Daytime Cognitive Performance in Response to Sunlight or Fluorescent Light Controlling for Sleep Duration

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Overview

It is well established that bright light, especially sunlight, is a potent synchronizing stimulus for our circadian rhythm. All humans have a natural sleep and wake schedule kept on track by circadian rhythms, which are physical, mental, and behavioral changes which follow a 24 hour cycle, in response to the light and darkness of the environment. These circadian rhythms are run by internal biological clocks. The circadian pacemaker is the internal biological clock located in the Superachiasmatic Nucleus (SCN). The SCN is a master pacemaker that coordinates all the biological clocks in our body. When you open your eyes in the morning and light reaches the retina in your eye, it signals the SCN that it is time to wake up and start the day. Insufficient lightning experienced by astronauts during deep space missions made lead to circadian desychr onization. Our findings may determined whether supplemental light should be included for deep space missions.

Abstract

Light is the primary synchronizer of the human circadian rhythm and also has acute alerting effects. Our study compares the alertness, performance, and sleep of participants working in two different office settings. The NASA Ames Sustainability Base which uses sunlight as its primary and a traditional office building (located at NASA) which uses over head fluorescent lightning and varying exposure to natural light. The purpose of this study is to determine whether the use of natural lighting as a primary light source improves daytime cognitive function and promotes nighttime sleep. Participants from the Sustainability Base will be matched by gender and age to individuals working in the traditional office building. In a prior study we found no differences in performance between those working in the Sustainability Base and those working in the traditional office building. Unexpectedly, we found that the average sleep duration among participants in both buildings was short (~6.5 h), which likely obscured our ability to detect a difference the effect of light exposure on alertness. Given that such sleep deprivation has negative effects on cognitive performance, in this iteration of the study we are asking the participants to maintain a regular schedule with eight hours in bed each night in order to control for the effect of self-selected sleep restriction. Over the course of one week, we will ask the participants to wear actiwatches continuously, complete a psychomotor vigilance task (PVT) and digit symbol substitution task (DSST) three times per day, and keep daily sleep/work diaries. We hope that this study will provide data to support the idea that natural lighting and "green" architectural design are optimal to enhance healthy nighttime sleep patterns and daytime cognitive performance.

Materials

- We collected sleep data using actigraphy (Figure 1) and daily sleep/work diaries (Figure 2)
- An actiwatch is a watch-like device that is worn continuously on the wrist
- The actiwatch contains an accelerometer to measure activity through wrist movement
- Sleep data can be estimated through periods of relative inactivity
- Self-reported sleep data derived from the sleep diaries improves the sleep estimations

Figure 1. The devices shown above is an actiwatch.

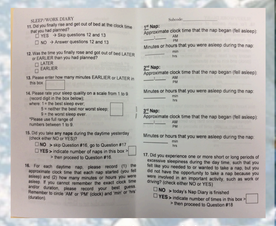


Figure 2. The participants completed a daily sleep/ work diary as shown above

- We assessed cognitive function using Joggle Research software on iPads (Figure 3) in a five-minute test battery
- We evaluated reaction time, using the Psychomotor Vigilance Task (PVT), which has been shown to reduce performance. The PVT is developed by Joggle.
- We also evaluated performance using the Digit Symbol Substitution Test which is a cognitive throughput task that includes measures of speed and accuracy
- Study participants self-rated their level of alertness throughout the workday in conjunction with cognitive tests using the PVT Test.
- We measured light intensity using light meters to evaluate lux (intensity) and spectrum (wavelength) in each work station at three points during a working day

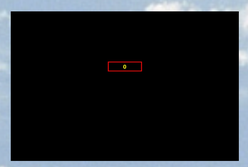


Figure 3. The PVT test. Participants were instructed to respond as quickly as possible after the presentation of a stimulus.

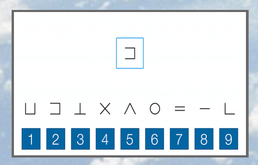


Figure 4. The DSST. Participants were instructed to select the number matching the target symbol as quickly and accurately as possible.

Methods

- Study participants were recruited from the NASA Ames Sustability Base, also known as the "Green" Building
- Control participants were recruited from traditional office buildings located at NASA Ames.
- Pre-study questionnaires were administered to all participants in order to evaluate typical sleep habits and likelihood of sleep disorders. Questionnaires included the Morningness-Eveningness questionnaire, Pittsburgh sleep quality index, and Fatigue severity scale
- Participants wore the actiwatch continuously and completed sleep/work diaries daily over the course of one work week
- Participants completed the cognitive test battery and Karolinska Sleepiness Scale three times daily, in the morning, around lunchtime and before leaving work for the five day duration of the study.
- Participants in the Sustainability Base were matched based on gender and age to individuals working in traditional office buildings
- In year 2 of the study, participants were asked to stay in bed for eight hours each night in order to control for the impact of sleep restriction on performance
- In year 1 of the study, there were no restrictions on sleep duration

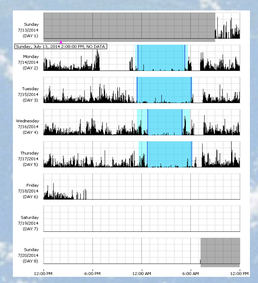
Preliminary Results (Year 1)

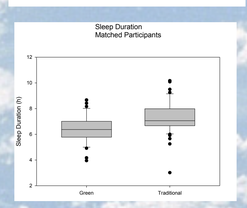
ALL PARTICIPANTS

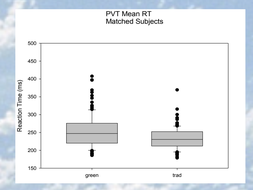
Table 1. Baseline characteristics among sustainable building workers compared to controls.

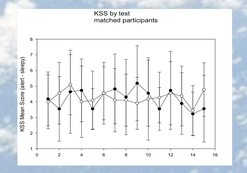
	Sustainable Building	Control Building
n	13	16
age	32.7 (10.6)	31.5 (12.7)
Cups of caffeine	1.4 (1.1)	1.4 (1.3)
Time at current job (w)	214.9 (321.9)	225.4 (456.5)
Hours of work per week (h)	38.8 (3.0)	40 (0)
Time in current office (w)	56.6 (55.8)	132 (207.3)
Baseline naps (number)	0.8 (1.1)	1.0 (1.5)
Baseline weekday bedtime (hh:mm)	23:24 (1.0)	24:00 (1.7)
Baseline weekend bedtime (hh:mm)	24:48 (1.2)	24:42 (1.8)
Desired bedtime (hh:mm)	22:48 (1.0)	23:06 (1.0)
Desired wakeTime (hh:mm)	7:00 (1.2)	7:24 (1.3)
PSQI (score)	7.5 (2.4)	6.4 (3.0)
MEQ (score)	52.4 (4.8)	50.3 (10.7)
FSS (score)	33.5 (7.8)	33.8 (9.9)
	n (%)	**n (%)**
Gender (m)	61.5	62.5
Job Type		
Engineering/Physical Science	30.8	31.3
Administrative	7.7	25.0
Human Research	0	37.5
Finance	61.5	6.3
Sleep disrupted by children	0	18.75
Sleep disorder	7.7	0
Sleep meds	0	6.25

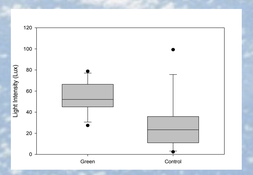
h = hours, w = weeks, hh:mm = hour:minutes, PSQI = Pittsburgh Sleep Quality Index, MEQ = Morningness-Eveningness Questionnaire, FSS = Fatigue Severity Scale











Conclusion

- In Year 1 analysis, sleep duration was shorter than expected in both types of buildings
- Light intensity is not sufficient to produce alerting effects when sleep duration is short.
- Year 2 analysis underway to evaluate the impact of light on alertness and performance with controlled sleep duration of 8 hours
- Findings may support the introduction of enhanced lighting regimes for deep space missions

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