ACTIVE AND PASSIVE LEARNING CONNECTIONS TO SLEEP MANAGEMENT

James M. Gregory\(^1\) Xuepeng Xie\(^2\) and Susan A. Mengel\(^3\)

Abstract - Strong evidence exists that active is more effective than passive learning. In fact, passive learning is more sensitive to sleep debt. Efficiencies for passive learning and passive activities, such as driving, are reduced by more than 50 percent with as little as 18 hours of sleep debt. This relationship obviously affects highway safety. Further, the relationship also affects academic success.

A sleep model, SLEEP (Sleep Loss Effects on Everyday Performance) Model developed in the College of Engineering at Texas Tech University, is used to predict the growth or decline in sleep debt and to predict resulting performance. It predicts active and passive performance efficiencies, time to fall asleep, and amount of sleep needed as a function of sleep, alcohol, and caffeine inputs. A steady-state form of the sleep model is included in GREG (Grade Requirements Evaluation Game). GREG predicts college GPA (grade point average) as a function of several academic management variables including sleep and caffeine. Results from both models are presented.

Index Terms—advising, education, active learning, passive learning, sleep management

INTRODUCTION

In addition to being affected by the teaching process, successful learning in engineering education is also a function of student alertness, which depends on sleep management [1]. Learning also depends on the nature of the learning process: active or passive. Because passive activities, such as driving, reading, and listening to lectures, are more sensitive to low levels of sleep debt than active learning tasks, there is a strong interaction between learning and the amount of sleep debt students have accumulated. On the other hand, active or highly stimulated tasks, such as combat or even watching an emotionally engaging athletic event, can be performed satisfactorily even with a couple of days of sleep debt.

Thus, sleep management is an important component of education. It also is an important component of life and safe living. According to the National Highway Transportation Safety Administration, 30 Texas college students died last year as a result of drowsy drivers [2]; five of these students attended Texas Tech University. Sleep management is serious business!

OBJECTIVE

The objective of this paper is to describe two software tools that can be used to understand and manage sleep and its effect on education along with other activities. Examples are given that compare different static or steady-state sleep conditions on academic performance. Both short- and long-term dynamic examples of changes in active and passive performances are given as sleep and/or alcohol input data are varied. Our ultimate objective is to educate people to manage their sleep better and to offer tools that allow people to predict danger or low performance before they engage in a given task.

OVERVIEW OF TOOLS

A system of web-based educational tools is under development at Texas Tech University. The College of Engineering is leading this development. These tools are packaged as an Electronic College Optimal Advisor and Career Helper (E—COACH). These tools are written using Microsoft Active Server Pages and SQL Server 2000. Access to these tools is provided through the College of Engineering website, www.coe.ttu.edu by clicking on the E—COACH selection.

E—COACH has three major functions: general education assessment and management; quick and efficient advising; and quality control of degree programs, known, respectively, as ED DOCTOR, QUICK Advisor, and QUALITY Assessment [3]. This paper will focus on the SLEEP Model and the GREG tools, which are part of the ED DOCTOR component.

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In 1990, work was started to model the learning process and to predict grade point average in college. In 1997, a sleep model was added to consider sleep effects on academic performance. Since 1997, the initial sleep subroutine has been expanded to produce the dynamic SLEEP Model, which considers age, alcohol, and caffeine as variables, as well as sleep time and duration.

The SLEEP Model provides a dynamic analysis for both short- and long-term simulations up to 35 days in length. If it is desirable to model a sequence of input longer than 35 days, the sleep debt at the end of the first simulation period can be used as a starting sleep debt for the next period. It models the effects of daily sleep length, time at which sleep occurs, and amount and timing of alcohol and caffeine consumption. It predicts active performance efficiency, passive performance efficiency, time to fall asleep, and amount of sleep debt. It predicts the average sleep need based on the age of the user. In addition, it predicts the length of sleep for individual days if the alarm clock is not used to restrict sleep. The SLEEP Model can be used to simulate the effect of jet lag or shift work on performance in addition to the effect of the build up or decrease of sleep debt on performance. Example applications are shown in the Results section.

The GREG program [4,5], also available as the "learning how to learn” button from the ED DOCTOR component of E—COACH, predicts the steady state effects of sleep management on academic performance. Both GREG and the SLEEP Model use the same basic sleep model. GREG computes performance after five weeks of steady-state sleep and caffeine input, but does not include the effects of alcohol.

**METHODS**

A total of 12 equations have been developed to describe the various main sleep processes. From these equations, active and passive performances are predicted. Generally, derived equations have been verified with measured data using R² values in excess of 0.8 and a significant level of 0.01 or better. Highlights of the model development are shown in Table I. Passive learning tasks, such as reading and listening to lectures, were related to general alertness or psychomotor vigilance tasks. The data set used for calibration is referenced in Table 1. Active learning tasks tend to be self-stimulating tasks. As shown in Table 1, the calibration for this task is based on a data set using duration of two days without sleep with the task of converting text to Morse Code. In the GREG program, this performance measure is used as a test-taking efficiency. General alertness is used as the learning efficiency.

### TABLE I

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**RESULTS**

In November 2002, on the Channel 11 News in Lubbock, Texas, it was reported that driving with 18 hours of sleep debt was equal to driving with 0.05 percent blood alcohol. We used SLEEP Model to compare these two conditions. On day two during the lunch period, we adjusted the alcohol input to equal 0.05 percent blood alcohol (Figure 1). On the evening of day five, we started an evening without sleep. The normal bedtime used for this simulation was 11:30 pm. We simulated results for a young adult, who typically needs eight hours of sleep. Wakeup time was, thus, 7:30 am. Active performance efficiency is shown as top curve (red) in Figure 1 and other figures generated by SLEEP Model. Passive performance efficiency is shown in blue as the lower curve. Note that the drop of passive performance associated with alcohol is approximately equal to the drop in passive performance associated with 18 hours of sleep debt. Both performances dropped by about 55 percent. Also, observe that SLEEP Model results are in close agreement with the comparison results reported on Channel 11 News. The match in performance for 0.05 percent blood alcohol and 18 hours of sleep debt is also very close to results reported by Lamond and Dawson [7].
0.05 % alcohol
18 hours of sleep debt

FIGURE 1
COMPARISON OF PERFORMANCE WITH 0.05 BLOOD ALCOHOL TO THAT FOR 18 HOURS OF SLEEP DEBT.

Figure 1 contains more information than just verification that SLEEP Model predictions match measured results reported in the literature. Results shown in Figure 1 for the sleep debt response also give insight about student academic performance. The top or red curve during the day following the night of no sleep is down only about seven percent. Active tasks, such as test taking (converting text to Morse Code), can be performed reasonably well after a night of no sleep when there is no prior sleep debt. The excitement of test taking generally keeps students awake and functional during tests. On the other hand, the efficiency for performing passive learning has dropped to about 70 percent—a drop of about two letter grades in academic performance. SLEEP Model predicts that the time to fall asleep with no stimulation has been cut approximately in half; thus, students generally fall asleep in lectures before the end of class.

One might question the predicted high test-taking performance with 0.05 percent blood alcohol. This prediction closely matches measurement for psychomotor task [7] with an $R^2$ of 0.97. Active performance decreases with the square of the variable for both alcohol and sleep debt. Sleep debt has an extra complication of circadian cycle. Otherwise, they have similar effect. Small amounts of alcohol or sleep debt may actually help people with severe test anxiety.

A small amount of alcohol in combination with sleep debt greatly lowers the passive performance variable. Thus, a one or two-beer lunch after a night of little sleep is dangerous for both driving and for attending lectures. Based on simulations with SLEEP Model, two or more beers in a one-hour period of time near and after midnight create a deadly combination for passive performance activities. Some of the sleep-related accidents in the early morning hours may have been caused in part by a few alcoholic drinks.

SLEEP Model also provides a simple guide for a user-selected day of activities (Figure 2). This guide is fashioned after a traffic light with green (G) for go, yellow (C) for caution, and red (R) for stop or high danger. Because sleep, alcohol, and caffeine inputs affect performance predictions, they also affect the recommendations produced by this guide. The results shown in this simulation are for five weeks of partial sleep loss with no alcohol or caffeine.

FIGURE 2
DAILY PERFORMANCE GUIDE BY SLEEP Model.

The results shown in Figure 2 are for input sleep amounts reported by Stanley Coren [12]. He started needing eight hours of sleep and gradually reduced his sleep amount until receiving only six hours of sleep on the day this performance guide was generated. He noted the following comments in his diary during the fifth week:

"Some people have said that I look a bit washed out and not as energetic as I usually do. I have had this sense that the work is getting out of hand, and worse, I have a feeling that I just don’t care. This was embarrassing. I fell asleep in the middle of a research talk."

While we did not calibrate from his data, our guide predicts that he was only marginally functional for the passive activities listed in Table 1, which should have been
typical for his type of work. Student learning and academic performance should be similar for similar sleep management.

There are some actions that an individual can use with the build up of sleep debt to combat the associated reduction in passive performance. Caffeine and other stimulants can be used to improve passive performance under most but not all conditions. SLEEP Model was run twice with exactly the same sleep input data: once without caffeine and once with two cups of fresh-brewed coffee at 8 am and two more cups of coffee at noon. The input data of needing eight hours of sleep, but receiving only four hours over approximately a two-week period, were selected to match the experimental conditions reported by Van Dongen et al. [10]. The results are shown in Figure 3.

First, note the general decline in both active and passive performance with no caffeine. These results closely match measured results by Van Dongen et al. [10]. They did not include a night without sleep at the end of their experiment as shown here.

The top curve for active performance is the same for both simulations. The passive performance greatly increased with the use of caffeine. The passive performance quickly increased within about 15 minutes after the intake of coffee. After about 45 minutes, the performance began to decline until the next intake of coffee. Because caffeine has a half-life of approximately six hours under most conditions, it is important that an individual stop or at least decrease caffeine use later in the day in order not to interfere with sleep. In addition to interfering with getting to sleep by increasing the time to fall asleep, excessive caffeine at bedtime can interfere with the onset of REM sleep. In SLEEP Model, 300 milligrams of caffeine (three cups of coffee) will reduce REM sleep by 30 percent. Six drinks of alcohol will also reduce REM sleep by 30 percent.

Finally, people are highly variable in their response to caffeine and tend to build up tolerance as caffeine use continues. Thus, the simulated responses to caffeine in SLEEP Model can only be used as rough estimates.

Based on SLEEP Model, a night of no sleep after a build up of sleep debt from partial sleep loss can be very treacherous. Both active and passive performances plummet for this condition as shown in Figure 3.

Note that caffeine has no benefit for this condition. The caffeine user is caught off guard by a night of no sleep under these conditions. While this can be deadly for drivers on highways, it may also explain why some students tend to crash during exams. If they gradually build up sleep debt during the semester then decide to cram to prepare for an exam, they may indeed reduce their test-taking ability to a failing level.

In addition to active and passive performance efficiencies, there is one other variable associated with sleep management that can have a major impact on education. This variable is the time it takes for an individual to fall asleep with no stimulation. SLEEP Model generally predicts a daytime value between 15 and 20 minutes depending on age and time of day. At night, this value drops to about 10 minutes. As a person builds up sleep debt, the time to fall asleep drops to only a few minutes, especially at night. The use of alcohol also reduces the time to fall asleep in SLEEP Model. Caffeine works in the opposite direction.

FIGURE 3
PERFORMANCE ASSOCIATED WITH APPROXIMATELY TWO WEEKS OF RECEIVING FOUR HOURS OF SLEEP EACH NIGHT, BUT NEEDING EIGHT HOURS WITH AND WITHOUT CAFFEINE.

Recently, Wankat and Oreovicz reported on ways to teach around the 15-minute barrier [13]. They define the 15-minute barrier as the amount of time before students tend to lose interest in the material and need a change in teaching.
style. Numerically, this 15-minute barrier is about the same magnitude as the time to fall asleep for a well-rested individual during the day and early evening. We speculate that the 15-minute barrier may actually be associated with the time to fall asleep. Passive teaching methods should indeed need a break to re-stimulate the student and to prevent the onset of sleep or at least poor learning. If our speculation is correct, then teachers who use stimulating lectures and active teaching styles are highly desirable.

On the other hand, students also contribute to the learning barrier. If they come to class with a major sleep debt, it may be nearly impossible to keep them stimulated and engaged in learning. We will use a simulated result with SLEEP Model to illustrate.

One of the results from the experiment by Stanley Coren as discussed earlier in association with Table 1 is the time to fall asleep. After 45 days into his experiment he reported that he fell asleep on his way home at two different traffic lights. The predicted time to fall asleep for the last 10 days of his experiment plus a few recovery days is shown in Figure 4. Note that the predicted values on the last day before recovery are at or below 30 seconds estimated for a typical traffic light. SLEEP Model, thus, did an excellent job in matching the qualitative results reported by Dr. Coren [12]. We think the results for this experiment strongly suggest that students can greatly reduce their time barrier for learning with poor sleep management.

Because academic performance on tests depends on both the active performance of taking a test and the prior learning before the test, sleep effects have to be integrated into both the learning and test-taking functions. In GREG, learning is assumed to be a passive performance activity and test taking is assumed to be an active process. GREG, thus, was designed to predict a minimum performance to help students to adjust their study, time, and sleep management to achieve academic success. GREG also simulates for long-term (minimum of five weeks) sleep management. GREG actually predicts GPA for the management used during a semester or quarter; thus, the five-week limit is not a problem for the GREG program. Results for individual study with seven hours of sleep but needing eight hours is shown in Figure 5.

The results for getting eight hours of sleep are shown respectively in Figure 6. If students typically get seven instead of the needed eight hours of sleep, they are probably reducing their academic performance by 0.6 GPA on a four-point scale. The good news is that they can recover about 0.3 GPA by using caffeine drinks.

**SUMMARY AND CONCLUSIONS**

It can be concluded both from the literature and from simulations with both SLEEP Model and GREG that sleep management is important for both safety and academic performance. We conclude that the sleep management model in both SLEEP Model and GREG performs well in simulating general responses associated with sleep management. Students sometimes are quick to criticize teachers for not being stimulating. The simulated results presented in this paper indicate that sleep management may be one of the reasons why students quickly fall asleep in the classroom. We conclude that active teaching methods will increase the length of time that students will stay alert in the classroom, especially for sleep deprived students. We also conclude that students need to be educated better on sleep management and learn to provide their body and mind rest.
FIGURE 5
RESULTS FROM GREG FOR SEVEN HOURS OF SLEEP WHEN NEEDING EIGHT HOURS OF SLEEP.

FIGURE 6
IMPROVEMENT ASSOCIATED WITH GOOD SLEEP MANAGEMENT.
REFERENCES


