Practical Interventions to Promote Circadian Adaptation to Permanent Night Shift Work: Study 4

Smith MR, Fogg LF, Eastman CI.

Scheduled bright light and darkness can phase shift the circadian clocks of night workers for complete adaptation to a night work, day sleep schedule, but few night workers would want this because it would leave them out of phase with the diurnal world on days off. This is the final study in a series designed to produce a compromise circadian phase position for permanent night shift work in which the sleepiest circadian time is delayed out of the night work period and into the first half of the day sleep episode. The target compromise phase position was a dim light melatonin onset (DLMO) of 3:00, which puts the sleepiest circadian time at approximately 10:00. This was predicted to improve night shift alertness and performance while permitting sufficient daytime sleep after work as well as late-night sleep on days off.

In a between-subjects design, 19 healthy subjects underwent 3 simulated night shifts (23:00-7:00), 2 days off, 4 more night shifts, and 2 more days off. Subjects "worked" in the lab and slept at home. Experimental subjects received four 15-min bright light pulses during each night shift, wore dark sunglasses when outside, slept in dark bedrooms at scheduled times, and received outdoor afternoon light exposure ("light brake") to keep their rhythms from delaying too far. Control subjects remained in normal room light during night shifts, wore lighter sunglasses, and had unrestricted sleep and outdoor light exposure. The final DLMO of the experimental group was 3:22 +/- 2.0 h, close to the target of 3:00, and later than the control group at 23:24 +/- 3.8 h. Experimental subjects slept for nearly all the permitted time in bed. Some control subjects who slept late on weekends also reached the compromise phase position and obtained more daytime sleep. Subjects who phase delayed (whether in the experimental or control group) close to the target phase performed better during night shifts. A compromise circadian phase position improved performance during night shifts, allowed sufficient sleep during the daytime after night shifts and during the late nighttime on days off, and can be produced by inexpensive and feasible interventions.

Night Shift Performance is Improved by a Compromise Circadian Phase Position: Study 3. Circadian Phase after 7 Night Shifts With an Intervening Weekend Off

Sleep. 2008 Dec 1;31(12):1639-45

Smith MR, Eastman CI.

STUDY OBJECTIVE: To produce a compromise circadian phase position for permanent night shift work in which the sleepiest circadian time is delayed out of the night work period and into the first half of the day sleep period. This is predicted to improve night shift alertness and performance while permitting adequate late night sleep on days off. DESIGN: Between-subjects. SETTING: Home and laboratory. PARTICIPANTS: 24 healthy subjects. INTERVENTIONS: Subjects underwent 3 simulated night shifts, 2 days off, and 4 more night shifts. Experimental subjects received five, 15 minute bright light pulses from light boxes during night shifts, wore dark sunglasses when outside, slept in dark bedrooms at scheduled times after night shifts and on days off, and received outdoor afternoon light exposure (the "light brake"). Control subjects remained in normal room light during night shifts, wore lighter sunglasses, and had unrestricted sleep and outdoor light exposure. MEASUREMENTS AND RESULTS: The final dim light melatonin onset (DLMO) of the experimental group was approximately approximately 04:30, close to our target compromise phase position, and significantly later than the control group at approximately 00:30. Experimental subjects performed better than controls, and slept for nearly all of the allotted time in bed. By the last night shift, they performed almost as well during the night as during...
daytime baseline. Controls demonstrated pronounced performance impairments late in the night shifts, and exhibited large individual differences in sleep duration. **CONCLUSIONS:** Relatively inexpensive and feasible interventions can produce adaptation to night shift work while still allowing adequate nighttime sleep on days off.

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**Shaping the Light/Dark Pattern For Circadian Adaptation to Night Shift Work**

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**Smith MR, Cullnan EE, Eastman CI.**

This is the second in a series of simulated night shift studies designed to achieve and subsequently maintain a compromise circadian phase position between complete entrainment to the daytime sleep period and no phase shift at all. We predict that this compromise will yield improved night shift alertness and daytime sleep, while still permitting adequate late night sleep and daytime wakefulness on days off.

Our goal is to delay the dim light melatonin onset (DLMO) from its baseline phase of approximately 21:00 to our target of approximately 3:00. Healthy young subjects (n=31) underwent three night shifts followed by two days off. Two experimental groups received intermittent bright light pulses during night shifts (total durations of 75 and 120 min per night shift), wore dark sunglasses when outside, slept in dark bedrooms at scheduled times after night shifts and on days off, and received outdoor light exposure upon awakening from sleep. A control group remained in dim room light during night shifts, wore lighter sunglasses, and had unrestricted sleep and outdoor light exposure. After the days off, the DLMO of the experimental groups was approximately 00:00-1:00, not quite at the target of 3:00, but in a good position to reach the target after subsequent night shifts with bright light. The DLMO of the control group changed little from baseline. Experimental subjects performed better than control subjects during night shifts on a reaction time task. Subsequent studies will reveal whether the target phase is achieved and maintained through more alternations of night shifts and days off.

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**Differences in Sleep, Light, and Circadian Phase in Offshore 18:00-06:00 h and 19:00-07:00 h Shift Workers.**


**Thorne H, Hampton S, Morgan L, Skene DJ, Arendt J.**

Complaints concerning sleep are high among those who work night shifts; this is in part due to the disturbed relationship between circadian phase and the timing of the sleep-wake cycle. Shift schedule, light exposure, and age are all known to affect adaptation to the night shift. This study investigated circadian phase, sleep, and light exposure in subjects working 18:00-06:00 h and 19:00-07:00 h schedules during summer (May-August). Ten men, aged 46+-10 yrs (mean+-SD), worked the 19:00-07:00 h shift schedule for two or three weeks offshore (58 degrees N). Seven men, mean age 41+-12 yrs, worked the 18:00-06:00 h shift schedule for two weeks offshore (61 degrees N). Circadian phase was assessed by calculating the peak (acrophase) of the 6-sulphatoxymelatonin rhythm measured by radioimmunoassay of sequential urine samples collected for 72 h at the end of the night shift. Objective sleep and light exposure were assessed by actigraphy and subjective sleep diaries. Subjects working 18:00-06:00 h had a 6-sulphatoxymelatonin acrophase of 11.7+-0.77 h (mean+-SEM, decimal hours), whereas it was significantly later, 14.6+-0.55 h (p=0.01), for adapted subjects working 19:00-07:00 h. Two subjects did not adapt to the 19:00-07:00 h night shift (6-sulphatoxymelatonin acrophases being 4.3+-0.22 and 5.3+-0.29 h). Actigraphy analysis of sleep duration showed significant differences (p=0.03), with a mean sleep duration for those working 19:00-07:00 h of 5.71+-0.31 h compared to those working 18:00-06:00 h whose mean sleep duration was 6.64+-0.33 h. There was a trend to higher morning light exposure (p=0.07) in the 19:00-07:00 h group. Circadian phase was later (delayed on average by 3 h) and objective sleep was shorter with the 19:00-07:00 h than the 18:00-06:00 h shift.
schedule. In these offshore conditions in summer, the earlier shift start and end time appears to favor daytime sleep.

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**Indoor Exposure to Natural Bright Light Prevents Afternoon Sleepiness.**

Sleep 2006;29(4):462-9

**Kaida K, Takahashi M, Haratani T, Otsuka Y, Fukasawa K, Nakata A.**

**STUDY OBJECTIVES:** The present study examined the effects of indoor exposure to natural bright light on afternoon sleepiness. **DESIGN:** Participants took part in 3 experimental conditions: (1) a natural bright light condition in which they carried out performance and arousal tests sitting near a window (3260.0 +/- 1812.43 lux) from 12:40 PM to 1:10 PM, (2) a nap condition in which they were provided a nap opportunity for 20 minutes from 12:45 PM, and (3) a control condition in which they performed the tests in less than 100 lux surroundings from 12:40 PM to 1:10 PM. Before and after each treatment, the same series of tests were administered. **SETTING:** A temperature- and light-controlled sleep laboratory. **PARTICIPANTS:** Sixteen healthy female paid volunteers aged 33 to 43 (38.1 +/- 2.68) years. **INTERVENTIONS:** Indoor natural bright light and a short nap. **MEASUREMENTS AND RESULTS:** Arousal levels were measured by the Psychomotor Vigilance Task, Alpha Attenuation Test, Karolinska Drowsiness Test, and Karolinska Sleepiness Scale. The tests were repeated every 30 minutes from 11:00 AM to 4:10 PM. Ambient light intensity was maintained at less than 100 lux, except during natural bright light exposure. Short-term exposure to natural bright light significantly improved afternoon arousal levels, as measured by the Karolinska Drowsiness Test and Alpha Attenuation Test, the effects of which continued for at least 60 minutes (1:10-2:10 PM). However, no significant differences were observed between conditions for Psychomotor Vigilance Test performance. **CONCLUSIONS:** Brief indoor exposure to natural bright light may decrease afternoon sleepiness. This technique of light could be used in work settings in which napping is not permitted.

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**A Compromise Phase Position for Permanent Night Shift Workers: Circadian Phase After Two Night Shifts With Scheduled Sleep and Light/Dark Exposure.**

Chronobiol Int 2006;23(4):859-75.

**Lee C, Smith MR, Eastman CI.**

**BACKGROUND:** Night shift work is associated with a myriad of health and safety risks. Phase-shifting the circadian clock such that it is more aligned with night work and day sleep is one way to attenuate these risks. However, workers will not be satisfied with complete adaptation to night work if it leaves them misaligned during days off. Therefore, the goal of this set of studies is to produce a compromise phase position in which individuals working night shifts delay their circadian clocks to a position that is more compatible with nighttime work and daytime sleep yet is not incompatible with late nighttime sleep on days off. This is the first in the set of studies describing the magnitude of circadian phase delays that occurs on progressively later days within a series of night shifts interspersed with days off. The series will be ended on various days in order to take a "snapshot" of circadian phase. **METHOD:** In this set of studies, subjects sleep from 23:00 to 7:00 h for three weeks. Following this baseline period, there is a series of night shifts (23:00 to 07:00 h) and days off. Experimental subjects receive five 15 min intermittent bright light pulses (approximately 3500 lux; approximately 1100 microW/cm2) once per hour during the night shifts, wear sunglasses that attenuate all visible wavelengths--especially short wavelengths ("blue-blockers")--while traveling home after the shifts, and sleep in the dark (08:30-15:30 h) after each night shift. Control subjects remain in typical dim room light (<50 lux) throughout the night shift, wear sunglasses that do not attenuate as much light, and sleep whenever they want after the night shifts. Circadian phase is determined from the circadian rhythm of melatonin collected during a dim light phase assessment at the beginning and end of each study. The sleepiest time of day, approximately by the body temperature minimum (Tmin), is estimated by adding 7 h to the dim light melatonin onset.
RESULTS: In this first study, circadian phase was measured after two night shifts and day sleep periods. The Tmin of the experimental subjects (n=11) was 04:24+/-.8 h (mean+/-.SD) at baseline and 7:36+/-.1.4 h after the night shifts. Thus, after two night shifts, the Tmin had not yet delayed into the daytime sleep period, which began at 08:30 h. The Tmin of the control subjects (n=12) was 04:00+/-.1.2 h at baseline and drifted to 4:36+/-.1.4 h after the night shifts. CONCLUSIONS: Thus, two night shifts with a practical pattern of intermittent bright light, the wearing of sunglasses on the way home from night shifts, and a regular sleep period early in the daytime, phase delayed the circadian clock toward the desired compromise phase position for permanent night shift workers. Additional night shifts with bright light pulses and daytime sleep in the dark are expected to displace the sleepiest time of day into the daytime sleep period, improving both nighttime alertness and daytime sleep but not precluding adequate sleep on days off.

Complete or Partial Circadian Re-Entrainment Improves Performance, Alertness, and Mood During Night-Shift Work

Crowley SJ, Lee C, Tseng CY, Fogg LF, Eastman CI.

STUDY OBJECTIVES: To assess performance, alertness, and mood during the night shift and subsequent daytime sleep in relation to the degree of re-alignment (re-entrainment) of circadian rhythms with a night-work, day-sleep schedule. DESIGN: Subjects spent 5 consecutive night shifts (11:00 pm-7:00 am) in the lab and slept at home in darkened bedrooms (8:30 am-3:30 pm). Subjects were categorized by the degree of re-entrainment attained after the 5 night shifts. Completely re-entrained: temperature minimum in the second half of daytime sleep; partially re-entrained: temperature minimum in the first half of daytime sleep; not re-entrained: temperature minimum did not delay enough to reach daytime sleep. SETTING: See above. PARTICIPANTS: Young healthy adults (n = 67) who were not shift workers. INTERVENTIONS: Included bright light during the night shifts, sunglasses worn outside, a fixed dark daytime sleep episode, and melatonin. The effects of various combinations of these interventions on circadian re-entrainment were previously reported. Here we report how the degree of re-entrainment affected daytime sleep and measures collected during the night shift. MEASUREMENTS AND RESULTS: Salivary melatonin was collected every 30 minutes in dim light (<20 lux) before and after the night shifts to determine the dim light melatonin onset, and the temperature minimum was estimated by adding a constant (7 hours) to the dim light melatonin onset. Subjects kept sleep logs, which were verified by actigraphy. The Neurobehavioral Assessment Battery was completed several times during each night shift. Baseline sleep schedules and circadian phase differed among the 3 re-entrainment groups, with later times resulting in more re-entrainment. The Neurobehavioral Assessment Battery showed that performance, sleepiness, and mood were better in the groups that re-entrained compared to the group that did not re-entrain, but there were no significant differences between the partial and complete re-entrainment groups. Subjects slept almost all of the allotted 7 hours during the day, and duration did not significantly differ among the re-entrainment groups. CONCLUSIONS: In young people, complete re-entrainment to the night-shift day-sleep schedule is not necessary to produce substantial benefits in neurobehavioral measures; partial re-entrainment (delaying the temperature minimum into the beginning of daytime sleep) is sufficient. The group that did not re-entrain shows that a reasonable amount of daytime sleep is not enough to produce good neurobehavioral performance during the night shift. Therefore, some re-alignment of circadian rhythms is recommended.

Suppression of Sleepiness and Melatonin by Bright Light Exposure During Breaks in Night Work.

Lowden A, Akerstedt T, Wibom R.

BACKGROUND: Night work is non-optimal for performance and recuperation because of a lack of circadian influence that fully promote a night orientation. METHOD: Our study assessed, in an industrial setting, the effects of bright light exposure (BL) on sleepiness, sleep and melatonin, during night work and during the following readaptation to day work. In a crossover design, 18 workers at a truck production plant were exposed to either BL (2500 lx) during breaks or normal light during four consecutive weeks. Twenty minute breaks were initiated by 67% of the workers between 03:00 and 04:00 hours. Sleep/wake patterns were assessed through actigraphs and ratings were given in a sleep/wake diary. Saliva melatonin was measured at 2-h intervals before, during and after night shift weeks. RESULTS: A significant interaction demonstrated a reduction of sleepiness in the BL condition particularly on the first two nights at 04:00 and 06:00 hours. Day sleep in the BL condition was significantly lengthened. Bright light administration significantly suppressed melatonin levels during night work and most strongly at 02:00 hours. Daytime melatonin during the readaptation after night work remained unaffected. CONCLUSION: The present findings demonstrate the feasibility and benefits of photic stimulation in industrial settings to increase adaptation to night work.

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Timed Bright-light Exposure and Complaints Related to Shift Work Among Women.


Leppämäki S, Partonen T, Piironen P, Haukka J, Lönnqvist J.

OBJECTIVES: This field study measured whether repeated, brief exposures to bright light during night shifts improved subjective well-being during and after night work. A secondary objective was to investigate whether this response differed by season (summer or winter), seasonality, or age. METHODS: Eighty-seven healthy female nurses were voluntarily exposed to brief periods (4 x 20 minutes) of bright (5000 lux) light at scheduled times during every night shift over a 2-week period. Each morning following a night shift the subjects filled out self-assessment questionnaires measuring subjective symptoms and distress caused by work at night. The questionnaires were also completed 2 weeks before and after the light intervention. The study had two phases, summer (May-June) and winter (November-December). Thirty-seven of the subjects participated during both periods. RESULTS: Light significantly alleviated the subjective distress associated with nightshift work, both in summer and in winter, independent of the subject’s age. The effect was stronger for those who reported routine seasonal changes in mood. CONCLUSIONS: Short pulses of timed bright-light exposure may enhance subjective adaptation to night work.

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Daytime Exposure to Bright Light, as Compared to Dim Light, Decreases Sleepiness and Improves Psychomotor Vigilance Performance.

Sleep 2003;26(6):695-700

Phipps-Nelson J, Redman JR, Dijk DJ, Rajaratnam SM

STUDY OBJECTIVES: This study examined the effects of bright light exposure, as compared to dim light, on daytime subjective sleepiness, incidences of slow eye movements (SEMs), and psychomotor vigilance task (PVT) performance following 2 nights of sleep restriction. DESIGN: The study had a mixed factorial design with 2 independent variables: light condition (bright light, 1,000 lux; dim light, < 5 lux) and time of day. The dependent variables were subjective sleepiness, PVT performance, incidences of SEMs, and salivary melatonin levels. SETTING: Sleep research laboratory at Monash University. PARTICIPANTS: Sixteen healthy adults (10 women and 6 men) aged 18 to 35 years (mean age 25 years, 3 months). INTERVENTIONS: Following 2 nights of sleep restriction (5 hours each night),
participants were exposed to modified constant routine conditions. Eight participants were exposed to bright light from noon until 5:00 pm. Outside the bright light exposure period (9:00 am to noon, 5:00 pm to 9:00 pm) light levels were maintained at less than 5 lux. A second group of 8 participants served as controls for the bright light exposure and were exposed to dim light throughout the entire protocol.

MEASUREMENTS AND RESULTS: Bright light exposure reduced subjective sleepiness, decreased SEMs, and improved PVT performance compared to dim light. Bright lights had no effect on salivary melatonin. A significant positive correlation between PVT reaction times and subjective sleepiness was observed for both groups. Changes in SEMs did not correlate significantly with either subjective sleepiness or PVT performance. CONCLUSIONS: Daytime bright light exposure can reduce the impact of sleep loss on sleepiness levels and performance, as compared to dim light. These effects appear to be mediated by mechanisms that are separate from melatonin suppression. The results may assist in the development of treatments for daytime sleepiness.

Bright Light Therapy of Subsyndromal Seasonal Affective Disorder in the Workplace: Morning vs. Afternoon Exposure.

Avery DH, Kizer D, Bolte MA, Hellekson C.

OBJECTIVE: Bright light therapy in seasonal affective disorder (SAD) has been studied extensively. However, little attention has been given to subsyndromal seasonal affective disorder (SSAD) or the use of bright light in the workplace. Many patients using bright light boxes complain of the inconvenience of use. Much of this inconvenience involves the often-recommended early timing of the bright light therapy. Patients, who already have difficulty awakening, often have difficulty using the bright light therapy soon after awakening before going to work. If bright light could be used effectively in the workplace, the treatment would be more convenient; the improved convenience would probably improve compliance. In this study, we studied the effectiveness of bright light therapy in subjects with SSAD in the workplace, comparing morning bright light with afternoon bright light. METHOD: Morning and afternoon bright light treatment (2500 lux) were compared in 30 subsyndromal seasonal affective disorder patients using the bright light therapy in the workplace. Hamilton Depression Ratings and subjective measures of mood, energy, alertness and productivity were assessed before and after 2 weeks of light therapy. RESULTS: Both morning and evening bright light significantly decreased the depression ratings and improved the subjective mood, energy, alertness and productivity scores. However, there were no significant differences between the two times of administration of the bright light treatment. Both bright light treatments were well tolerated. CONCLUSION: Bright light given in the workplace improves subjective ratings of mood, energy, alertness and productivity in SSAD subjects. Morning and afternoon bright lights resulted in similar levels of improvement.

Bright Light Treatment Used for Adaptation to Night Work and Re-adaptation Back to Day Life. A Field Study at an Oil Platform in the North Sea


Bjorvatn B, Kecklund G, Akerstedt T.

BACKGROUND: Night workers complain of sleepiness, reduced performance and disturbed sleep due to lack of adjustment of the circadian rhythm. In simulated night-work experiments scheduled exposure to bright light has been shown to reduce these complaints. METHOD: Here we studied the effects of bright light treatment on the adaptation to 14 days of consecutive night work at an oil platform in the North Sea, and the subsequent readaptation to day life at home, using the Karolinska sleep/wake diary. Bright light treatment of 30 min per exposure was applied during the first 4 nights of the night-shift period and the first 4 days at home following the shift period. The bright light exposure was scheduled individually to phase delay the circadian rhythm. RESULTS: Bright light treatment modestly facilitated the subjective
adaptation to night work, but the positive effect of bright light was especially pronounced during the re-adaptation back to day life following the return home. Sleepiness was reduced and the quality of day was rated better after exposure to bright light. The modest effect of bright light at the platform was, possibly, related to the finding that the workers seemed to adapt to night work within a few days even without bright light. CONCLUSION: These results suggest that short-term bright light treatment may help the adaptation to an extended night-work period, and especially the subsequent re-adaptation to day life.

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**Effects of Bright Artificial Light on Subjective Mood of Shift Work Nurses.**

Ind Health 1997;35(1):41-7

**Iwata N, Ichii S, Egashira K**

**BACKGROUND:** The effects of bright artificial light on the subjective mental state of 10 female nurses working shifts at a university hospital were assessed. **METHOD:** We investigated two series of five consecutive workshifts rotations comprising one normal, two night and two evening shifts, using two self-administered rating scales. The subjects were exposed to artificial light, brighter than 3,000 lux, for a total of 30 min during each workshift of the second series, whereas they worked under normal lighting conditions (approximately 250 lux) during the first series. **RESULTS:** A three-way layout ANOVA, with repeated measures, revealed that bright light tended to improve eagerness and reduce tension, and improved vigor, eagerness, appetite and impairment (the latter only on the second night) significantly or nearly significantly during night, but not evening, shifts. **CONCLUSION:** These results suggest that bright artificial light affects the mental state of nurses during night, but not evening, shift work.