Improving Sleep Attributes of Military Personnel in Operational Settings by Controlling Exposure to Blue Light

Alex Ryan, Panagiotis Matsangas, Andrew Anglemyer and Nita Lewis Shattuck
Operations Research Department, Naval Postgraduate School, Monterey, CA

Military members often work in challenging environments. Their sleep is degraded by extended operational commitments and the requirement to work in shifts. Exposure to light at circadian inappropriate times may also have a detrimental impact on service members' sleep, fatigue levels, and mood. This two-week field study assessed whether sleep-related attributes can be improved by limiting exposure to blue light prior to sleep. Participants (N=30) were observed for one week without using blue light blocking glasses followed by a second week when they used blue light blocking glasses for two hours prior to their bedtimes. Sleep was assessed with wristworn actigraphy. Daytime sleepiness decreased ($p=0.011$), and mood improved ($p<0.001$) after wearing the glasses. Insomnia symptoms decreased while sleep onset latency and sleep quality improved, although not at statistically significant levels. These findings suggest that controlling exposure to blue light for two hours prior to sleep has a beneficial effect on sleep quality and mood.

INTRODUCTION

Sleep propensity and human wake/rest patterns are affected by two internal processes, the circadian and the homeostatic process (Achermann, 2004; Achermann & Borbély, 2003). As part of the homeostatic process, sleep propensity increases according to the length of time we are awake. The circadian process affects sleep propensity in an approximately 24-hour cyclical pattern. Military members, however, operate in a challenging operational environment with irregular work/rest behavioral patterns (Miller, Matsangas, & Kenney, 2012; Miller, Matsangas, & Shattuck, 2008; Troxel et al., 2015). Their sleep opportunities are affected, and often restricted, by operational commitments and the requirement to work in shifts (Brown, Matsangas, & Shattuck, 2015; Matsangas & Shattuck, 2016; Shattuck & Matsangas, 2015; Shattuck, Matsangas, Eriksen, & Kulubis, 2015).

One problem with the work/rest patterns of active duty service members is that their daily schedule is frequently misaligned with the human biological clock that dictates our physiological work/rest schedule. This issue is further exacerbated by exposure to light (both sunlight and artificial light) at circadian inappropriate times. Light, the most important "zeitgeber" for sleep and wakefulness, can affect the circadian clock and sleep propensity by suppressing the release of pineal melatonin (Brainard, Rollag, & Hanifin, 1997; Duffy & Czeisler, 2009; Gooley et al., 2011; Roenneberg & Merrow, 2002). Even though exposure to light in general affects the circadian pacemaker, research has shown that melatonin secretion is most sensitive to visible blue light ranging from 450 to 480 nm in wavelength (Brainard et al., 2001; Brainard et al., 1997). These wavelengths are also emitted by devices like television, smartphones, computer screens, tablets, etc. Studies conducted in the military operational environment have shown that exposure to light may interfere with sleep, and hence have a detrimental impact on service members' sleep, reported sleepiness level, and mood (Miller & Nguyen, 2003; Nguyen, 2002).

Given this background, the overarching goal of this study was to assess whether sleep-related attributes can be improved by controlling exposure to blue light prior to sleep. We hypothesized that wearing High Energy Visible (HEV) light-blocking glasses for two hours prior to bedtime would improve sleep quality, sleep quantity, alertness, and mood.

METHOD

Participants

Participants were enlisted active duty military members deployed in military facilities performing security duties (N=30, 24.2±3.3 years, 28 males). The study sample included 28 watchstanders working either on a 3-section/8-hour shift schedule or on a 2-section /12-hour shift schedule. Watchstanders worked for either 2 or 3 days, and then were allowed either 1 or 2 days off. Participants had been working the same schedule for several weeks before the data collection commenced.

Equipment and Instruments

The demographic information collected included age, gender, and the participants watch schedule. The Epworth Sleepiness Scale (ESS) was used to assess average daytime sleepiness (Johns, 1991). The Insomnia Severity Index (ISI) was used to assess the severity of insomnia symptoms (Bastien, Vallieres, & Morin, 2001). Sleep quality was assessed with the Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989). To measure mood states and assess changes in mood, participants filled out the Profile of Mood States (POMS) scale (McNair, Lorr, & Droppelman, 1971). The POMS questionnaire assesses various dimensions of mood using six subscales: anger - hostility, confusion - bewilderment, depression, fatigue, tension – anxiety, and vigor – activity. The Total Mood Disturbance (TMD) score is derived by adding five of the subscales and subtracting the score for vigor.

The Philips Respironics Spectrum Plus actiwatch was used to assess sleep; sleep scoring was augmented with daily activity logs. Data were collected in 1-minute epochs, and were scored using Actiware software version 6.0.9 (Phillips Respironics, Bend, Oregon). The medium sensitivity threshold (40 counts per epoch) was used, with 10 immobile minutes as the criterion for sleep onset and sleep end (all values are default for this software).

The Dozer RO W914 Blue Blocker 500 glasses with tinted lenses were utilized in this study. The glasses were procured from the Naval Ophthalmic Support and Training Activity (NOSTRA), Yorktown, Virginia.

Procedures

This study was longitudinal and quasi-experimental in nature (i.e., non-randomized participants performing their typical duties in their normal working environment for a period of two weeks). The study protocol was approved by the Naval Postgraduate School Institutional Review Board. Personnel wishing to volunteer signed consent forms and were issued equipment for the study.

The 14-day study was divided in two phases, a control week followed by a treatment week. During the treatment week, participants were instructed to wear the blue light-blocking glasses for 2 hours prior to bedtime. During the control week, participants were instructed not to use the glasses.

In the beginning of the study, participants were issued an actiwatch and a pair of HEV-blocking glasses. Participants were instructed to wear their actiwatch for the entire data collection period, and to complete daily activity logs. Subjective data (PSQI, ESS, ISI, and POMS) were collected at three times during the study: at the beginning, after the control week, and at the end of the treatment week.

Analysis

Statistical analysis was conducted with a statistical software package (RStudio, version 1.0.136, RStudio, Inc.). Study figures were developed with JMP Pro 12 (SAS Institute; Cary, NC). After assessing and rejecting the data for normality with the Shapiro-Wilk W test, comparisons were based on nonparametric methods. The 1-sided Wilcoxon Signed Rank test was used for pairwise comparisons. The criterion for statistical significance was set at $p = 0.05$. Data are presented as mean (M) ± standard deviation (SD). Sleep analysis was based on the actigraphy data aided by the activity logs to determine the start and end times of sleep intervals. Aggregated by participant, actigraphic metrics were averaged for the control and treatment weeks. The analysis presented in this paper focuses on the comparison between T3 (scores the end of the treatment week) and T2 (scores at the end of the control week).

RESULTS

Because some participants did not complete the entire course of the study, our analysis is based on the data from 24 participants (19 of whom completed all questionnaires; 20 had useable actigraphic data).

Sleep

During the entire 14-day period of the study, participants rested on average 7.52 ± 1.25 hours per day, and slept on average 6.95 ± 1.42 hours per day. From the 20 participants with actigraphic sleep data, 55% (n=11) were sleeping on average less than seven hours per day during the entire study.

Analysis showed that daily rest (time in bed) and sleep duration did not differ between the control and the treatment week. Sleep onset latency, however, decreased by approximately two minutes after wearing the glasses (after control week: 10.4±7.37; after treatment week: 8.41±7.77; Wilcoxon Signed Rank, $V=63.0$, $p=0.062$).

The average PSQI Global score improved from 7.21±2.25 (ranging from 4 to 12) at the end of the control week to 6.73±3.38 (ranging from 1 to 13) after wearing the glasses (Wilcoxon Signed Rank, $V=25.5$, $p=0.152$). This improvement becomes more evident if we consider that at the end of the control week, 79% of the participants were classified as "poor sleepers" (PSQI>5). After wearing the glasses, however, only 58% of the participants were classified as "poor sleepers."

Next, we assessed average daytime sleepiness with the ESS. The average ESS score at the end of the control week (without wearing the glasses) was 8.52 ± 4.31 (ranging from 1 to 19) improving to 7.21 ± 4.26 (ranging from 0 to 13) after wearing the glasses (Wilcoxon Signed Rank, V=16, p=0.011). These results indicate that participants reported less daytime sleepiness after wearing the glasses. The average ISI score at the end of the control week was 9.21 ± 5.40 (ranging from 2 to 20) improving to 8.52 ± 5.70 (ranging from 0 to 20) after wearing the glasses (Wilcoxon Signed Rank, V=42.5, p=0.274). Sleep onset latency, PSQI, ISI, and ESS results are shown in Figure 1.

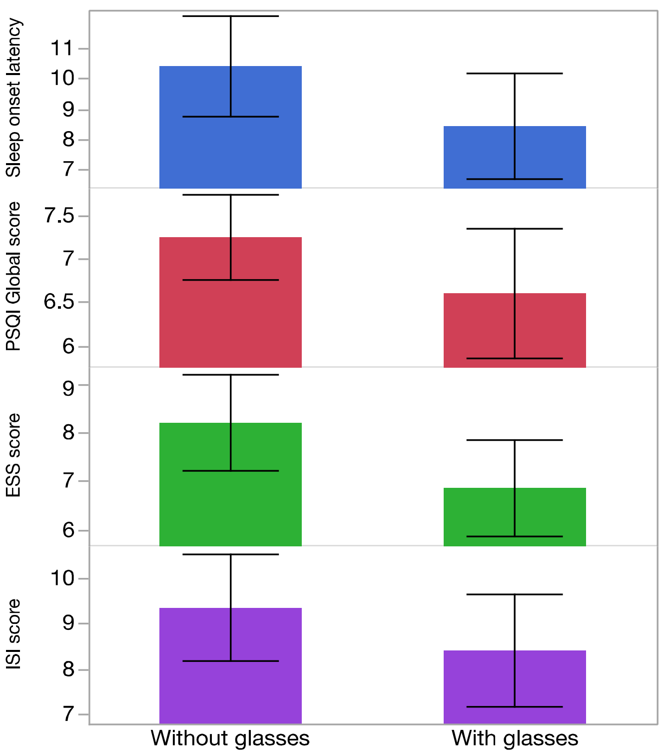

Figure 1. PSQI, ISI, and ESS scores. Vertical lines denote the Standard Error of the Mean (SEM).

Mood States

Analysis showed that mood improved after wearing the glasses (Wilcoxon Signed Rank, V=11, p<0.001). Specifically, the POMS TMD score at the end of the control week was 15.6 ± 20.9 (ranging from -12 to 69). After wearing the glasses for a week, the POMS TMD decreased to 7.68 ± 19.6 (ranging from -20 to 61). Notably, five of the six POMS subscale scores improved after wearing the glasses. These results are shown in Figure 2 and Table 1.

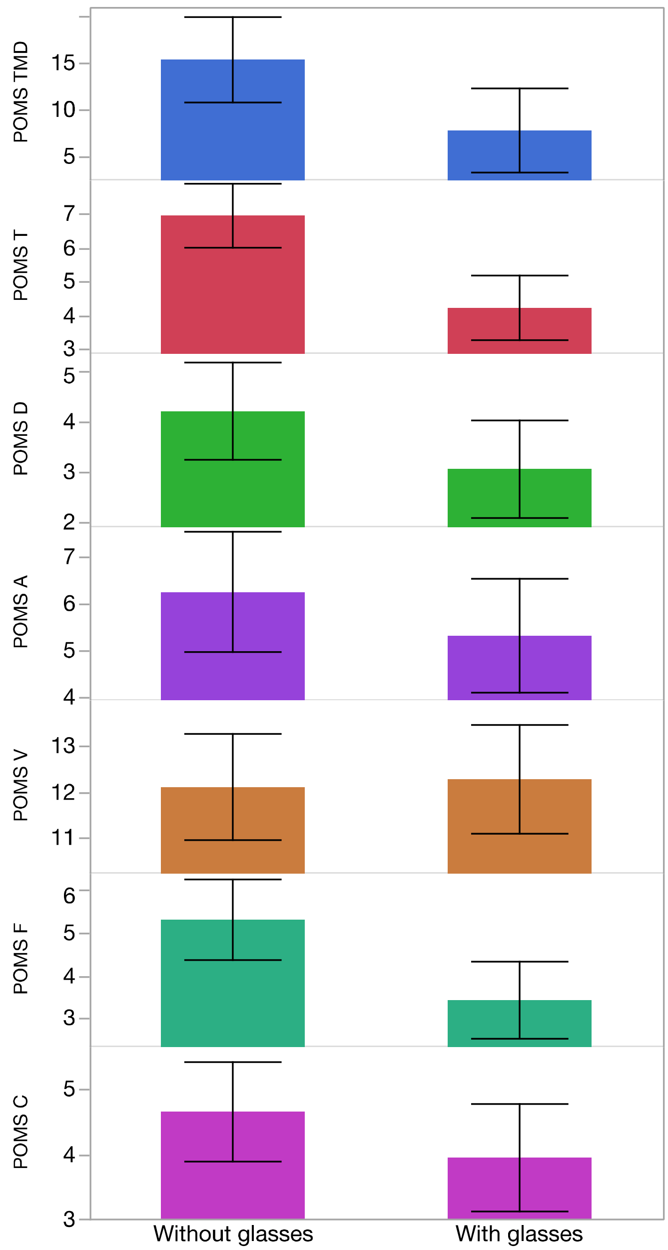

Figure 2. POMS TMD and subscale scores. Vertical lines denote the Standard Error of the Mean (SEM).

Table 1. POMS subscale scores.

POMS subscales	Without the glasses	After wearing the glasses	p-value
Tension – Anxiety (T)	6.95±4.25	4.21±4.20	<0.001
Depression (D)	4.20±4.30	3.05±4.21	0.002
Anger – Hostility (A)	6.25±5.75	5.32±5.30	0.015
Vigor – Activity (V)	12.10±5.14	12.26±5.13	0.725
Fatigue (F)	5.30±4.21	3.42±3.93	<0.001
Confusion-Bewilderment (C)	4.65±3.41	3.95±3.58	0.053

DISCUSSION

The goal of our operational study was to assess whether sleep-related attributes can be improved by controlling exposure to blue light prior to sleep. Results suggest that wearing HEV-blocking glasses for two hours prior to bedtime can improve sleep quality, alertness, and mood. Table 2 provides a summary of the findings of our field study.

Table 2. Behavioral changes after wearing the HEV-light blocking glasses.

Daily sleep duration	No change
Sleep onset latency	Improved but not at statistically significant level
Sleep Quality (PSQI)	Improved but not at statistically significant level
Daytime sleepiness (ESS)	Improved
Insomnia symptoms (ISI)	Improved but not at statistically significant level
Mood (POMS)	Improved

These findings are aligned with earlier research regarding the beneficial effect of blocking blue light for three hours before sleep (Burkhart & Phelps, 2009).

From an operational perspective, our findings may be beneficial for active duty service members. Controlling light exposure by wearing HEV-blocking glasses before going to bed provides a simple and inexpensive method to improve service members' sleep quality. Service members with better sleep will be more alert when needed, their performance will improve, and their overall quality of life will be better.

The results of this study may also be applicable to shift workers in other occupations beyond the military, including medical professionals, firefighters, and law enforcement officers.

Study limitations

This study had a few limitations. First, we could not control the work schedule for the participants between the control week and treatment week. Second, since each subject was from one of four different locations, there may be factors present at each location that are not present at any of the others. Due to operational limitations we could not counterbalance the order of treatment, i.e., the 7-days of wearing the HEV-blocking glasses. Lastly, compliance with the study protocol was less than we had planned – probably due to high operational tempo and competing demands placed on the participants. Replication of our findings in future assessments should included a larger number of participants in the study sample.

Acknowledgments

We acknowledge the support of the Naval Ophthalmic Support and Training Activity, Yorktown, Virginia and the military members who participated in the study. The study was funded under Document # M5405016WRSLP02.

Disclaimer

The views expressed in this study are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, or the U.S. Government.

LIST OF REFERENCES

Achermann, P. (2004). The two-process model of sleep regulation revisited. *Aviation Space and Environmental Medicine*, *75*(3, Suppl.), A37-A48.

Achermann, P., & Borbély, A. (2003). Mathematical models of sleep regulation. *Frontiers in Bioscience*, *8*, s683-s693.

Bastien, C. H., Vallieres, A., & Morin, C. M. (2001). Validation of the Insomnia Severity Index as an outcome measure for insomnia research. *Sleep Medicine*, *2*(4), 297-307.

Brainard, G. C., Hanifin, J. P., Greeson, J. M., Byrne, B., Glickman, G., Gerner, E., & Rollag, M. D. (2001). Action spectrum for melatonin regulation in humans: Evidence for a novel circadian photoreceptor. *The Journal of Neuroscience*, *21*(16), 6405-6412.

Brainard, G. C., Rollag, M. D., & Hanifin, J. P. (1997). Photic regulation of melatonin in humans: ocular and neural signal transduction. *Journal of Biological Rhythms*, *12*(6), 537-546.

Brown, S., Matsangas, P., & Shattuck, N. L. (2015, October 26 - 30). *Comparison of a circadian-based and a forward rotating watch schedules on sleep, mood, and psychomotor vigilance performance* Paper presented at the Human Factors and Ergonomics Society (HFES) Annual Meeting, Los Angeles, CA.

Burkhart, K., & Phelps, J. R. (2009). Amber lenses to block blue light and improve sleep: A randomized trial. *Chronobiology International*, *26*(8), 1602-1612.

Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A New Instrument for Psychiatric Practice and Research. *Journal of Psychiatric Research*, *28*(2), 193–213.

Duffy, J. F., & Czeisler, C. A. (2009). Effect of light on human circadian physiology. *Sleep Medicine Clinics*, *4*(2), 165-177.

Gooley, J. J., Chamberlain, K., Smith, K. A., Khalsa, S. B., Rajaratnam, S. M., Van Reen, E., . . . Lockley, S. W. (2011). Exposure to room light before bedtime suppresses melatonin onset and shortens melatonin duration in humans. *The Journal of Clinical Endocrinology and Metabolism*, *96*(3), E463-E472.

Johns, M. W. (1991). A new method for measuring daytime sleepiness: The Epworth Sleepiness Scale. *Sleep*, *14*, 540–545.

Matsangas, P., & Shattuck, N. L. (2016). Sleep quality in crewmembers of US Navy ships while underway. *Sleep*, *39*(Abstract Supplement), A98-A99.

McNair, D. M., Lorr, M., & Droppelman, L. F. (1971). *Manual of the profile of mood states*. San Diego, CA: Educational and Industrial Testing Service.

Miller, N. L., Matsangas, P., & Kenney, A. (2012). The Role of Sleep in the Military: Implications for Training and Operational Effectiveness. In J. H. Laurence & M. D. Matthews (Eds.), *The Oxford Handbook of Military Psychology* (pp. 262–281). New York: Oxford University Press.

Miller, N. L., Matsangas, P., & Shattuck, L. G. (2008). Fatigue and its effect on performance in military environments. In P. A. Hancock & J. L. Szalma (Eds.), *Performance under stress* (1st ed., pp. 231–250). Burlington, VT: Ashgate Publishing.

Miller, N. L., & Nguyen, J. L. (2003). *Working the nightshift on the USS John C. Stennis: Implications for enhancing warfighter effectiveness.* Paper presented at the Human Systems Integration Symposium (HSIS) 2003: Enhancing Human Performance in Naval & Joint Environments, Vienna, VA.

Nguyen, J. L. (2002). *The effects of reversing sleep-wake cycles on sleep and fatigue on the crew of USS JOHN C. STENNIS*. Naval Postgraduate School, Monterey, California.

Roenneberg, T., & Merrow, M. (2002). Light reception: Discovering the clock-eye in mammals. *Current Biology*, *12*(5), R163-R165.

Shattuck, N. L., & Matsangas, P. (2015). Operational assessment of the 5-h on/10-h off watchstanding schedule on a US Navy ship: Sleep patterns, mood, and psychomotor vigilance performance of crew members in the nuclear reactor department. *Ergonomics*, *59*(5), 657-664. doi: 10.1080/00140139.2015.1073794

Shattuck, N. L., Matsangas, P., Eriksen, E., & Kulubis, S. (2015). Comparison of Two Watch Schedules for Personnel at the White House Military Office President's Emergency Operations Center. *Human Factors*, *57*(5), 864-878.

Troxel, W. M., Shih, R. A., Pedersen, E., Geyer, L., Fisher, M. P., Griffin, B. A., . . . Steinberg, P. S. (2015). *Sleep in the military: Promoting healthy sleep among U.S. servicemembers*. Santa Monica, CA: RAND.