *Social Science & Medicine, 130*, 91–98.

Ben-Simon, E., Walker, M.P. (2018). Sleep loss causes social withdrawal and loneliness. *Nature Communications, 9*, 3146.

Beyens, I., Frison, E., Eggermont, S. (2016). "I don't want to miss a thing": Adolescents' fear of missing out and its relationship to adolescents' social needs, Facebook use, and Facebook related stress. *Computers in Human Behavior, 64,* 1–8.

Boase, J. A., Ling, R. (2013). Measuring mobile phone use: Self-report versus log data. *Journal of Computer Mediated Communication, 18*(4), 508–519.

Brossoit, R.M., Crain, T.L., Leslie, J.J., Hammer, L.B., Truxillo, D.M., Bodner, T.E. (2019). The effects of sleep on workplace cognitive failure and safety. *Journal of Occupational Health Pyschology, 24*(4), 411–422.

Buysse, D.J., Reynolds, C.F., Monk, T.H., Berman, S.R., Kupfer, D.J. (1989). The Pittsburgh sleep quality index (PSQI): A new instrument for psychiatric research and practice. *Psychiatry Research, 28*(2), 193–213.

Cain, N., Gradisar, M. (2010). Electronic media use and sleep in school-aged children and adolescents: A review. *Sleep Medicine, 11*(8), 735–742.

Cordi, M.J., Ackermann, S., Rasch, B. (2019). Effects of relaxing music on healthy sleep. *Scientific Reports,* *9*, 9079.

Demirci, K., Akgönül, M., Akpinar, A. (2015). Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students. *Journal of Behavioral Addictions, 4*(2), 85–92.

Edens, K.M. (2006). The relationship of university students sleep habits and academic motivation. *NASPA Journal, 43*(3), 432–445.

Exelmans, L., Van den Bulck, J. (2016). Bedtime mobile phone use and sleep in adults. *Social Science & Medicine, 148*, 93–101.

Exelmans, L., Van den Bulck, J. (2017). Binge viewing, sleep, and the role of pre-sleep arousal. *Journal of Clinical Sleep Medicine, 13*(8), 1001–1008.

Eyvazlou, M., Zarei, E., Rahimi, A., Abazari, M. (2016). Association between overuse of mobile phones on quality of sleep and general health among occupational health and safety students. *Chronobiology International, 33*(3), 293–300.

Feeney, B.C., Kirkpatrick, L.A. (1996). Effects of adult attachment and presence of romantic partners on physiological responses to stress. Journal of Personality and Social Psychology, 70(2), 255–270.

Gallicchio, L., Kalesan, N. (2009). Sleep duration and mortality: A systematic review and meta-analysis. *Journal of Sleep Research, 18*(2), 148–158.

Hack-Polay, D. (2012). When home isn't home: A study of homesickness and coping strategies among migrant workers and expatriates. *International Journal of Psychological Studies, 4*(3), 62–72.

Hannsson, E., Mattisson, K., Björk, J., Östergren, P-O., Jakobsson, K. (2011). Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden. *BMC Public Health*, 11:834.

Hale, L., Guan, S. (2015). Screen time and sleep among school-aged children and adolescents: A systematic literature review. *Sleep Medicine Reviews, 51*, 50–58.

Hartmann, M.E., Prichard, J.R. (2018). Calculating the contribution of sleep problems to undergraduates' academic success. *Sleep Health, 4*(5), 463–471.

Higuchi, S., Motohashi, Y., Liu, Y., Maeda, A. (2005). Effects of playing a computer game using a bright display on presleep physiological variables, sleep latency, slow wave sleep and REM Sleep. *Journal of Sleep Research, 14*(3), 267–273.

Keseru, I., Macharis, C. (2017). Travel-based multitasking: review of the empirical evidence. *Transport Reviews, 38*(2), 162–183.

Kwon, M., Lee, J-Y., Won, W-Y., Park, J-W., Min, J-A., Hahn, C., Gu, X., Choi, J-H., Kim, D-J. (2013). Development and validation of a Smartphone Addiction Scale (SAS). *Plos One*, *8*(2), e56936.

Lepp, A., Barkley, J.E., Karpinski, A.C. (2014). The relationship between cell phone use, academic performance, anxiety, and satisfaction with life in college students. *Computers in Human Behavior*, *31*, 343–350.

Li, J., Lepp, A., Barkley, J.E. (2015). Locus of control and cell phone use: Implications for sleep quality, academic performance, and subjective well-being. *Computers in Human Behavior, 52*, 450–457.

Liu, S., Wing, Y.K., Hao, Y.L., Li, W.X., Zhang, J.H., Zhang, B. (2019). The associations of long-time mobile phone use with sleep disturbances and mental distress in technical college students: a prospective cohort study. *Sleep, 42*(2), zsy213.

McFarland, S.G. (1981). Effects of question order on survey responses. *The Public Opinion Quarterly, 45*(2), 208–215.

Mohammadbeigi, A., Absari, R., Valizadeh, F., Saadati, M., Sharifimoghadam, S., Ahmadi, A., Mokhtari, M., Ansari, H. (2016). Sleep quality in medical students: The impact of over-use of mobile cell-phone and social networks. *Journal of Research in Health Sciences*, *16*(1), 46–50.

Nolen-Hoeksema, S., Larson, J., Grayson, C. (1999). Explaining the gender difference in depressive symptoms. *Journal of Personality and Social Psychology*, *77*(5), 1061–1072.

Nuckols, T.K., Bhattacharya, J., Wolman, D.M., Ulmer, C., Escarce, J.J. (2009). Cost implications of reduced work hours and workloads for resident physicians. *New England Journal of Medicine, 360*(21), 2202–2215.

RAND Europe (2016). *Why sleep matters – the economic costs of insufficient sleep. A cross-country comparative analysis*. Cambridge, UK.

Rosen, L., Whaling, K., Carrier, L.M., Cheever, N.A., Rokkum, J. (2013). The media and technology usage and attitudes scale: An empirical investigation. *Computers in Human* Behavior*, 29*, 2501–2511.

Sahin, S., Ozdemir, K., Unsal, A., Temiz, N. (2013). Evaluation of mobile phone addiction level and sleep quality in university students. *Pakistan Journal of Medical Sciences, 29*(4), 913–918.

Sanford, L.K., Suchecki, D., Meerlo, P. (2014). Stress, arousal, and sleep. In P. Meerlo, R.M. Benca & T. Abel (Eds.), *Sleep, Neuronal Plasticity and Brain Function* (pp. 379–410). Berlin.

Schneeberger, A.R., Seixas, A., Schweinfurth, N., Lang, U.E., Cajochen, C., Bux, D.A., Richards, S., Jean-Louis, G., Huber, C.G. (2019). Differences in insomnia symptoms between immigrants and non-immigrants in Switzerland attributed to emotional distress: analysis of the Swiss health survey. *International Journal of Environmental Research and Public Health, 16*(2), 289.

Selcuk, E., Stanton, S.C.E., Slatcher, R.B., Ong, A.D. (2017). Perceived partner responsiveness predicts better sleep quality through lower anxiety. *Social Psychological and Personality Science, 8*(1), 83–92.

Tavernier, R., Willoughby, T. (2014). Sleep problems: predictor or outcome of media use among emerging adults at university? *Journal of Sleep Research*, *23*(4), 389–396.

The Guardian (2017). Sleep should be prescribed: What those late nights out could be costing you. Retrieved on 4 September 2018 from https://www.theguardian.com/lifeandstyle/2017/sep/24/why-lack-of-sleep-health-worst-enemy-matthew-walker-why-we-sleep.

Valkenburg, P.M., Peter, J. (2013). The differential susceptibility to media effects model. *Journal of Communication*, *63*(2), 221–243.

Vallerand, R.J., Pelletier, L.G., Blais, M.R., Briere, N.M., Senecal, C., Vallieres, E.F. (1992). The Academic Motivation Scale: A measure of intrinsic, extrinsic and amotivation in education. *Educational and Psychological Measurement, 52*(4), 1003–1017.

Van der Schuur, W.A., Baumgartner, S.E., Sumter, S.R (2018). Social media use, social media stress, and sleep: Examining cross-sectional and longitudinal relationships in adolescents. *Health Communication*, 1–8.

Van der Schuur, W.A., Baumgartner, S.E., Sumter, S.R., Valkenburg, P.M. (2018). Media multitasking and sleep problems: A longitudinal study among adolescents. *Computers in Human Behavior, 81*, 316–324.

Zeiders, K.H., Doane, L.D., Adam, E.K. (2011). Reciprocal relations between objectively measured sleep patterns and diurnal cortisol rhythms in late adolescence. *Journal of Adolescent Health, 48*(6), 566–571.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

Table 1. Data description

	(1) Average	(2)	(3)	(4)
	Full sample N = 1,889	Subsample: Overall smartphone use below average N = 843	Subsample: Overall smartphone use above average N = 1,046	Difference: (3) – (2)
A. Smartphone use				
Overall smartphone use	5.764	4.970	6.403	1.432*** [51.717]
Smartphone addiction	2.424	2.266	2.552	0.285*** [11.667]
B. Control variables				
Female	0.527	0.542	0.515	−0.027 [1.347]
Age	18.785	18.756	18.809	0.052 [0.561]
Migration background	0.154	0.113	0.187	0.075*** [19.981]
Dutch is not main language at home	0.086	0.069	0.100	0.031* [5.600]
Highest diploma mother: no tertiary education	0.343	0.327	0.356	0.028 [1.652]
Highest diploma mother: tertiary education outside college	0.418	0.429	0.409	−0.020 [0.786]
Highest diploma mother: tertiary education in college	0.239	0.243	0.235	−0.008 [0.164]
Highest diploma father: no tertiary education	0.382	0.382	0.382	0.000 [0.000]
Highest diploma father: tertiary education outside college	0.291	0.287	0.294	0.007 [0.123]
Highest diploma father: tertiary education in college	0.327	0.331	0.323	−0.008 [0.130]
At least one parent passed away	0.028	0.025	0.030	0.005 [0.389]
Divorced parents	0.224	0.208	0.238	0.030 [2.488]
Number of siblings: none	0.110	0.109	0.111	0.002 [0.015]
Number of siblings: one	0.508	0.524	0.494	-0.030 [1.687]
Number of siblings: two	0.286	0.282	0.290	−0.007 [0.123]
Number of siblings: more than two	0.096	0.084	0.105	0.021 [2.362]
In a relationship	0.375	0.380	0.371	−0.009 [0.149]
Academic motivation scale	4.994	4.934	5.053	0.108*** [3.798]
Living in a student room	0.394	0.408	0.382	−0.026 [1.287]
Survey year: 2017	0.499	0.456	0.533	0.078*** [11.344]

C. Sleep quality				
PSQI subjective sleep quality component	1.934	1.981	1.897	−0.084*** [9.184]
PSQI sleep duration component	2.826	2.873	2.789	−0.084*** [19.094]

Notes. See Section 2.2 for a description of the data. T-tests (continuous variables) and χ2-tests (discrete variables) are performed to test whether the differences presented in column (3) are significantly different from 0. *** (**) ((*)) indicates significance at the 1% (5%) ((10%)) significance level. T-statistics or χ2-statistics are between brackets.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

Table 2. Association between overall smartphone use and PSQI subjective sleep quality component: main analyses

	(1)	(2)	(3)	(4)
Overall smartphone use	**0.896** (0.041)**	**0.914* (0.043)**	**0.914* (0.043)**	**0.897** (0.042)**
Female	-	0.828** (0.077)	0.832** (0.077)	0.824** (0.076)
Age	-	1.016 (0.024)	1.012 (0.024)	1.011 (0.024)
Highest diploma mother: tertiary education outside college	-	1.112 (0.127)	1.115 (0.127)	1.114 (0.127)
Highest diploma mother: tertiary education in college	-	1.128 (0.159)	1.131 (0.159)	1.141 (0.161)
Highest diploma father: tertiary education outside college	-	1.080 (0.128)	1.085 (0.129)	1.091 (0.130)
Highest diploma father: tertiary education in college	-	1.027 (0.129)	1.035 (0.131)	1.018 (0.129)
At least one parent passed away	-	1.261 (0.351)	1.250 (0.348)	1.285 (0.358)
Divorced parents	-	0.920 (0.105)	0.919 (0.105)	0.905 (0.104)
Dutch is not main language at home	-	0.800 (0.156)	0.794 (0.155)	0.796 (0.155)
Migration background	-	0.750* (0.117)	0.748* (0.117)	0.743* (0.116)
Number of siblings: one	-	0.911 (0.139)	0.913 (0.139)	0.919 (0.140)
Number of siblings: two	-	0.823 (0.135)	0.824 (0.135)	0.838 (0.138)
Number of siblings: more than two	-	0.822 (0.147)	0.720 (0.147)	0.730 (0.149)
In a relationship	-	1.378*** (0.133)	1.382*** (0.133)	1.359*** (0.132)
Survey year: 2017	-	1.061 (0.097)	1.062 (0.098)	1.074 (0.099)
Living in a student room	-	-	0.936 (0.089)	0.926 (0.088)
Academic motivation scale	-	-	-	1.255*** (0.096)
Cut-off: 1	−4.203 (0.190)	−3.999 (0.506)	−3.985 (0.506)	−3.001 (0.604)
Cut-off: 2	−1.245 (0.055)	−1.018 (0.472)	−1.005 (0.472)	−0.014 (0.577)
Cut-off: 3	1.569 (0.061)	1.843 (0.474)	1.857 (0.474)	2.859 (0.582)
Number of observations	1,889			

Notes. The dependent variable is whether the student perceives his sleep as bad (outcome value 0), rather bad (outcome value 1), rather good (outcome value 2), or good (outcome value 3). The overall smartphone use was standardised by subtracting the mean of the variable and dividing by its standard deviation. Coefficients are odds ratios. Standard errors are in parentheses. * (**) ((***)) indicates significance at the 10% (5%) ((1%)) level.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

Table 3. Association between overall smartphone use and PSQI sleep duration component: main analyses

	(1)	(2)	(3)	(4)
Overall smartphone use	0.661*** (0.047)	0.719*** (0.051)	0.718*** (0.051)	0.717*** (0.052)
Female	-	1.262* (0.169)	1.235 (0.166)	1.233 (0.166)
Age	-	0.970 (0.028)	0.960 (0.028)	0.959 (0.028)
Highest diploma mother: tertiary education outside college	-	1.271 (0.215)	1.250 (0.212)	1.250 (0.212)
Highest diploma mother: tertiary education in college	-	0.906 (0.176)	0.893 (0.174)	0.894 (0.174)
Highest diploma father: tertiary education outside college	-	1.503 (0.274)	1.454** (0.266)	1.455** (0.267)
Highest diploma father: tertiary education in college	-	1.133 (0.200)	1.081 (0.192)	1.080 (0.192)
At least one parent passed away	-	1.401 (0.580)	1.487 (0.616)	1.491 (0.618)
Divorced parents	-	0.735* (0.116)	0.733** (0.116)	0.732** (0.116)
Dutch is not main language at home	-	0.875 (0.204)	0.933 (0.220)	0.933 (0.220)
Migration background	-	0.405*** (0.077)	0.405*** (0.078)	0.405*** (0.078)
Number of siblings: one	-	0.604** (0.151)	0.606** (0.151)	0606** (0.151)
Number of siblings: two	-	0.691 (0.183)	0.690 (0.183)	0.690 (0.183)
Number of siblings: more than two	-	0.667 (0.203)	0.673 (0.205)	0.675 (0.206)
In a relationship	-	1.222 (0.176)	1.200 (0.174)	1.198 (0.174)
Survey year: 2017	-	1.002 (0.133)	1.004 (0.134)	1.005 (0.134)
Living in a student room	-	-	1.536*** (0.225)	1.534*** (0.225)
Academic motivation scale	-	-	-	1.022 (0.111)
Cut-off: 1	−5.831 (0.410)	−6.731 (0.726)	−6.819 (0.724)	−6.727 (0.863)
Cut-off: 2	−3.993 (0.168)	−4.886 (0.623)	−4.973 (0.620)	−4.881 (0.778)
Cut-off: 3	−1.785 (0.068)	−2.623 (0.602)	−2.704 (0.599)	−2.611 (0.762)
Number of observations		1,889		

Notes. The dependent variable is whether the student sleeps on average less than 5 hours (outcome value 0), between 5 and 6 hours (outcome value 1), between 6 and 7 hours (outcome value 2), or more than 7 hours (outcome value 3) a night. The overall smartphone use was standardised by subtracting the mean of the variable and dividing by its standard deviation. Coefficients are odds ratios. Standard errors are in parentheses. * (**) ((***)) indicates significance at the 10% (5%) ((1%)) level.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

Table 4. Association between smartphone addiction and PSQI subjective sleep quality component: main analyses

	(1)	(2)	(3)	(4)
Smartphone addiction	0.790*** (0.036)	0.788*** (0.036)	0.789*** (0.036)	0.783*** (0.036)
Female	-	0.853* (0.079)	0.856* (0.079)	0.850* (0.079)
Age	-	1.007 (0.024)	1.009 (0.024)	1.002 (0.024)
Highest diploma mother: tertiary education outside college	-	1.103 (0.126)	1.106 (0.126)	1.105 (0.126)
Highest diploma mother: tertiary education in college	-	1.115 (0.157)	1.117 (0.157)	1.129 (0.159)
Highest diploma father: tertiary education outside college	-	1.087 (0.129)	1.091 (0.130)	1.095 (0.130)
Highest diploma father: tertiary education in college	-	1.007 (0.127)	1.014 (0.128)	0.994 (0.126)
At least one parent passed away	-	1.195 (0.333)	1.185 (0.331)	1.215 (0.340)
Divorced parents	-	0.928 (0.106)	0.927 (0.106)	0.912 (0.104)
Dutch is not main language at home	-	0.798 (0.155)	0.792 (0.155)	0.793 (0.155)
Migration background	-	0.731** (0.114)	0.729** (0.113)	0.720** (0.112)
Number of siblings: one	-	0.925 (0.141)	0.926 (0.141)	0.934 (0.142)
Number of siblings: two	-	0.835 (0.137)	0.837 (0.137)	0.854 (0.140)
Number of siblings: more than two	-	0.724 (0.147)	0.722 (0.147)	0.734 (0.150)
In a relationship	-	1.411*** (0.136)	1.415*** (0.137)	1.394*** (0.135)
Survey year: 2017	-	1.074 (0.099)	1.075 (0.099)	1.085 (0.100)
Living in a student room	-	-	0.939 (0.090)	0.930 (0.089)
Academic motivation scale	-	-	-	1.252*** (0.095)
Cut-off: 1	−4.223 (0.191)	−4.161 (0.508)	−4.148 (0.509)	−3.178 (0.604)
Cut-off: 2	−1.258 (0.056)	−1.170 (0.474)	−1.157 (0.474)	−0.180 (0.576)
Cut-off: 3	1.582 (0.061)	1.720 (0.475)	1.734 (0.476)	2.722 (0.581)
Number of observations		1,889		

Notes. The dependent variable is whether the student perceives his sleep as bad (outcome value 0), rather bad (outcome value 1), rather good (outcome value 2), or good (outcome value 3). The overall smartphone use was standardised by subtracting the mean of the variable and dividing by its standard deviation. Coefficients are odds ratios. Standard errors are in parentheses. * (**) ((***)) indicates significance at the 10% (5%) ((1%)) level.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

Table 5. Association between smartphone addiction and PSQI sleep duration component: main analyses

	(1)	(2)	(3)	(4)
Smartphone addiction	**0.787*** (0.051)**	**0.775*** (0.051)**	**0.775*** (0.051)**	**0.776*** (0.051)**
Female	-	1.339** (0.180)	1.308** (0.176)	1.309** (0.176)
Age	-	0.961 (0.027)	0.952* (0.027)	0.952* (0.027)
Highest diploma mother: tertiary education outside college	-	1.309 (0.221)	1.288 (0.218)	1.288 (0.218)
Highest diploma mother: tertiary education in college	-	0.928 (0.180)	0.915 (0.178)	0.915 (0.178)
Highest diploma father: tertiary education outside college	-	1.492** (0.272)	1.448** (0.265)	1.447** (0.265)
Highest diploma father: tertiary education in college	-	1.078 (0.190)	1.029 (0.183)	1.030 (0.183)
At least one parent passed away	-	1.318 (0.545)	1.398 (0.579)	1.396 (0.578)
Divorced parents	-	0.725** (0.114)	0.725* (0.114)	0.725** (0.114)
Dutch is not main language at home	-	0.862 (0.201)	0.918 (0.216)	0.918 (0.216)
Migration background	-	0.370*** (0.070)	0.371*** (0.071)	0.371*** (0.071)
Number of siblings: one	-	0.615* (0.153)	0.617* (0.154)	0.617* (0.154)
Number of siblings: two	-	0.714 (0.189)	0.712 (0.188)	0.712 (0.188)
Number of siblings: more than two	-	0.681 (0.207)	0.690 (0.210)	0.689 (0.210)
In a relationship	-	1.252 (0.180)	1.229 (0.178)	1.231 (0.178)
Survey year: 2017	-	0.992 (0.132)	0.993 (0.132)	0.992 (0.132)
Living in a student room	-	-	1.529*** (0.223)	1.531*** (0.224)
Academic motivation scale	-	-	-	0.982 (0.106)
Cut-off: 1	−5.778 (0.409)	−6.855 (0.722)	−6.925 (0.719)	−7.002 (0.858)
Cut-off: 2	−3.942 (0.167)	−5.012 (0.618)	−5.081 (0.615)	−5.159 (0.773)
Cut-off: 3	−1.748 (0.065)	−2.754 (0.596)	−2.816 (0.592)	−2.894 (0.756)
Number of observations		1,889		

Notes. The dependent variable is whether the student sleeps on average less than 5 hours (outcome value 0), between 5 and 6 hours (outcome value 1), between 6 and 7 hours (outcome value 2), or more than 7 hours (outcome value 3) a night. The overall smartphone use was standardised by subtracting the mean of the variable and dividing by its standard deviation. Coefficients are odds ratios. Standard errors are in parentheses. * (**) ((***)) indicates significance at the 10% (5%) ((1%)) level.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

Table 6. Association between overall smartphone use and PSQI subjective sleep quality component: interactions with student characteristics

	(1)	(2)	(3)	(4)	(5)
Overall smartphone use	1.023 (0.071)	0.887** (0.046)	0.924 (0.054)	0.901* (0.053)	1.028 (0.087)
Female x overall smartphone use	0.785*** (0.073)	-	-	-	0.788** (0.074)
Migration background x overall smartphone use	-	1.067 (0.132)	-	-	1.064 (0.132)
In a relationship x overall smartphone use	-	-	0.918 (0.089)	-	0.943 (0.092)
Living in a student room x overall smartphone use	-	-	-	0.986 (0.095)	1.009 (0.097)
Background characteristics	Yes	Yes	Yes	Yes	Yes
Academic characteristics	Yes	Yes	Yes	Yes	Yes
Academic motivation scale	Yes	Yes	Yes	Yes	Yes
Cut-off: 1	−3.006 (0.600)	−2.998 (0.602)	−2.976 (0.605)	−2.998 (0.604)	−2.989 (0.600)
Cut-off: 2	−0.017 (0.573)	−0.012 (0.575)	0.010 (0.578)	−0.011 (0.577)	0.000 (0.573)
Cut-off: 3	2.865 (0.578)	2.862 (0.580)	2.885 (0.583)	2.862 (0.582)	2.883 (0.578)
Number of observations			1,889		

Notes. The dependent variable is whether the student perceives his sleep as bad (outcome value 0), rather bad (outcome value 1), rather good (outcome value 2), or good (outcome value 3). The overall smartphone use was standardised by subtracting the mean of the variable and dividing by its standard deviation. Coefficients are odds ratios. Standard errors are in parentheses. * (**) ((***)) indicates significance at the 10% (5%) ((1%)) level.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

Table 7. Association between overall smartphone use and PSQI sleep duration component: interactions with student characteristics

	(1)	(2)	(3)	(4)	(5)
Overall smartphone use	0.715*** (0.071)	0.677*** (0.058)	0.741*** (0.062)	0.706*** (0.061)	0.678*** (0.086)
Female x overall smartphone use	1.006 (0.143)	-	-	-	1.014 (0.146)
Migration background x overall smartphone use	-	1.213 (0.186)	-	-	1.203 (0.187)
In a relationship x overall smartphone use	-	-	0.891 (0.140)	-	0.908 (0.146)
Living in a student room x overall smartphone use	-	-	-	1.050 (0.159)	1.071 (0.165)
Background characteristics	Yes	Yes	Yes	Yes	Yes
Academic characteristics	Yes	Yes	Yes	Yes	Yes
Academic motivation scale	Yes	Yes	Yes	Yes	Yes
Cut-off: 1	−6.728 (0.863)	−6.750 (0.856)	−6.672 (0.869)	−6.737 (0.864)	−6.723 (0.864)
Cut-off: 2	−4.882 (0.779)	−4.904 (0.771)	−4.827 (0.785)	−4.892 (0.780)	−4.877 (0.780)
Cut-off: 3	−2.613 (0.762)	−2.637 (0.754)	−2.558 (0.768)	−2.621 (0.763)	−2.610 (0.763)
Number of observations			1,889		

Notes. The dependent variable is whether the student sleeps on average less than 5 hours (outcome value 0), between 5 and 6 hours (outcome value 1), between 6 and 7 hours (outcome value 2), or more than 7 hours (outcome value 3) a night. The overall smartphone use was standardised by subtracting the mean of the variable and dividing by its standard deviation. Coefficients are odds ratios. Standard errors are in parentheses. * (**) ((***)) indicates significance at the 10% (5%) ((1%)) level.

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

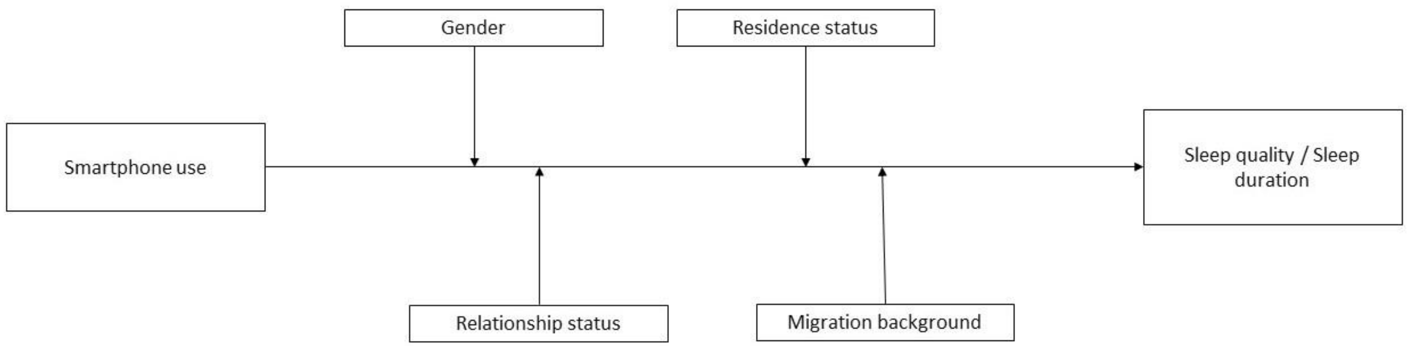

Figure 1. Moderation model

This article is forthcoming in Journal of Sleep Research. Please cite the journal article.

Appendix

Table A1. Main Estimation Results: Alternative Independent Variable Combinations

Outcome variable	(1) PSQI Sleep quality component	(2) PSQI Sleep quality component	(3) PSQI Sleep duration component	(4) PSQI Sleep duration component
Overall smartphone use	0.897** (0.042)	-	0.717*** (0.052)	-
Overall smartphone use (item): Read e-mail on a mobile phone	-	0.982 (0.028)	-	1.036 (0.043)
Overall smartphone use (item): Get directions or use GPS on a mobile phone	-	1.018 (0.038)	-	0.914* (0.046)
Overall smartphone use (item): Browse the web on a mobile phone	-	0.943 (0.038)	-	0.954 (0.059)
Overall smartphone use (item): Listen to music on a mobile phone	-	0.921*** (0.025)	-	0.884*** (0.038)
Overall smartphone use (item): Take pictures using a mobile phone	-	1.042 (0.042)	-	0.962 (0.057)
Overall smartphone use (item): Check the news on a mobile phone	-	1.001 (0.028)	-	0.969 (0.041)
Overall smartphone use (item): Record video on a mobile phone	-	0.954 (0.038)	-	0.965 (0.054)
Overall smartphone use (item): Use apps (for any purpose) on a mobile phone	-	1.002 (0.036)	-	1.018 (0.055)
Overall smartphone use (item): Search for information with a mobile phone	-	1.045 (0.044)	-	0.976 (0.061)
Additional control variables	All	All	All	All
Number of observations	1,850			

Note. The overall smartphone use was standardised by subtracting the mean of the variable and dividing by its standard deviation. Coefficients are odds ratios. Standard errors are in parentheses. * (**) ((***)) indicates significance at the 10% (5%) ((1%)) level.