

## ARTICLE

# Use of Personal EEG Monitors in a Behavioral Neuroscience Course to Investigate Natural Setting Sleep Patterns and the Factors Affecting Them in College Students

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Sleep is often a topic of avid interest to college students, yet it is one that does not yield itself well to hands-on, interactive learning modules. Supplementing classroom learning with interactive “real world” laboratory activities provides students with a deeper understanding of behavior and its neural control. The project described here was designed to supplement the teaching of EEGs, sleep and circadian rhythms and involved students in the empirical process from hypothesizing about the factors that affect sleep, to personal data collection, data analysis and writing in the style of a peer-reviewed manuscript. Students enrolled in Behavioral Neuroscience at Connecticut College were provided with a home-based personal EEG monitor used to collect sleep data in their natural sleep setting. Participants recorded sleep data with the use of the ZEO® Personal Sleep Coach system and completed a nightly sleep journal questionnaire for seven nights. The ZEO® system uses EEG patterns to define sleep stages including wakefulness, light, deep and REM sleep. The

journal included questions about factors known to affect sleep such as stress, caffeine, academic activity, exercise and alcohol. A class data set was compiled and used by students to perform univariate correlations examining the relationships between ZEO® variables and sleep journal variables. The data set allowed students to choose specific variables to investigate, analyze and write a peer-reviewed style manuscript. Significant class-wide correlations were found between specific sleep stages and behavioral variables suggesting that the ZEO® system is sophisticated yet inexpensive enough to be used as an effective tool in the classroom setting. Overall student feedback on the exercise was positive with many students indicating that it significantly enhanced their understanding of sleep architecture and made them keenly aware of the factors that affect quality of sleep.

*Key words: sleep architecture; electroencephalogram (EEG); caffeine; bedtime stress; sleep quality; alcohol; daily stress; sleep latency*

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Interactive, empirically based laboratory exercises that encourage critical thinking and introduce students to contemporary investigative tools are an essential part of the learning process in the neuroscience classroom. While many animal-based laboratory tools are available for demonstrating brain-behavior relationships, until recently human-based tools like the electroencephalogram (EEG) were out of reach in an academic setting. The stages of sleep and the factors affecting them are popular topics among neuroscience students; however, few if any laboratory learning applications of sleep behavior have been described.

While theories of the purpose of sleep are continually debated, consensus exists that adequate sleep quality and quantity is essential for human well-being and health. Sleep quality and quantity are both important in affecting students' health; therefore, there is a growing concern about student sleep patterns and habits (Tsui and Wing, 2009). When considered with other health-related and social variables, sleep habits have the greatest affect on first-year college student GPA (Pilcher and Walters, 1997; Trockel et al., 2000). College students often sleep in less-than-ideal dorm room environments that contribute to sleep deprivation and decreased sleep quality. Lack of sleep which is typical of college students has been positively correlated with reports of negative mood (Jean-Louis et al., 1998). In one recent large study, 60% of college students were characterized as poor-quality sleepers, the

overwhelming majority of whom stated that emotional and academic stress negatively impacted their sleep (Lund et al., 2010). In addition, students often use alcohol and take prescription, over-the-counter and recreational, psychoactive drugs to alter sleep/wakefulness (Lund et al., 2010). Specifically, caffeine consumption has a significant effect on reports of subjective sleepiness, wakeful EEG patterns, sleep architecture and sleep EEG patterns (Landolt et al., 2004). The exercise described here is designed to teach students about sleep stages and quality, and by using personal sleep data, educate students about the numerous variables that may be affecting their sleep and impacting their academic performance.

The ZEO® Personal Sleep Coach ([www.myzeo.com](http://www.myzeo.com)) is an inexpensive EEG monitor that records frontal cortex EEG patterns using a headband containing three electrodes that wirelessly communicates with a bedside display unit. The system is marketed to people suffering from sleep disturbances and provides feedback about sleep patterns coupled with online advice about how to improve sleep quality. The system uses algorithms to discriminate between EEG patterns that define wakefulness, light, deep and REM sleep. While the ZEO® system does not report specific EEG records, it is sophisticated enough to be used as an educational tool. This report describes a laboratory module that used the ZEO® system in conjunction with a self-report sleep journal to educate students about EEGs, sleep stages the factors

affecting sleep. The exercise allowed students to compare personal sleep data to class averages and design their own correlational data analysis. The exercise culminated in students preparing a report of their findings in the style of a peer-reviewed manuscript submission to the Journal of Sleep Research.

## MATERIALS AND METHODS

### Participants:

Participants were 18 Connecticut College students, 17 females and one male, who were enrolled in a Behavioral Neuroscience course at Connecticut College in the spring of 2011. Participants completed this study as part of a course requirement.

### Materials:

The ZEO® Personal Sleep Coach, records EEG activity from the frontal cortex using a headband with three soft, disposable electrodes (see Figure 1). The headband communicates wirelessly with a bedside unit that converts EEG patterns and reports sleep stages in 5-minute increments. Reported sleep parameters include: latency to sleep (Time to Z), total time in sleep (Total Z), number of awakenings (Number of Awakenings), time in wakefulness (Time in Wake), time in light sleep (Time in Light), time in deep sleep (Time in Deep), time in REM sleep (Time in REM) and ZQ score. ZQ score is a system-defined indicator of sleep quality that weights recorded parameters according to the formula:  $ZQ = 8.5 * (\text{Total Z}) + 0.5 * (\text{Time in REM}) + 1.5 * (\text{Time in Deep}) - 0.5 * (\text{Time in Wake}) - 0.07 * (\text{Number of Awakenings})$ .



Figure 1. Left: Photo of the ZEO® Personal Sleep Coach bedside unit display with docked wireless headband. Right: Outside and Inside view of the wireless headband (Zeo, Inc., n.d.).

In conjunction with EEG-based sleep stage data, participants kept a sleep journal and responded daily to a 17 question survey containing open ended, scaled and yes or no questions. Individuals were asked to rate the following questions on a 1-10 Likert scale:

- How would you rate your level of stress during the day yesterday? (1 = extremely relaxed, 10 = extremely stressed)
- How would you rate your level of stress when you went to bed last night? (1 = extremely relaxed, 10 = extremely stressed)
- How much trouble did you have turning off your mind

when going to sleep last night? (1 = no trouble, 10 = extreme trouble)

- How ideal (comfort of your bed, temperature, light level, noise level, etc) was your bedroom for sleeping last night? (1 = ideal, 10 = not ideal at all)
- How much was your sleep disrupted by someone or something else (roommate, partner, noise) last night? (1 = not disrupted at all, 10 = not ideal at frequently disrupted)
- How tired were you when you went to bed last night? (1 = extremely tired, 10 = not tired at all)
- Rate your eating, starting with your last meal before bedtime in terms of sugar/carbohydrate content, fat content, spiciness. (1 = low, 10 = high, Rated sugar/carbs, fat & spiciness separately)
- How stimulating were your digital or screen-related mental activities (computer, phone, TV, video games) within one hour of bedtime last night? (1 = extremely stimulating, 10 = not stimulating at all)
- How mentally taxing was your studying, reading, academic work, etc. within one hour of bedtime last night? (1 = very taxing, 10 = not at all taxing)
- On a general scale, how would you rate your regular ability to fall asleep? (1 = no trouble, 10 = extreme trouble)
- On a general scale, how would you rate your regular ability to stay asleep during the night? (1 = no trouble, 10 = extreme trouble)

Individuals were asked to answer the following open – ended questions:

- How many servings of caffeine (coffee, tea, caffeinated soda, chocolate, etc.) did you have within six hours of bedtime yesterday?
- How many servings of alcohol did you have within three hours of bedtime last night?
- As best you can, estimate you caloric intake within three hours of bedtime last night.
- How much time (in minutes) did you spend exercising or engaged in physical activity yesterday?

Individuals were asked to answer the following yes or no questions:

- Did you take any medication yesterday that may have had a significant effect on your sleep? Y/N
- Did you sleep in the same bedroom as the other nights during this data collection? Y/N

### Procedure:

Students were informed about the materials and procedures involved in the sleep study and signed an informed consent document. The Connecticut College Institutional Review Board approved all procedures. Since only ten ZEO® units were available for 18 students, the class was divided into two groups and data were collected for each group during two different weeks. The data collection for group 1 occurred during the week prior to

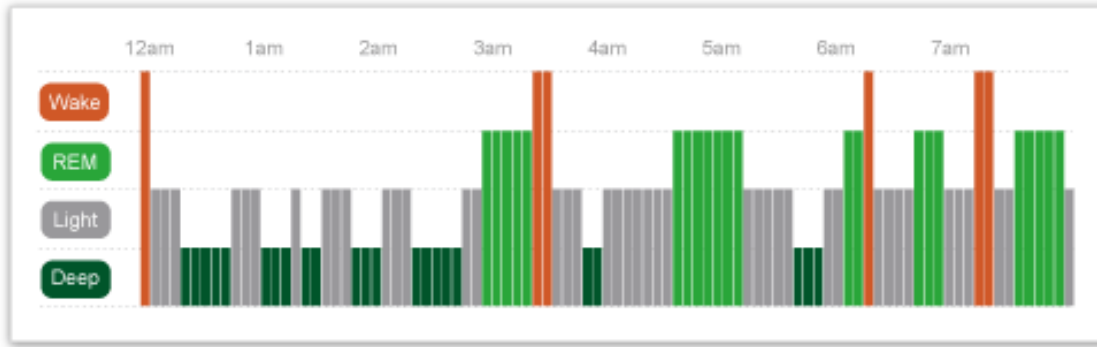


Figure 2. Example of a personalized sleep graph produced by the [www.myzeo.com](http://www.myzeo.com) website showing an individual's progress through the different levels of sleep. Each line represents a 5-minute increment (Zeo, Inc., n.d.).

spring break (pre-spring break) and the data collection for group 2 occurred during the week of spring break (during spring break). This division proved to be useful for a comparison of variables in two separate sleep settings and time periods during the academic year.

At the beginning of each group's data collection week, each participant was given a ZEO® system and an accompanying serial number. The serial number was used to set up an account on the [www.myzeo.com](http://www.myzeo.com) website so that sleep stage data can be downloaded from the site in Excel format. Personal sleep data uploaded to the [www.myzeo.com](http://www.myzeo.com) website remained confidential and was only identified by the unpublished email address used to set up the account. Participants were asked to read the accompanying instructions, set up their ZEO® system at home and set up their account on the ZEO® website. Participants in each group were given a ZEO® unit for a little over one week, so that they could become acclimated to wearing the headband before actual data collection began. Participants followed their normal sleep schedule during collection and the aim was for each participant to collect seven nights of data.

During each night of data collection, participants placed the headband, positioned the electrodes on the forehead and verified that the system was recording immediately before entering bed. Upon waking, participants placed the headband in a dock on the bedside display and verified that a complete set of sleep data was collected and completed the sleep journal questions. Data was downloaded to a USB flash drive and uploaded to the [www.myzeo.com](http://www.myzeo.com) website account where data was displayed, summarized and compared to previous nights' data (Figure 2) (Zeo, Inc., n.d.). Following seven nights of data collection, participants downloaded an Excel file from their [www.myzeo.com](http://www.myzeo.com) account containing each night's sleep stage data and added it to their answers to the sleep journal questions. To ensure confidentiality, sleep data was deleted from each ZEO® unit before being used by the second group of participants. Additionally, each participant in the second group received a new headband and a different serial number in order to create a separate, personal [www.myzeo.com](http://www.myzeo.com) account.

Each participant anonymously submitted an Excel file containing their data to the professor who compiled a group data set and distributed it to all students through the

course's website. Students were required to perform their own statistical analyses on the data set to investigate correlations between variables of their choice using SPSS. Students were referred to the instructions for authors for the *Journal of Sleep Research* to use as the guidelines for preparing their reports in the style of a manuscript for peer-review. Once the study and lab reports were complete, participants were asked to fill out a short survey to gain information about their overall opinions of the project, how helpful they found the activity and the knowledge they gained from participating. This survey consisted of nine questions to which responses were recorded on a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Survey questions included:

1. I learned a great deal about sleep patterns and the variables affecting sleep as a result of using the ZEO® system.
2. This activity clearly demonstrated the importance of the EEG and how it demonstrates brain activity during sleep.
3. I learned more about EEG during this activity than if I had not participated.
4. I would recommend this course to my fellow peers because of this activity.
5. The instructor should use this activity again in future classes.
6. This activity was an enjoyable experience.
7. This activity provided me with the opportunity to use personal and peer data to learn more about the stages of sleep.
8. This activity allowed me to investigate questions about the factors that affect sleep.
9. This activity helped me to organize and analyze data sets and learn to write in the scientific method.

## RESULTS

To investigate the factors that may affect sleep in college students, participants selected a variety of personally interesting factors from the sleep journal and ZEO® data and performed univariate correlations using SPSS. Some participants choose to examine the class data as a whole, while others defined and analyzed the data of specific groups, such as the pre-spring break and the during spring break groups. The extensive data set that was obtained allowed students to explore a wide variety of questions

Table 1.

Variable	ZQ	Time to Z	Total Z	Time in Wake	Time in Light	Time in Deep	Time in REM
Overall Stress	<b>-.187*</b>	-.118	<b>-.243**</b>	-.006	<b>-.241*</b>	-.002	<b>-.189*</b>
Bedtime Stress	<b>-.328**</b>	.033	<b>-.363**</b>	-.068	<b>-.342**</b>	-.068	<b>-.306**</b>
Caffeine 6 hrs	-.043	<b>-.266**</b>	-.064	.011	-.076	.004	-.076
Alcohol 3 hrs	-.049	.044	-.069	.095	-.127	-.063	.066
Calories 3 hrs	.019	-.165	.079	.027	.092	-.014	.029
Exercise	.082	.057	.046	.139	-.009	.027	.119
Screen Activity	.068	-.097	.055	-.148	.017	.085	.053
Academic Activity	.095	.003	.102	.003	<b>.244*</b>	-.147	.094

\*\* p < 0.01, \* p < 0.05

*Table 1.* All Data. Pearson correlation coefficients (r) for the associations between several sleep journal variables and dimensions of sleep for all participants.

Table 2.

Variable	ZQ	Time to Z	Total Z	Time in Wake	Time in Light	Time in Deep	Time in REM
Overall Stress	-.039	-.119	-.128	-.137	-.183	.042	-.022
Caffeine 6 hrs	<b>-.306*</b>	<b>-.307**</b>	<b>-.313*</b>	.032	-.219	-.198	<b>-.322*</b>
Alcohol 3 hrs	-.258	.115	<b>-.286*</b>	.230	<b>-.315*</b>	-.035	-.222
Calories 3 hrs	.068	-.205	.127	.091	.172	.053	-.019
Exercise	.062	.171	.076	.255	-.129	-.061	.018
Screen Activity	.204	-.074	.152	-.122	-.095	.301*	.272
Academic Activity	.143	.058	.138	<b>.311*</b>	.123	.072	.097

\*\* p < 0.01, \* p < 0.05

*Table 2.* Pre-Spring Break Data. Pearson correlation coefficients (r) for the associations between several sleep journal variables and dimensions of sleep for participants collecting data before Spring Break.

about the relationships between behavioral, physiological and environmental factors and their effects on varying dimensions of sleep in college students.

Some commonly examined survey variables that students chose to examine were overall stress, bedtime stress, caffeine six hours before bedtime, alcohol three hours before bedtime, calories three hours before bedtime, exercise, screen activity and academic activity. Correlations were performed between these variables and several ZEO® factors, such as ZQ, Time to Z, Total Z, Time in Wake, Time in Light, Time in Deep and Time in REM. While specific hypotheses about the relationship between sleep stages and the factors affecting them were not evaluated in the current study, several interesting correlations were observed. Significant negative correlations were found between overall stress and ZQ, Total Z, Time in Light, and Time in REM (Table 1), suggesting that higher levels of stress are associated with lower quality of sleep. Bedtime stress was also significantly correlated with the same ZEO® variables. Interestingly, a significant positive correlation was found between academic activity and Time in Light, suggesting that more demanding academic activity before bedtime may affect specific sleep patterns. When correlations between pre-spring break and during break groups were

compared, several interesting findings emerged. Significant negative correlations were found between caffeine and alcohol intake and several sleep parameters for the pre-spring break group but not the during break group (Tables 2 and 3). Additionally, significant negative correlations were found between overall stress and sleep parameters for the during spring break group but not for the pre-spring break group (Table 2 and 3). Interestingly, a significant positive correlation was found between academic activity and Time in Wake for the pre-spring break group but a significant negative correlation was found between these variables for the during break group. These comparisons suggest that sleep behavior and how it is associated with stress and drug use is different in college students depending on the phase of the academic calendar. Following the sleep lab module, students completed a survey designed to assess the effectiveness of the exercise. The survey statements and the average  $\pm$  SD Likert scale (1-7) responses were:

1. I learned a great deal about sleep patterns and the variables affecting sleep as a result of using the ZEO® system. ( $5.39 \pm 0.98$ )
2. This activity clearly demonstrated the importance of the EEG and how it demonstrates brain activity during sleep. ( $5.67 \pm 1.19$ )

Table 3.

Variable	ZQ	Time to Z	Total Z	Time in Wake	Time in Light	Time in Deep	Time in REM
Overall Stress	<b>-.335*</b>	-.077	<b>-.348**</b>	.034	<b>-.291*</b>	-.158	<b>-.307*</b>
Caffeine 6 hrs	.045	-.082	.109	.012	.184	.048	-.037
Alcohol 3 hrs	.082	.115	.079	-.057	.027	-.132	.247
Calories 3 hrs	-.073	-.093	.010	-.132	.003	-.192	.056
Exercise	.074	.006	.001	.042	-.155	.103	.180
Screen Activity	-.030	-.135	-.017	<b>-.316*</b>	.152	-.191	-.094
Academic Activity	.029	-.133	.042	<b>-.260*</b>	<b>.375**</b>	<b>-.344**</b>	.022

\*\* p < 0.01, \* p < 0.05

*Table 3.* During-Spring Break Data. Pearson correlation coefficients (r) for the associations between several sleep journal variables and dimensions of sleep for participants collecting data during Spring Break.

3. I learned more about EEG during this activity than if I had not participated. ( $5.06 \pm 1.59$ )
4. I would recommend this course to my fellow peers because of this activity. ( $5.22 \pm 1.35$ )
5. The instructor should use this activity again in future classes. ( $5.94 \pm 1.59$ )
6. This activity was an enjoyable experience. ( $4.67 \pm 1.61$ )
7. This activity provided me with the opportunity to use personal and peer data to learn more about the stages of sleep. ( $6.06 \pm 0.94$ )
8. This activity allowed me to investigate questions about the factors that affect sleep. ( $6.05 \pm 0.87$ )
9. This activity helped me to organize and analyze data sets and learn to write in the scientific method. ( $5.50 \pm 1.38$ )

## DISCUSSION

Through the use of the ZEO® system, we were able to record several dimensions of sleep and investigate the variables that affect them in college students. This study allowed students to select and investigate variables they found personally interesting, leading to the examination of a wide variety of associations. Several interesting findings about the variables affecting sleep in college students were observed that were consistent with previously published reports of sleep behavior in college students (Jean-Louis et al., 1998; Trockel et al., 2000; Lund et al., 2010) suggesting that the ZEO® system provide accurate data that is useful for examining sleep behavior in the behavioral neuroscience laboratory or classroom. Participation in this activity helped students to understand EEGs and sleep architecture, organize and analyze a large data set and write in the scientific style. The survey results also suggest that students enjoyed the activity, felt that it aided them in learning about the factors affecting sleep, and thought that it should be implemented in future classes.

While this study yielded interesting results and was extremely beneficial to students, several limitations were present. Several participants indicated that the ZEO® headbands fell off during the night, leading to missing data. Additionally, some participants had difficulty uploading their sleep data to the ZEO® website and were required to

record their data by hand from the bedside unit. Each www.myzeo.com account requires a separate serial number that was graciously provided by the manufacturer because the system was being used for academic purposes. Excel formatted data can only be obtained by downloading them from the www.myzeo.com website. For logistical purposes, separate www.myzeo.com accounts will not be used for future classes as data sets can be manually constructed by copying information from the bedside unit. This will also reduce concerns that personal sleep data may be accessible on the internet.

For the sleep journal, individuals provided subjective answers to several open-ended questions, such as servings of caffeine and alcohol and calories consumed. Without quantifying intake, estimates of a serving may have differed between individuals. Additionally, our sample size was relatively small and did not have an equal gender distribution. Despite these limitations, significant correlations were found between several sleep journal variables and the dimensions of sleep recorded by the ZEO® system.

The ZEO® system retails for \$199. Through an agreement with the manufacturer, ten ZEO® units were purchased for \$1600 with funds from an internal Connecticut College grant. Compared to traditional, wired EEG systems, the ZEO® is inexpensive, yet sophisticated enough for investigating EEGs and sleep patterns in an undergraduate setting. The units can be re-used for multiple courses by simply purchasing new headbands (\$12) for each new participant. The flexibility that the system provides for recording sleep data in a natural setting is offset by the lack of control over the sleep environment that is standard in sleep labs.

This study demonstrates the beneficial outcomes of utilizing innovative tools, such as a personal EEG monitor, in the Behavioral Neuroscience classroom and laboratory. Overall, this study was a successful supplementary activity to the teaching of sleep behavior and provided the students with an interesting and insightful hands-on experience.

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