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IZA DP No. 14547

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ABSTRACT

Deteriorated Sleep Quality Does Not Explain the Negative Impact of Smartphone Use on Academic Performance*

University students' smartphone use has recently been shown to negatively affect their academic performance. Surprisingly, research testing the empirical validity of potential mechanisms underlying this relationship is very limited. In particular, indirect effects of negative health consequences due to heavy smartphone use have never been investigated. To fill this gap, we investigate, for the first time, whether deteriorated sleep quality drives the negative impact on academic performance. To this end, we examine longitudinal data on 1,635 students at two major Belgian universities. Based on a combination of a random effects approach and seemingly unrelated regression, we find no statistically significant mediating effect of sleep quality in the relationship between smartphone use and academic performance.

JEL Classification: I21, I23, J24

Keywords: smartphone use, academic performance, sleep quality, mediation analysis

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1. Introduction

By 2019, the amount of smartphone users worldwide has risen up to 3.3 billion (Newzoo, 2020). This strong penetration of the technology indicates that smartphones are in general perceived as rather helpful. Nevertheless, smartphone use has extensively been associated with negative consequences (Busch & McCarthy, 2021) concerning (i) mental health (Chen, Yan, Tang, Yang, Xie & He, 2016; Rozgonjuk, Levine, Hall, & Elhai, 2018), (ii) physical health (Haripriya, Samuel, & Megha, 2019; Kim, Kim, & Yee, 2015), (iii) social behaviour (Choi, Choi, & Kim, 2017; Hawi & Samaha, 2017), and (iv) professional performance (Roberts & David, 2020).

A negative effect of smartphone use on academic performance (Nayak, 2018) can be considered as part of the latter group of consequences. A growing body of empirical studies examined a potential negative impact of smartphone use on academic performance. Based on a systematic literature review, Amez and Baert (2020) find a dominance of empirical studies supporting a negative association between students' smartphone use and academic performance. Nevertheless, they identify two major gaps in the empirical literature: (i) a lack of studies drawing causal interpretations, and (ii) very limited empirical research on the mechanisms underlying this association.

These limitations are substantial, from a policy point of view. First, a negative association between smartphone use and academic performance might not be problematic in itself when it only manifests variation in other unobserved characteristics. To the best of our knowledge, three empirical studies aimed to draw causal inferences, and all report a negative causal effect of smartphone use on university students' performance. Baert et al. (2020) analysed cross-sectional data by means of instrumental variable estimation techniques and found a strong negative impact of smartphone use on academic performance. Alternatively, Amez, Vujić, De Marez and Baert (in press) followed students for three consecutive years to be able to take unobserved individual heterogeneity into account. They report that an increase of one standard deviation in smartphone use yields a decrease of more than a third of a point (out of 20) on students' exam scores. Finally, Bjerre-Nielsen, Andersen, Minor, and Lassen (2020) monitored the actual smartphone use of Danish university students and found – based on a fixed effects approach – a negative relationship with their exam scores. However, they state that the magnitude of the effect strongly decreases when taking individual fixed effects into account.

Second, if a negative impact of smartphone use on academic performance is affirmed, it is essential to reveal the underlying mechanisms driving this relationship to create and implement effective smartphone policies. Multiple theoretical mechanisms have been discussed in the literature to date.[1] As such, multitasking or task-switching might lead to a cognitive overload (Junco, 2012). This multitasking behaviour might be induced by auditive or visual notifications (Junco & Cotten, 2012). Alternatively, this might be the result of a desire not to miss out on anything happening online (Chen & Yan, 2016) or destructive addictive behaviour (Vitak, Crouse, & LaRose, 2011). Next, students may perceive their smartphones as providing an easy and tempting escape from academic tasks (Hawi & Samaha, 2016). Moreover, there might be a time trade-off à la Becker (1965) whereby every minute spent on the smartphone cannot be used productively.

Surprisingly, indirect effects through negative health consequences caused by smartphone use have received little attention. In particular, students' sleep quality might

[1] A more thorough description of these theoretical mechanisms can be found in Amez and Baert (2020).

mediate the impact of smartphone use on academic performance. On the one hand, proper sleep quality has shown to be crucial for performing well academically (Baert, Omey, Verhaest, & Vermeir, 2015; Hysing, Harvey, Linton, Askeland, & Sivertsen, 2016). Smartphone use, on the other hand, has recently been associated with deteriorated sleep quality (Amez, Vujić, Soffers, & Baert, 2020; Exelmans & Van den Bulck, 2016; Li, Lepp, & Barkley, 2015). Therefore, we hypothesise that the relationship between students' smartphone use and academic performance might be (partly) mediated by a negative effect of smartphone use on their sleep quality. To test this hypothesis, we run a state-of the-art mediation analysis on longitudinal data containing rich information on university students' smartphone use, sleep quality, exam scores and a wide range of control variables.

2. Method

2.1. Research population

For three successive years, students from eleven separate study programmes at two representative Belgian universities, i.e. University of Antwerp and Ghent University, were recruited to participate. During the first year of data collection, 2016, all freshmen students enrolled for the included study programmes, were approached by the main researcher at the start of a main course during the last week of the first semester. All attending students were requested to fill-in a paper-and-pen questionnaire. At the end of the questionnaire, students were asked for active consent to combine their answers on the questionnaire with their exam scores from the following examination period. For all students who consented, an independent third party received (i) students' exam scores from the faculty administration and (ii) the survey answers from the main researcher. Next, this independent third party linked the information and provided the anonymised dataset to the researchers. The next two years, i.e. 2017 and 2018, this data collection procedure was repeated targeting both freshmen students and all students who had participated the previous year(s). At Ghent University, no additional data collection was organised in 2018.[2]

Next, all filled-in questionnaires were evaluated based on three major exclusion criteria. First, all students for whom the faculty administration was not able to provide exam results were excluded. This might have been because students (i) dropped out before the examination period or (ii) switched to a different study programme which was not included in the targeted population. In other cases, exams were excluded because successful matching was impossible, due to small errors in the unique student identifiers needed to obtain the respective exam scores. Second, all students who did not participate (earlier) as a first-year student were dropped, leaving a homogenous group of students. Third, the remaining questionnaires were checked for missing values with respect to the main variables. This procedure resulted in a final sample of 1,883 questionnaires filled-in by 1,635 unique individuals.[3]

2.2. Measures

As discussed above, the main source of data was the paper-and-pen questionnaire completed by the participating students. The questionnaire consisted of three main parts.

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[2] The current data collection was organised simultaneously with the data gathering process of Amez et al. (in press).

[3] After applying all three exclusion criteria on the initial sample 1,884 observations remained. However, we needed to exclude one additional observation to successfully run the Stata-command (see infra). We have no reason to believe that the main findings of our analyses would have changed drastically by dropping one single observation from a relatively large sample.

The first section asked students more about their smartphone use. Next, the second section contained questions concerning their sleep quality. The final part of the survey inquired the participating students with respect to a broad range of control variables (see infra).

The first section of the questionnaire started with the question 'Do you own a smartphone (i.e. a mobile phone which enables more computer capabilities than sending text messages and making calls)?' to assess whether the student qualified to participate (Baert et al., 2020). Next, overall smartphone use was measured by means of the Smartphone Usage Subscale of Rosen, Whaling, Carrier, Cheever, and Rokkum (2013). This scale consisted of nine statements concerning nine different activities (e.g. checking the news or read e-mails) whereby students were asked to indicate how frequently they perform these activities on their smartphone. Participating students scored every single activity on a 10-point scale, ranging from 1 (corresponding to 'never') to 10 (corresponding to 'all the time'). Thereafter, these nine separate scores were averaged, resulting in a score between 1 and 10, where a higher score indicates a higher frequency of smartphone use. The average score on the Smartphone Usage Subscale, henceforth referred to as *overall smartphone use*, was 5.744 as can be seen in Panel A of Table 1.[4]

<Table 1 about here>

Subsequently, section 2 of the survey queried students about their sleep quality. This was assessed by means of a subscale of the well-validated Pittsburgh Sleep Quality Index (PSQI) of Buysse et al.(1989). Concretely, students' sleep quality was measured by the PSQI subjective sleep subscale which consists of the question 'During the past month, how would

[4] For ease of presentation, we present the summary statistics in Table 1 on the year-student observation level. Summary statistics on the individual student level are available upon request.

you rate your overall sleep quality?'. Four potential answers were presented: (i) 'very bad'; (ii) 'fairly bad'; (iii) 'fairly good', (iv), 'very good'. Next, students' answers were scored – in contrast with the original PSQI subjective sleep quality subscale – such that higher scores indicate better sleep quality. Specifically, the answer 'very bad' corresponds with the score 0 while the score 3 indicates a 'very good' sleep quality. Panel B of Table 1 shows an average score of 1.912 which is very close to a 'fairly good' sleep quality.

The final part of the questionnaire consisted of questions concerning a wide variety of control variables. As can be seen in Table 1, we divided control variables in three categories depending on how they change over time: (i) time invariant control variables (Panel C), (ii) predetermined time varying control variables (Panel D), and (iii) time varying control variables (Panel E). First, we collected information with respect to control variables that do not change over time but are likely to be correlated with students' academic performance. As education research typically reports a female advantage in school performance (Voyer, & Voyer, 2014), students' gender was included in our empirical analyses. Next, we captured whether students had a migration background (Dockery, Koshy, & Li, 2020) by way of two related questions. Participants were asked (i) about their origin and (ii) whether Dutch was the main language spoken at home. This was followed by questions about parental education. However, we only included the information concerning the fathers' highest diploma since this was highly correlated with the academic achievement of the students' mothers. Household composition was assessed by asking students how many siblings they had at the time of the data collection. As earlier educational performance has shown to be a strong predictor of academic performance (Galla et al., 2019; Westrick et al., 2015), students were asked about (a) their study programme in high school and (b) their general end marks in high school. Panel C of Table 1 presents the summary statistics for these time invariant control variables. To summarise, a slight majority (53.7%) of our finale sample consisted of female participants while only less than a fifth (16.9%) of the participating students had a foreign origin.

Furthermore, students were surveyed on predetermined time varying control variables. These are variables that might change over time but are – in principle – determined at the beginning of the academic year. With respect to household composition, we constructed two dummy variables indicating whether (i) at least one of the student's parents passed away and whether (ii) his/her parents are divorced. Next, we also included a dummy variable which has the value 1 when the student lives in a student room as students' residence status has shown to be associated with academic performance (Schudde, 2011; Simpson, & Burnett, 2019). To assess each student's course load, we calculated the total number of ECTS-credits the student aims to obtain in the observed semester (Amez et al., 2020). Lastly, we also constructed dummy variables for all eleven study programmes, assigning a value of 1 if the student is enrolled for the respective programme. As can be seen in Panel D of Table 1, slightly more than a third (34.0%) of the students lived in a student room. Moreover, the final sample of participants contained almost as many students enrolled at the University of Antwerp (47.3%) as at Ghent University.

Additionally, we collected information on time varying control variables that are not determined at the start of the semester. First, students' academic motivation was evaluated by means of the College Version of the Academic Motivation Scale of Vallerand et al. (1992). This well-established scale instrument has 28 items that have to be evaluated on a 7-point Likert scale. Subsequently, all items were scored such that higher scores demonstrate higher academic motivation and are then averaged. As can be seen in Panel E of Table 1, the average score for academic motivation was close to 5 (4.972). Next, students were asked about their current perceived health status. Based on the three answer possibilities, we constructed three dummy variables, through which each student indicated her/his health to be either (i) very good, (ii) fairly good, or (iii) (fairly) bad. Lastly, students had to indicate whether they were in a romantic relationship at the time of completing the questionnaire.

Finally, our outcome of interest, academic performance, was assessed by the actual exam scores that were provided by the faculty administration to an independent third party (see supra). This variable was operationalised by taking the average exam score of all the exams the participant took in the next examination period. In Belgium, exams at university are typically graded on a scale of 20 points.[5] As shown in Panel F of Table 1, the participating students on average passed their exams with a score of almost 11 (10.987) out of 20 points.

2.3. Statistical approach

To test whether sleep quality mediates the relationship between smartphone use and academic performance, we needed to estimate two separate equations. On the one hand, we had to regress students' average exam scores on their overall smartphone use and a broad set of control variables. On the other hand, we had to estimate the association between their sleep quality and smartphone use, while holding other drivers of sleep quality constant. However, it is expected that the error terms across the two equations are correlated for a given student. Therefore, we applied a set of seemingly unrelated regressions instead to allow for this cross-equation correlation. Moreover, exploiting this correlation improved the efficiency of our estimator (Cameron & Trivedi, 2010).

[5] Analyses which include exams that students did not take yield very similar results and are available upon reasonable request.

As described in Subsection 2.1., we collected data on students' smartphone use, sleep quality and academic performance for three consecutive years. Compared to cross-sectional observational data, we were able to take (unobserved) individual heterogeneity into account (Verbeek, 2012). Moreover, the longitudinal character of the data allowed us to explore both between-student and within-student variation (Bell, Fairbrother, & Jones, 2019) which further increased the efficiency of our estimations. As such, we combined a random individual effects approach with seemingly unrelated regressions by means of the custom-made *xtsur*-command in Stata by Nguyen (2008).

The estimates of our random effects approach might be interpreted in a causal way under two main assumptions. First, all factors that affect students' exam scores that have not been included in our analyses were identically and independently distributed over all students (Amez et al., 2020). Therefore, all those unobserved factors can be summarised by a random error term. Second, our main independent variable, i.e. overall smartphone use is uncorrelated with the individual specific effect and is strictly exogenous (Verbeek, 2012).

3. Results

Our mediation model, which is visualised in Figure 1, shows that overall smartphone use is linked with students' average exam scores in two ways: (i) a direct way and (ii) an indirect way via the included mediator, i.e. the PSQI subjective sleep quality subscale. This model consisting of a system of two related regressions was estimated by the statistical approach described in Subsection 2.3. The estimation results are presented in Figure 1 and Table 2.

<Figure 1 about here>

Most interestingly with respect to our main research goal is the estimated mediating effect of sleep quality. This effect is the product of (i) the effect of overall smartphone use on the PSQI subjective sleep quality subscale (a in Figure 1), and (ii) the effect of students' sleep quality on their average exam scores (b in Figure 1). In contrast with earlier (cross-sectional) findings of – amongst others – Amez et al. (2020) we find no significant association between students' overall smartphone use and their score on the PSQI subjective sleep quality subscale (b = 0.052, p = 0.819). In contrast, the association of sleep quality with students' average exam scores is statistically significant and completely in line with Baert et al. (2015) and Hysing et al. (2016) – as discussed in the Introduction section (a = 0.688, p = 0.000). However, multiplying both estimated coefficients does not yield a statistically significant mediation effect of sleep quality ($a*b$ = 0.036, p = 0.819), implying that deteriorated sleep quality does not drive the negative impact of students' overall smartphone use on academic performance.

In line with the theoretical reasoning in the Introduction section and the recent empirical literature (Amez et al., in press; Baert et al., 2020; Bjerre-Nielsen et al., 2020), we find a significant direct effect of students' overall smartphone use on their average exam scores (c' = −0.157, p = 0.029).

<Table 2 about here>

Before concluding, we briefly discuss some secondary results with respect to other determinants of academic achievement. The coefficient estimates for these determinants are presented in the first column of Table 2. In line with earlier educational research we find that students who perform well are those that (i) do not have a migration background, (ii) have a highly educated father, (iii) performed well in secondary education, and (iv) are in good health. However, we do not replicate the well-documented gender gap in academic performance. We do not find a statistically significant association of student's gender with exam scores (p = 0.804).

4. Conclusion

With the current study, we contributed to the empirical literature on the relationship between smartphone use and academic performance in two major ways. First, we explored – for the first time worldwide – the empirical validity of the theoretical mechanisms postulating that a negative impact of smartphone use on academic performance can be (partly) explained by negative health consequences and in particular students' sleep quality. Second, we applied our mediation analysis on longitudinal data which allowed us to give a causal interpretation to the estimated associations between smartphone use, sleep quality and exam results under weaker assumptions than in earlier literature.

We found no statistically significant mediating effect of students' sleep quality in the relationship between smartphone use and academic performance. This implies that the negative impact of smartphone use on academic performance that we confirmed based on our longitudinal data cannot be explained by worse sleep quality due to smartphone use. Based on this finding, the negative relationship between smartphone use and academic performance should not be treated by smartphone policies targeting a negative impact through students' sleep quality. To be able to accurately tackle this negative impact, future studies must test the empirical validity of other theoretical mechanisms discussed in the literature.

We end this manuscript by acknowledging its main limitations and relate them with directions for future research. First, although we used a well-established scale instrument to measure overall smartphone use, research has shown that the correlation between self-reported smartphone use and actual use is smaller than expected (Araujo, Wonneberger, Neijens, & de Vreese, 2017; Uzun & Kilis, 2019). Therefore, we encourage studies to replicate the current study based on objectively logged smartphone use.

Second, the number of students we observed multiple times is rather limited. As a consequence, fixed effects estimations were imprecise. Nevertheless, we believe our benchmark panel model controlling for random effects is still superior to cross-sectional observational studies since it allowed us to control for unobserved heterogeneity being at the same time more efficient than ordinary least squares estimations by considering both within-student and between-student variation (Bell, Fairbrother, & Jones, 2019). Nevertheless, future research might aim to expand the number of students observed multiple times and use fixed-effects estimators to replicate the current findings.

Third, we focus on measuring students' smartphone use only. In particular, we ignore the fact that students might (simultaneously) use other mobile technology such as laptops or tablet computers (Hale & Guan, 2015). Although the focus of the current study was on identifying potential mediation of sleep quality in the relationship between smartphone use and academic performance, further studies might expand this focus to include other mobile devices.

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Table 1. Summary Statistics

	(1) Average	(2) Standard deviation
A. Smartphone use		
Overall smartphone use	5.744	0.903
B. Mediator variable		
PSQI Subjective sleep subscale	1.912	0.658
C. Time invariant control variables		
Female	0.537	-
Foreign origin	0.169	-
Dutch is not the main language at home	0.090	-
Highest diploma father: no tertiary education	0.372	-
Highest diploma father: tertiary education outside college	0.292	-
Highest diploma father: tertiary education in college	0.336	-
Number of siblings: none	0.105	-
Number of siblings: one	0.508	-
Number of siblings: two	0.275	-
Number of siblings: more than two	0.112	-
Programme in secondary education: Economics—Languages	0.133	-
Programme in secondary education: Economics—Maths	0.191	-
Programme in secondary education: Ancient Languages	0.147	-
Programme in secondary education: Exact sciences—Maths	0.146	-
Programme in secondary education: Other	0.384	-
General end marks secondary education: less than 70%	0.339	-
General end marks secondary education: between 70% & 80%	0.536	-
General end marks secondary education: more than 80%	0.125	-
D. Predetermined time varying control variables		
At least one parent passed away	0.030	-
Divorced parents	0.216	-
Living in a student room	0.340	-
Number of ECTS-credits in programme	22.765	5.780
Programme: University of Antwerp	0.473	-
Programme: Ghent University, Business and Economics	0.223	-
Programme: Ghent University, Commercial Sciences	0.247	-
Programme: Ghent University, Public Administration and Management	0.057	-
Programme: University of Antwerp, Business Economics	0.191	-
Programme: University of Antwerp, Economic Policy	0.025	-
Programme: University of Antwerp, Business Engineering	0.088	-
Programme: University of Antwerp, Management Information Systems	0.029	-
Programme: University of Antwerp, Communication Studies	0.032	-
Programme: University of Antwerp, Political Science	0.013	-
Programme: University of Antwerp, Social and Economic Sciences	0.065	-
Programme: University of Antwerp, Sociology	0.022	-
Programme: Other	0.008	-
E. Time varying control variables		
Academic motivation scale	4.972	0.607
General health: (fairly) bad	0.043	-
General health: fairly good	0.579	-
General health: very good	0.378	-
In a relationship	0.350	-
F. Academic performance		
Average exam score	10.987	3.160
Number of observations	1,883	

Note. See Section 2 for a description of the data. No standard deviation is provided for binary variables.

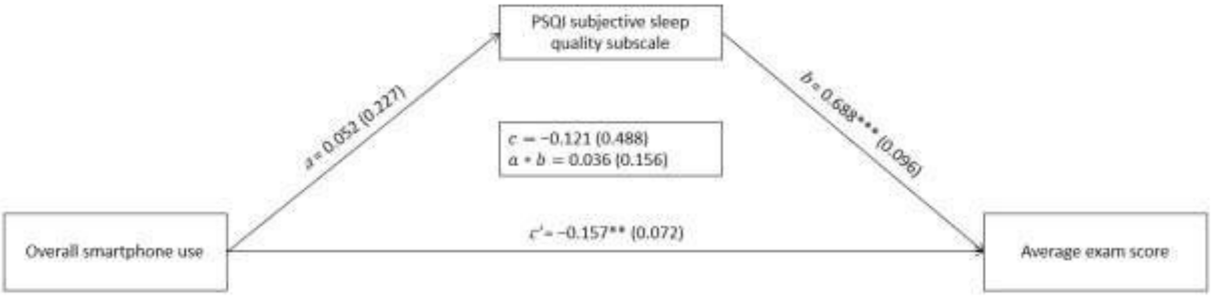

Figure 1. Mediation model

Notes: The presented statistics are coefficient estimates and standard errors. Standard errors are in parentheses. *** (**) ((*)) indicates significance at the 1% (5%) ((10%)) significance level. *c* stands for the total association, *c'* for the direct association; and *a*b* for the indirect association between overall smartphone use and exam score.

Table 2. Estimation Results: Benchmark Analysis

Dependent variable	Exam score	PSQI subjective sleep subscale
Overall smartphone use	−0.157** (0.072)	0.052 (0.227)
PSQI subjective sleep quality	0.688*** (0.096)	-
Program: University of Antwerp	2.152** (1.061)	−0.114 (2.187)
Female	0.029 (0.115)	−0.009 (0.335)
Foreign origin	−0.923*** (0.200)	−0.043 (0.744)
Dutch is not main language at home	−0.740*** (0.252)	−0.052 (0.853)
Highest diploma father: tertiary education outside college	0.678*** (0.151)	0.028 (0.415)
Highest diploma father: tertiary education in college	0.785*** (0.165)	−0.043 (0.455)
Number of siblings: one	0.772*** (0.246)	0.070 (0.746)
Number of siblings: two	0.660** (0.279)	0.005 (0.858)
Number of siblings: more than two	0.492* (0.271)	−0.055 (0.894)
Programme in secondary education: Economics—Languages	−0.002 (0.201)	-
Programme in secondary education: Economics—Maths	0.948*** (0.182)	-
Programme in secondary education: Ancient Languages	1.518*** (0.161)	-
Programme in secondary education: Exact sciences—Maths	0.999*** (0.208)	-
General end marks secondary education: between 70% & 80%	1.692*** (0.120)	-
General end marks secondary education: more than 80%	2.861*** (0.244)	-
At least one parent passed away	1.200*** (0.301)	0.021 (0.880)
Divorced parents	0.099 (0.134)	0.000 (0.428)
Living in a student room	0.174 (0.152)	0.035 (0.467)
Number of ECTS-credits in programme	0.191*** (0.041)	-
Academic motivation scale	0.013 (0.091)	0.182 (0.324)
General health: fairly good	1.691*** (0.219)	0.564 (0.739)
General health: very good	1.508*** (0.230)	0.915 (0.766)
In a relationship	−0.096 (0.129)	0.087 (0.355)
Academic program controls	Yes	No
Number of observations	1,883	

Notes. See Section 2.3 for a description of the mediation model. The presented results are coefficient estimates, with standard errors in parentheses. *** (**) ((*)) indicates significance at the 1% (5%) ((10%)) significance level.