Advising Sleep Deprived Students to Take Online Classes

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Abstract
Surveys indicate that nearly three-fourths of all college students do not get an adequate amount of sleep on most nights and over half report daytime sleepiness. Sleep deficiency impairs cognitive function, diminishes academic performance, and impedes learning. Asynchronous online education, which provides flexibility to participate in learning exercises and complete assignments at a time and pace that better matches a student's sleep schedule, may offer a solution to this problem. In this study, we examine the impact of reported sleep deprivation on learning outcomes for a group of students who took an asynchronous online class versus a similar group of students who took the same class in a face-to-face (F2F) setting (N = 399). Our results indicate that whereas sleep deprivation, all other factors held constant, significantly negatively affects learning for F2F students, no such influence is observed for online learners. Student counselors and school administrators should therefore consider advising sleep-deprived students to take more online classes to enhance student learning outcomes, which in turn may improve student retention and degree completion.

Keywords: college students, sleep deprivation, face-to-face education, asynchronous online learning, improved learning outcomes, student retention, degree completion

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Sleep deprivation is defined as an insufficient duration of sleep or impaired sleep quality over an extended period (Gaultney, 2010). Numerous academic studies document that many college students suffer from some degree of, perhaps even chronic, sleep deprivation (Buysse et al., 1989; Hershner & Chervin, 2014; Breese, 2020; Hirshkowitz et al., 2015). Problems associated with sleepiness include impaired memory, degraded sequential thinking, diminished creativity, risky behavior, increased stress, depression, irritability, and aggression (Kelly et al., 2001; Lowry et al., 2010; Taylor et al., 2013; Schlarb et al, 2017). Sleep deprivation lessens cognitive abilities and can harm academic performance.

Even prior to COVID-19, online student enrollment was steadily growing. Between 2002 and 2018, the average annual growth rate in the number of students taking online courses was seven times greater than the annual growth rate in overall higher education (Seaman et al., 2018; Duffin, 2020). Surveys indicate that, particularly for asynchronous online classes, convenience and flexibility are key reasons why students choose to take their courses remotely (Harris & Martin, 2012). More specifically, in asynchronous online classes, students do not have to "show up" at a specific time for class. They can participate in learning exercises and complete tasks at a pace that most appropriately matches their learning style and at a time that best fits their schedule.

The purpose of this study is to empirically investigate whether, all else equal, the flexible nature of an asynchronous online course helps offset the negative impact of sleep deprivation on learning. More specifically, we examine the major factors (including a sleep deprivation variable) that affect learning outcomes of 399 college students who took a face-to-face (F2F) course relative to students who took the same course, taught by the same instructor, in an asynchronous online setting. All aspects of the course, other than mode of instruction, were designed to be as identical as possible. The impact of sleep deprivation on both course average and score on the common, comprehensive final exam (that all students took in a closely proctored classroom) are examined to determine how sleepiness influences learning in the different settings.

Our study and findings have important implications for students, advisement officers, teachers, and administrators seeking to improve student retention and degree completion. To the extent that the negative consequences of sleep deprivation on student learning are reduced in a virtual format, students who know they have sleep issues should consider taking more online courses, especially asynchronous online classes. Moreover, academic advisors should encourage advisees to complete a sleep quality questionnaire (e.g., the Pittsburgh Sleep Quality Index) and then consider advising students who score poorly to take more of their required course load online. And administrators and teachers should consider increasing asynchronous online offerings at their schools to enhance student learning outcomes, which in turn may improve student retention and degree completion. This final lesson is particularly important for schools with a large percentage of students who also hold part-time or full-time jobs or schools with a significant at-risk student population.

Research Questions

The purpose of this study is to empirically examine whether the combination of convenience and flexibility offered by an asynchronous online class format mitigates the impact of sleep deprivation on student learning outcomes. Our specific research objective is to investigate whether perceived sleep deprivation plays different roles in explaining student performance in F2F vs. asynchronous online courses. In this study, we propose to answer the following research questions:

1. Does the nature of reported sleep deprivation among the college students in our dataset correspond with existing literature?
2. All else constant, are student learning outcomes in a F2F class negatively impacted by a self-reported measure of sleep deprivation?
3. All else constant, is the impact of sleep deprivation on student performance reduced (or perhaps eliminated) by taking the same class in an asynchronous online environment?

Literature Review

Gaultney (2010), using the Pittsburgh Sleep Quality Index, a validated self-rated questionnaire that measures sleep quality and patterns (Buysse et al., 1989), reports that over 60 percent of the 1,845 college students in their survey claim to experience poor sleep quality and as many as 27 percent are at risk of having at least one sleep disorder. Hershner & Chervin (2014) find that over 50 percent of college students report daytime sleepiness and nearly 71 percent allege that they do not get an adequate amount of sleep on most nights, especially during the school week. Breese (2020) notes that in a survey of over 10,000 college students in the United States, the average number of hours that students report sleeping is 6.5 hours per night; the National Sleep Foundation recommends that young adults ages 18 to 25 should get 7 to 9 hours of sleep per night (Hirshkowitz et al., 2015). Obviously, sleep deprivation is a serious problem for many college students.

It is tempting to classify college student sleep problems as merely an immature reaction to newfound independence. Doing so, however, overly simplifies a highly complex issue. There are biological, technological, and societal components to college student sleep deprivation.

Biological Factors

Biology, coupled with questionable high school scheduling and the typical college lifestyle, significantly influences teen and college student sleep issues. All organisms have a biological clock that regulates the cycle of circadian rhythms (National Institute of General Medical Sciences, 2020). In humans, there is an internal clock that controls wakefulness and sleepiness. More specifically, the light-related circadian rhythm tells humans to sleep at night and be awake during the day. The circadian cycle influences hormone production, brain wave patterns, cellular reproduction, and more. Circadian rhythm disorders have been associated with poor concentration, impaired performance, diminished cognitive skills, lack of coordination, and headaches (Barion & Zee, 2007).

According to Hagenauer et al. (2009), researchers have discovered that the typical circadian sleep rhythm differs significantly between youth, teens, and adults. Somewhere in the early teen years, about the time most children begin high school, a biologically driven hormonal change occurs. Scientists identify this change as an internal clock shift that tells teenagers to stay awake for an additional two hours per day compared to what they did as pre-teens. The clock shift reverses itself around age 25.

During this period, teens still need the same number of hours of sleep; they merely want to stay awake later at night and sleep longer each morning. However, most high school classes begin at 8 am or earlier. In fact, in many cities in the U.S., high schoolers start classes before elementary school students. Consequently, high schoolers stay up later (for biological reasons) and wake earlier to go to school (often to accommodate after-school programs such as sports), thus disrupting their natural circadian sleep rhythm. To make matters worse, most young teens stay up even later and sleep longer on weekends and holidays, creating a pattern disruption that further disturbs normal sleep cycles (Richter, 2015; Barnes et al., 2016).

Then, after up to four years of unhealthy sleep throughout high school, teens go to college where they experience being “freed” from having to be in class at 8 every morning. Because they can now sleep in longer, new college students often stay up still later each night. Inevitably, however, a major assignment is due, tomorrow is exam day, or it is finals week, and they pull an all-nighter. Still worse, the typical college lifestyle involves weekend parties that often include drugs and alcohol, further impairing sleep quality (Roehrs & Roth, 2001). Consequently, the college experience, which is supposed to provide young adults an environment where they can develop independence while gaining knowledge and understanding, may instead become the perfect storm for sleep deprivation to thrive (Hershner & Chervin, 2014).

Technological Factors

As the sun sets, the body naturally starts releasing melatonin, a hormone that produces feelings of sleepiness. Electronic devices, such as televisions, cell phones, e-readers, and computer screens emit light within the blue spectrum (called “blue light”) that is similar in color and wavelength to daylight. When these screens are viewed at night, the body stops producing melatonin, which impacts sleep (West et al., 2011).

In a study involving 1,508 participants, aged 13 to 64, Gradisar et al. (2013) report that nine out of ten Americans use a blue-light-emitting technological device in the hour before they go to bed. Of this group, 72 percent of those who are high school and college age use a cell phone just before going to bed. In this same study, cell phones, which are interactive technological devices, are shown to have significantly more negative impacts on sleep quality than televisions, which are passive devices. Robb (2019), in a survey of over 1,000 children and parents, finds that 40 percent of teens use their cellphone within five minutes of going to bed and 36 percent of teens wake up and check their cellphone at least one time every night, the majority of which do so to check social media. Mei et al. (2018) conducted a meta-analysis of 19 peer reviewed sleep research studies, involving over 250,000 adolescents. The authors confirm that research conclusively demonstrates that excessive technology usage significantly prolongs sleep onset and reduces sleep duration.

Societal Factors

Sleep deprivation extends well beyond traditional college students. Cort-Blackson (2018) reports that non-traditional college students with full-time jobs, family responsibilities and other life stressors have a higher prevalence of sleep deprivation compared to the general population. Caceres & Hickey (2020) find that sexual minorities have a significantly more sleep problems than their straight counterparts. Roth (2009) notes a strong relationship between sleep challenges and individuals with multimorbidity. Although causality is difficult to establish, the author reports that as many as ninety percent of patients who report comorbid physical or mental illnesses, such as cardiovascular and respiratory diseases, hypertension, diabetes and mood disorders, also report abnormally high levels of sleep deprivation.

Moreover, sleep deprivation is a worldwide issue affecting all income groups, genders, and age categories (AlDabal & BaHammam, 2011). Sleep issues associated with wealth, stress, active lifestyles, and technology are to be expected, and indeed are well documented, in western countries (Krueger & Friedman, 2009; Groeger et al., 2004). Stranges et al. (2012), who examine sleep problems in Africa and Asia, find that individuals in low-income countries are just as likely to suffer from sleep issues as those in richer countries. In a survey of over 7,000 teens, Amaral et al. (2016) report that females are more likely to experience insomnia than males (24.4% to 15.4%), but high levels of insufficient sleep are reported by both genders at approximately the same rate (females = 29.9%, males = 30.4%). Even the young and the elderly suffer from sleep problems. Fricke-Oerkermann et al. (2007) cite studies indicating that 41 percent of parents report sleep issues in their 2- to-14-year-old children and 31 percent of children aged 6 to 13 claim to have problems initiating and sustaining sleep. Williams et al. (2013) find that a significant percent of older adults also experience insomnia and poor sleep quality.

The World Health Organization (WHO) estimates that nearly two-thirds of adults around the world sleep less than eight hours per night, prompting WHO to refer to sleeplessness as a “global pandemic” (Lyon, 2019). Liu et al. (2016) note that the CDC recently declared that sleep deprivation is a “public health epidemic.” Chattu et al. (2018) suggest that insufficient sleep syndrome should be classified on a global level as “one of the major noncommunicable diseases” (p. 61).

With regards to sleep deprivation, COVID-19 has made an already bad situation much worse. Increased stress and anxiety, disrupted routines, diminished activity, increased use of electronic devices, and a lack of stimulation is accentuating the circadian rhythm disorders discussed above. In fact, sleep experts have created a new term for the impact that COVID-19 is having on human sleep: “coronasomnia” (Berg, 2020).

Impact of Sleepiness on Academic Performance

Several studies assert that sleep deprivation negatively impacts student learning outcomes. Kelly et al. (2001) discover that students who sleep six or fewer hours per night (short sleepers) have significantly lower GPAs than those who report sleeping nine or more hours nightly (long sleepers). Lowry, Dean, & Manders (2010) find a significant positive relationship between hours of sleep per night and GPA. They also note that their data indicates a strong negative correlation between sleep quality (i.e., the average number of days a student gets five or fewer hours of sleep) and GPA. Controlling for psychological, demographic, and educational factors, Taylor et al. (2013) find that sleep variables are significant predictors of academic performance in college students; specifically, holding all other variables constant, poor sleep negatively impacts academic performance.

Sleep deprivation in college age students is also associated with mental health problems. Individuals with insomnia report higher levels of chronic fatigue, anxiety, stress, negative thoughts, and a lower quality of life (Schlarb et al., 2017). Sleepiness is correlated with depression, excessive fear of an upcoming stressful life event (e.g., a test or major assignment due), and increased use of stimulants. Unfortunately, these further deteriorate the quality of sleep thus feeding the poor sleep cycle.

Why Students Choose Online Classes

In surveys, students offer many reasons for choosing to take their courses online instead of face-to-face, but chief among these is flexibility/convenience (Harris & Martin, 2012). When students are free to choose between online or F2F instruction at the same school for the same cost, those who choose online, do so because they prefer a learning environment that allows them to fit their classes around work, family, and other commitments instead of figuring out how to arrange those activities around a fixed class schedule (O'Neill et al., 2021).

Some studies find that personal characteristics may influence student performance in online classes and thus students with these characteristics may be more apt to choose an online version of a course instead of a F2F counterpart. Using the Felder and Silverman (1988) learning styles measure, Battalio (2009) finds that reflective learners are more successful than active learners in online classes and sequential learners outperform global learners. In a study of over 1,150 students enrolled in online and F2F courses over a 14-year period, Boghikian-Whitby & Mortagy (2016) investigated the relationship between Myers-Briggs personality types and learning outcomes. They concluded that Sensing, Thinking, and Perceiving personality groups learned significantly more in an online setting than in a face-to-face modality.

More interestingly, Jaggars (2014) finds evidence that students are beginning to actively choose between an online course and a face-to-face course for specific reasons. For example, Jaggars (2014) reports that some students explicitly stated that they learned more effectively in an online course and others touted the lack of distraction from other students in the room. The author also found that students preferred to take "easy" courses online and to take more challenging and "important" courses face-to-face. These findings are particularly relevant for this current study because to the degree that we find that sleep-deprived students perform better in online courses, making these students aware of this finding may help them to choose more effectively which course modality is most appropriate.

Data and Methodology

The data used in this study is comprised of 399 students: 198 students who took an undergraduate course in finance in a traditional F2F setting and 201 students who took the same course online. The F2F and online sections of the course (taught pre-COVID) were purposely designed to be as similar as possible in all ways except setting. All sections of the class (F2F and online) were taught by the same instructor, shared a common syllabus, and followed the same weekly calendar.

The course used in this study is the core finance course in the business curriculum at a large, urban university. All business students, regardless of major, must take this fifteen-week course. The data was collected over two semesters. The online class had an average enrollment of approximately 100 students per semester. The F2F sections of about 50 students per section were taught each semester at various day/time combinations.

In both settings (online and F2F), the course was highly structured. Specific material was covered, and assignments were due each week. After the week ended, any assignments not completed received a score of 0. The major difference between the two courses was that the F2F class had regular classroom meetings during which the instructor lectured, collected completed problem sets, and administered quizzes and exams, and the online class used video lectures (which students could view whenever convenient during the week) and students were able to complete weekly online quizzes or electronically submit completed problem sets anytime during the week up to midnight on the due date.

The data set was formed by combining information on student course performance, student demographic data, and student surveys. Prior approval from the university's IRB was received for this research project. Once the three sets of data were merged into one electronic file, all student-specific identifiers were removed to strictly protect student anonymity.

The independent variables used in this study (except perceived sleep deprivation) have been validated in the finance education literature as being key determinants of student learning outcomes in an introductory finance course (Bredthauer & Fendler, 2016). Student-specific demographic data was provided by the university: GPA (college grade point average to date), gender, major, age, and semester course load (number of course hours taking during semester when taking this finance course). A math assessment variable was based on a short algebra test given at the start of the semester. In an end-of-semester survey, students were asked to indicate if their weekly schedule was highly predictable (4), generally predictable (3), generally unpredictable (2), or highly unpredictable (1). This variable is coded as Predictable Schedule. Students were asked if they "have a job or play a sport." This binary variable is coded as Have Job/Sport (yes = 1). The Hours Job/Sport variable represents the number of hours per week that students indicated that they engaged in either work, sport, or both.

Two questions in the end-of-semester survey regarded sleep. Specifically, students were asked to answer the following:

1. To the nearest half hour (for example, 8.0, 7.5, 7.0, 6.5, etc.), how many hours of sleep per night do you believe you need to function at your optimal level? Put another way, if you had no restrictions whatsoever on how many hours you could sleep per night, what number of hours (to the nearest half hour) would you most likely choose to sleep each night so that whatever you do while you are awake, you are able to do to the best of your ability?
2. To the nearest half hour (for example, 8.0, 7.5, 7.0, 6.5, etc.), what is the average number of hours per night that you actually sleep? Put another way, on average, how many hours of sleep do you actually get each night?

The first variable was coded as "Optimal Sleep Hours" and the second measure was coded as "Actual Sleep Hours." Table 1 provides summary statistics for these two variables for the entire group.

Table 1

Optimal Sleep Hours vs. Actual Sleep Hours for Entire Group

Measure	Min	Max	Mean (SD)
Optimal Sleep Hours	5.0	11.0	7.69 (1.07)
Actual Sleep Hours	2.5	9.0	6.12 (1.27)
Optimal - Actual	0.0	6.0	1.53 (1.21)
Perceived Sleep Deprivation (%)	0.0	70.6	19.3 (14.4)

The means and standard deviations for Optimal Sleep Hours and for Actual Sleep Hours in our dataset correspond with the literature. As noted in the previous section, the National Sleep Foundation recommends that young adults get 7 to 9 hours of sleep per night. The majority (i.e., mean plus or minus one standard deviation) of the students in our data set believe they should get between 6.6 and 8.8 hours of sleep per night. In a survey of over 10,000 college students, Breese (2020) found that the average number of hours that students claim they sleep per night is 6.5 hours. The average student in our dataset claims to sleep 6.1 hours per night.

The range of values for Optimal Sleep Hours is particularly interesting. Whereas some students believe that as few as 5 hours of sleep per night is optimal, others think they need up to 11 hours of sleep per night to perform at their best. This wide range is most likely due to factors such as health and sleep quality. Regardless of the specific reason, these differences are very important for our study because Actual Sleep Hours does not properly measure sleep deprivation. A student who averages 6 hours of sleep per night and believes that 6 hours of sleep is optimal is not sleep deprived. However, a student who gets 6 hours of sleep per night but believes that 10 hours is ideal is highly sleep deprived.

Row three in Table 1 displays summary statistics for Optimal Sleep Hours minus Actual Sleep Hours. For our entire dataset, this value ranges from 0.0 hours to 6.0 hours and has an average of 1.53 hours. Although this measure is interesting, it also does not accurately measure sleep deprivation because it ignores relative scale. For example, a student who believes that 11 hours of sleep per night is optimal but only gets 10.5 hours per night of actual sleep, has an "optimal – actual" amount of 0.5. A student who believes that 3 hours of sleep per night is optimal but only get 2.5 hours per night of actual sleep, also has an "optimal – actual" amount of 0.5. But the first student is getting 10.5/11 = 95.5% of an optimal amount of sleep per night and the second student is only getting 2.5/3 = 83.3% of an optimal amount of sleep per night.

Accordingly, we created a unique variable for our study called "Perceived Sleep Deprivation." This is a measure that relates the actual amount of sleep a student gets to what that student believes is the optimal amount of sleep on a relative basis. Perceived Sleep Deprivation is measured as:

$$\text{Perceived Sleep Deprivation} = 1 - \left(\frac{\text{Actual Sleep Hours}}{\text{Optimal Sleep Hours}}\right) \tag{1}$$

For example, a student whose self-reported optimal amount of sleep is eight hours but only gets seven hours would have a Perceived Sleep Deprivation score of 12.5% (1 - 7/8). Similarly, a student who sleeps six hours per night but believes they need eight, would have a higher perceived sleep deprivation ratio of 25% (1 - 6/8). By asking students to indicate the actual number of hours that they sleep and what they believe would be an optimal number of hours of sleep, our perceived sleep deprivation measure is standardized across all individuals in our dataset. A Chi-Squared Goodness-of-Fit test indicates that the distribution for each of the variables listed in Table 1 is normal.

Finally, our study relies on two dependent variables to measure student performance. The first is course average, which is calculated as follows: 10 percent quiz average, 10 percent problem set average, 20 percent mid-term exam one grade, 20 percent mid-term exam two grade, and 40 percent final exam grade. As this introductory finance course is heavily math oriented, the assessment of all quizzes, problem sets, and exams used to determine the course grade (in both the online and F2F sections) was primarily objective. That is, student answers were either right or wrong, and grading answers required no instructor interpretation. As a result, grading was very similar between course settings.

The second dependent variable used in the study is the student's score on a common, comprehensive final exam. All students (F2F and online) took this common final exam in a physical classroom at the same time on the same day. The final exam was a carefully proctored, strictly timed, closed-book, closed-notes exam.

We examine the possible impact of sleep deprivation on both variables because they measure different aspects of scholarship. Course average is a broader measure of student success. In addition to learning, it is also influenced by persistence and diligence in participating in all activities throughout the entire course. On the other hand, the final exam score is a purer measure of specific student learning outcomes in the course. This comprehensive examination covers every topic in the course in approximately equal weight to how much that topic was stressed in class readings and lectures (whether F2F or video).

Descriptive statistics for all variables used in this study are presented in Table 2. The far-right column in this table indicates whether the differences in mean values between the online group and the F2F group are significant based on t-tests for continuous variables and Chi-square tests for binary variables.

Table 2
Descriptive Statistics for the Online and F2F Group

	Online Group N = 201	**F2F Group** N =198	**Sig.**
Dependent Variables	**Mean (SD)**	**Mean (SD)**	
Course Average (%)	77.91 (10.60)	78.92 (10.39)	*n.s.*
Final Exam Score (%)	68.42 (18.12)	67.14 (15.30)	*n.s.*
Independent Continuous Variables			
GPA	3.25 (0.45)	3.13 (0.43)	$p < 0.01$
Perceived Sleep Deprivation (%)	19.31 (14.72)	20.33 (16.18)	*n.s.*
Age—Years	24.20 (4.61)	23.93 (3.82)	*n.s.*
Course Load—Hours	12.94 (3.62)	13.43 (3.10)	$p < 0.10$
Math Assessment	68.41 (18.61)	65.94 (21.89)	*n.s.*
Predictable Schedule	1.86 (0.69)	1.89 (0.65)	*n.s.*
Hours Job/Sport	23.41 (15.32)	25.62 (15.01)	*n.s.*
Independent Binary Variables	**Percent of Total**	**Percent of Total**	
Female	53.71	51.02	*n.s.*
Have Job/Sport	79.09	88.44	$p < 0.05$
Fin./Acct. Major	29.43	31.31	*n.s.*

As shown in Table 2, students who completed the course in the different settings were very similar. Indeed, GPA is the only variable that is highly significantly different between the online and F2F groups, with the online students having the higher GPA. The F2F students tend to carry a larger course load and are more likely to have a job or play a sport than the online students; however, the course-load difference is only weakly significant. Our university is an urban school which contributes to the generally older age (about 24 years old), many students who work (or play a sport), and a fairly large number of hours per week spent working. It is interesting to note that our perceived sleep deprivation variable is statistically similar between the two groups.

Results

Table 3, which shows the frequency distribution of perceived sleep deprivation overall and for each sub-group, provides an answer to research question 1. As shown in Table 3, only 20 percent of our total sample believe that they are getting an optimal amount of sleep. Thus, 80 percent of the students in our study believe that they have some degree of sleep deprivation. Over 70 percent of our sample believe they have a sleep deprivation of 11 percent or more and nearly 45 percent report having sleep deprivation of 21 percent or greater.

Comparing the different groups, a larger percent of the F2F group gets the optimal amount of sleep (23% vs. 16%). On the other hand, a larger percentage of the F2F group (48% vs. 43%) have a sleep deprivation of 21% or greater.

Table 3
Degree of Perceived Sleep Deprivation—Total and By Group

	ALL		F2F GROUP		ONLINE GROUP	
Perceived Sleep Deprivation	**N**	**% of All**	**N**	**% of F2F**	**N**	**% of Online**
0%	79	20%	46	23%	33	16%
1% to 10%	43	11%	16	8%	27	13%
11% to 20%	98	25%	42	21%	56	28%
21% to 30%	70	17%	33	17%	37	18%
31% to 40%	73	18%	39	20%	34	17%
41% to 50%	27	7%	18	9%	9	5%
51%+	9	2%	4	2%	5	3%
Total	**399**	**100%**	**198**	**100.0%**	**201**	**100.0%**

Research questions 2 and 3 can be answered with regression analysis. One approach is to create a pair of regression equations (one for the online group and one for the F2F group) for each dependent variable and then compare the significant coefficients in each pair. However, this approach has two limitations. First, any comparison of differences in the magnitudes of the coefficients for any independent variable between the F2F and online groups is invalid because a simple regression does not show the significance of that difference. Second, individual simple regressions ignore potential interactions between teaching format and other key variables in our model. For example, it is possible that asynchronous online coursework can have negative effects on students with lower GPAs.

To address these limitations, we instead estimate a single total interaction regression model for each dependent variable, which interacts each independent variable with class format (for the face-to-face group, F2F = 1; for the online group, F2F = 0). The regression coefficient for the variable in the total interaction model equals the regression coefficient for that variable in a simple regression using only online students. The sum of the coefficients of each variable and its interaction with F2F in the total interaction model equals the coefficient of the single variable in a simple regression model using only F2F students. However, the interaction variable indicates whether the coefficient's relationship with the outcome is significantly stronger (or weaker) in the F2F setting in comparison to the online setting. Regarding the variable of interest for this study (i.e., Perceived Sleep Deprivation), the significance of the F2F*SleepDeprivation variable will indicate whether sleep deprivation impacts learning positively, negatively, or not at all, for the F2F students relative to the online students, completely controlling for the interaction effects in the entire model.

Table 4 presents the total interaction model with final exam score as the dependent variable. As noted above, for example, the coefficient for GPA in Table 4 (i.e., 13.40) equals the regression coefficient for GPA in a simple regression using only online students and the sum of the coefficient for GPA and F2F*GPA in Table 4 (i.e., 13.40 – 2.44) equals the coefficient for GPA in the simple regression for the F2F group (i.e., 10.96). Thus, the simple regression models can, in fact, be derived from the total interaction model. However, for the variable GPA, the total interaction model shows that the entire significant impact of GPA on course grade is due to GPA's direct impact on the dependent variable. The interaction impact is effectively zero because the coefficient on F2F*GPA is insignificant. Thus, for our sample, the relationships between GPA and final exams scores, as measured by the slopes of the regression lines, are not statistically different between the two learning environments.

Table 4

Total Interaction Model with Final Exam Score as the Dependent Variable

	Online Group	
Variable	**Coefficient**	**S.E.**
Intercept	13.34	11.81
F2F	9.46	17.65
Gender (female = 1)	-7.95**	2.10
F2F*Gender	6.92*	3.00
GPA	13.40**	2.59
F2F*GPA	-2.44	3.66
Sleep Deprivation	0.05	0.07
F2F*SleepDeprivation	-0.24*	0.10
Age	0.13	0.25
F2F*Age	0.14	0.39
Course Load Hours	0.32	0.32
F2F*CourseLoadHours	-0.35	0.49
Job/Sport Hours	-0.10	0.07
F2F*Job/SportHours	0.14	0.10
Finance/Acct Major (yes=1)	5.39*	2.41
F2F*Finance/AcctMajor	3.65	3.38
Predictable Schedule	-1.15	1.56
F2F*PredictableSchedule	0.27	2.28
Math Assessment	0.15**	0.06
F2F*MathAssessment	-0.06	0.08
Equation Statistics:		
Number of Observations	399	
R-Square	.27	
Adjusted R-Square	.23	

Note. †$p < 0.10$, *$p < 0.05$, **$p < 0.01$

Concerning the focus of this study, the coefficient on Sleep Deprivation is insignificant; however, the coefficient on F2F*SleepDeprivation is highly significant and negative. Thus, sleep deprived students, all else equal, including possible interaction effects, perform significantly worse on the common final exam than online students. More specifically, for the instrument that most appropriately measures overall student learning outcomes in the course, sleep deprived students learned significantly less in the F2F class than they did in the online class. Therefore, our total interaction model suggests that, controlling for all personal factors and controlling for the possible interaction effects, the answers to research questions 2 and 3 are yes.

Figure 1
Final exam score: Interaction between sleep deprivation and course format

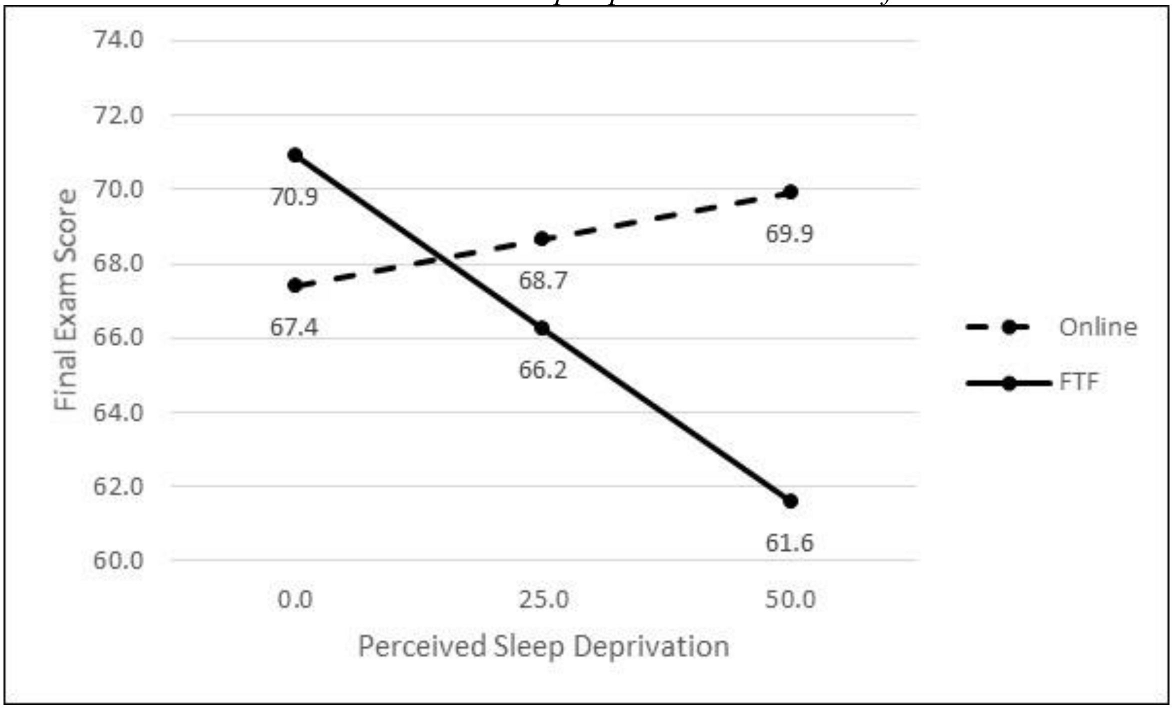

Figure 1 plots the relationship between final exam score and degree of perceived sleep deprivation for both modalities, holding all other factors constant. This graph shows that non-sleep-deprived students appear to perform better on the final exam in F2F courses than they do in online courses, medium-sleep-deprived students perform about the same, and highly-sleep deprived students perform much better in online courses. The breakeven point in this chart is perceived sleep deprivation of 14.8. For our sample, 20 percent of all students have no perceived sleep deprivation, 25.1 percent have perceived sleep deprivation of greater than 0 but less than 14.8, and 55.1 percent have perceived sleep deprivation of greater than 14.8. More than one-quarter of the students in our sample have perceived sleep deprivation of greater than 30.0.

Table 5 presents the total interaction model with course average as the dependent variable. In this regression, the coefficient for F2F*SleepDeprivation is negative, but it is not significant. Thus, whereas a higher degree of perceived sleep deprivation significantly negatively impacted learning in F2F classes, it did not have the same effect on the overall grade earned in the different modalities.

Table 5

Total Interaction Model with Course Average as the Dependent Variable

	Online Group	
Variable	**Coefficient**	**S.E.**
Intercept	35.93**	7.31
F2F	11.46	10.93
Gender (female = 1)	-2.89*	1.30
F2F*Gender	1.91	1.86
GPA	8.90**	1.60
F2F*GPA	0.04	2.27
Sleep Deprivation	-0.03	0.05
F2F*SleepDeprivation	-0.08	0.06
Age	0.13	0.16
F2F*Age	-0.10	0.24
Course Load Hours	0.35†	0.20
F2F*CourseLoadHours	-0.24	0.30
Job/Sport Hours	-0.04	0.04
F2F*Job/SportHours	0.08	0.06
Finance/AcctMajor (yes=1)	2.99*	1.49
F2F*Finance/AcctMajor	2.97	2.10
Predictable Schedule	0.95	0.97
F2F*PredictableSchedule	-1.53	1.41
Math Assessment	0.09*	0.04
F2F*MathAssessment	-0.05	0.05
Equation Statistics:		
Number of Observations	399	
R-Square	.29	
Adjusted R-Square	.25	

Note. †$p < 0.10$, *$p < 0.05$, **$p < 0.01$

One possible explanation for the difference in findings is that although the F2F course and the online course examined in this study were highly similar, there were a few significant differences. In particular, the midterm exams in the F2F class were closed-book, closed-notes proctored exams that were taken in a physical classroom by all students on the same day. Conversely, for the midterm exams in the online class, students were allowed take the online exam during any 150-minute period over the three days that the exam was open. The online exams did not use proctoring software, and although effort was made to reduce cheating on these exams, cheating is a concern for any online, unproctored examination or assignment (Dendir & Maxwell, 2020).

Thus, whereas differences in midterm exam testing procedures as well as academic dishonesty concerns for tests and other assignments completed in a remote setting may impede the purity of course average for the online group (relative to the F2F group), no such differences exist for final exam score since all students in both settings took the same final exam under the same circumstances. Specifically, all students took the exact same final exam in a carefully proctored classroom on the same day at the same time.

Figure 2
Course average: Interaction between sleep deprivation and course format

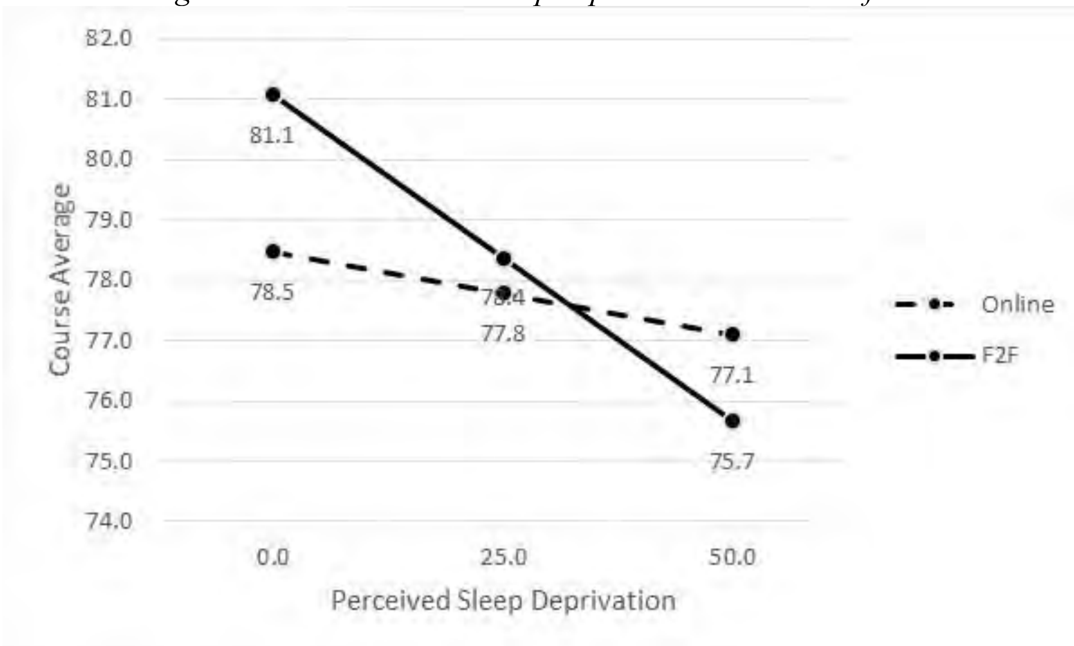

Figure 2 shows the relationship between course average and degree of perceived sleep deprivation for both modalities, holding all other factors constant. As shown in this figure, for perceived sleep deprivation of less than the breakeven point (i.e., 32.2), F2F students have a higher overall course average than online students. But for high levels of sleep deprivation, F2F students perform worse than online students. In our sample, 23 percent of all students had perceived sleep deprivation of greater than 32.3.

Discussion

Sleep deprivation among college students is a national crisis. And there is reason to believe that at-risk college students, who for socio-economic reasons may be more likely to hold a job while going to school and may have poorer sleep-hygiene habits, probably experience more sleep deprivation than other students (Patel et al., 2010; Adenekan et al., 2013). Our study shows that whereas perceived sleep deprivation significantly negatively impacts the learning outcomes of students in a F2F class, this same effect is not observed for students enrolled in an asynchronous online class. Therefore, advising students with sleep deprivation issues, especially at-risk students, to take more of their coursework in an online setting, may allow these students to better maintain the grades necessary to complete their degree programs.

Indeed, college completion rates are a major concern for higher education. Shapiro et al. (2019) report that as of 2019, the six-year completion rate for the fall 2012 four-year public college student cohort was only 65.7 percent. That is, less than two-thirds of all students who started a four-year college program at a public school in 2012 graduated within six years. Even more concerning, this study reveals that Black and Hispanic students are significantly more likely to drop out of college without completing a degree than white and Asian students. Given that overall student debt in the U.S. now tops $1.5 trillion, with a significant portion of this debt held by minority students (Hansen & Shaw, 2020) who all too often borrow money to start college but then do not finish, finding ways to improve graduation rates is imperative.

For over a decade, researchers have questioned whether online education improves or impairs college completion rates (see Wayle & Ozogul [2019]) for an excellent review of this literature). Although most of the early research on this topic suggests a negative relationship between online education and completion, recent studies are more positive. This pattern reflects Moore et al. (2009), who suggest that as students gain experience in taking online courses, and as teachers get better at designing and teaching asynchronous online courses, completion rates will improve. Indeed, in a recent comprehensive study on this topic, James et al. (2016), using the Predictive Analytics Reporting database, examine over 650,000 community college students and conclude that taking some online classes has no negative impact on student retention rates. Wayle & Ozogul (2019), who investigated graduation rates of nearly 13,000 students enrolled in four-year college programs, find that, controlling for student demographic and academic performance variables, taking at least some online classes significantly increases the likelihood of successful degree completion.

Our research supports these more recent studies. In this study, we show that, all else equal, highly sleep deprived students learn significantly less in a F2F setting than in an online version of the same class. As suggested in Jaggars (2014), students are beginning to choose course modality for specific reasons. If students who are aware that they have sleep deprivation issues know that they are likely to learn more in an online version of a course, we would expect that more sleep-deprived students will choose the online class.

Additional study of the relationship between sleep deprivation, retention and degree completion is an interesting area for future research. Research could also explore the trade-offs associated with students who have poorer academic preparation for success in online courses versus the gains to sleep deprived students taking asynchronous online courses. That is, additional research along these lines could shed light on which teaching modality is likely better for, say, a sleep-deprived student who also performs better with the support and structure traditionally associated with a F2F course.

Limitations

As with most empirical research, our study has some limitations. One potential limitation is that, although care was taken to align the online class with the F2F class as much as possible, differences still inevitably exist (in particular, the online class size was about 100 students and the F2F average class size was approximately 50). Another potential limitation of the empirical results is that the studied course is a highly quantitative course with a focus on solving math-oriented problems. Thus, the results of this study may not apply well to a more qualitative course. Put differently, the analysis presented in this paper opens the avenue for similar studies comparing F2F with online settings for purely qualitative courses.

A third potential limitation of this study is that the sample set is based on students at a downtown, urban university who do not generally live on campus and very likely work full- or part-time. Hence, the results of this study may not apply well to, say, a school where the students generally live on, or near, campus and are full-time students. The students at these two different types of schools may have very differing reasons for selecting an online version of a course over a F2F version, or vice versa. Also, online education is relatively new at our university. The average number of previous online courses taken by students in this sample is less than four.

However, this might be a strength of our study because sleep-deprived students are not yet self-selecting into the online offering of the course.

Finally, it must be noted that the online course examined in this study was an asynchronous course in every aspect except for the final exam. A synchronous online course loses some of the flexibility of an asynchronous course, and to the degree that increased flexibility influences the results we report, we would assume that sleep deprivation may play a larger role in a synchronous online course. However, because we cannot determine from our dataset the precise relationship between the flexibility offered by an asynchronous online course and lack of sleep, the question or whether this same effect (i.e., elimination of the negative impact of sleep deprivation on learning) would occur for a synchronous online course is an area for future research.

Conclusions

Sleep deprivation, and its negative impact on academic performance, is a major concern for college students. In this study, we explore the possibility that the flexibility and convenience offered by asynchronous online courses may reduce, or even eliminate, the adverse effect of sleep problems on student learning outcomes. Indeed, for final exam score (a specific measure of student learning), we find that sleep-deprived students perform better in an asynchronous online course environment than they do in a F2F setting.

The results reported in this study should be shared with college students, especially those who struggle with sleep disorders. In addition, academic advisors need to understand that the sleep issues that many students experience in college might be offset by advising these students to take more online courses. And teachers and administrators may need to consider more online course offerings as means of achieving the ultimate goals of higher education, namely, enhanced student learning and improved graduation rates.

Few would argue that coronavirus has been good for education. However, the forced conversion of nearly all F2F classes to an online format in spring 2020 and the continued concentration of online course offerings at traditional colleges and universities in fall 2021, has exposed teachers who never thought of virtual teaching and students who never considered virtual learning to experience something completely new. In an era in which sleeplessness is considered a global pandemic and sleep deprivation is increasingly being recognized as a detriment to student learning, perhaps one day COVID-19 will be thought of as the spark that promoted more online course offerings to the learning benefit, and degree completion progress, of college students who are not getting adequate sleep.

Declarations

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The authors declared that ethical approval was provided by the Institutional Review Board at Georgia State University.

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