THE EFFECTS OF LIGHT EXPOSURE ON CREWMEMBER FATIGUE AND JETLAG: TO IMPROVE TRANSPORTATION SAFETY AND PRODUCTIVITY

Lori J. Brown
Western Michigan University, College of Aviation

Keywords: *pilot, flight attendant, jet lag, circadian clock, fatigue, phototherapy,*

Abstract

At many airlines, crewmembers are forced to work to the point of exhaustion because of poorly scheduled duty time, lengthened duty day, minimum scheduled rest requirements, working the backside of the clock, and often experiencing long commutes to work. The need to reduce accidents and incidents caused by human fatigue in the aviation industry remains on the National Transportation Safety Boards' (NTSB), most wanted list. Research has identified key findings concerning fatigue in aviation, where sleep deprivation and disruption of circadian rhythms are known to occur. Crewmembers on transmeridian long-haul flights are often exposed to changes in external time, followed by changes in circadian rhythm, which leads to several symptoms known as jet lag. Additionally, crew members incur long duty days with multiple short legs, also experience sleepiness, decreased performance and alertness, caused by fatigue. Decreasing fatigue and its associated errors would improve safety and enable operational improvements to meet the business requirements of today's airlines in these lean economic times. The goal of this study is to assuage fatigue effects and jet-lag symptoms with exposure to short-wavelength (blue) range 460 nm light, opening up a whole new range of possibilities for using light to improve aviation safety, crewmember health and business productivity.

1 Introduction

Research efforts on human factors including the effects of fatigue, sleepiness, sleep disorders, and circadian factors on transportation safety has become a top priority [1]. Research has identified key findings concerning fatigue in the pilot and flight attendant occupation, where sleep deprivation and disruption of circadian rhythms are known to occur [5,11, 12].

Pilots and Flight attendants are frequently "experiencing issues consistent with fatigue and tiredness" and "fatigue appears to be a salient issue warranting further evaluation." Based on incident reports, pilot and flight attendant comments, and the outcomes from the sampling of actual duty and rest time, it appears that the opportunities for adequate rest need to be further evaluated [5, 11, 12].

Lean economic times have resulted in airline mergers, base closures, base changes, and reductions, which often require crewmembers to commute long distances to their base domicile assignments. There is a lack of information on the effects of 'commuting' on pilot and flight attendant fatigue. Unfortunately, in some instances aircraft accidents with fatigue causation factors can prove to be fatal for all onboard, as in the crash of Colgan flight 3407, which crashed in Buffalo, New York, on February 12, 2009. This fatal crash has brought out several serious safety concerns for the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB).

A crewmember can choose to commute to their scheduled base for work, allowing pilots and flight attendants to live in another city or country- regardless of their work base city. A pilot who commutes has to travel from the city or country in which they live before checking in for duty. In the ill-fated Colgan flight 3407, the first officer had commuted all night from Seattle on a Fed-EX cargo aircraft and the Captain had commuted and slept in the crew room before signing in for the flight. The time commuting to work is not included in duty time, which increases the crewmembers' "time since awake." Research shows that after 17 hours of 'time since awake', performance can be similar to someone who is legally drunk. The effects of off duty activity pertaining to commuting are not part of intentional calculations regarding fatigue now, but deserve observation and study, and further point to the importance of fatigue risk management systems, fatigue education, and effective countermeasures to mitigate the effects of operator fatigue.

2 Previous Research

Research has shown that such work environments as are provided by the aviation industry, can result in an inability to get to sleep (possibly leading to further disruption of the circadian rhythm) and to the accumulation of sleep debt. The results of these potentially cascading effects show themselves as a decrease in alertness and performance. Sleep loss has been shown in several studies to create waking neurobehavioral deficits; which include vigilance degradations, increased lapses of attention, cognitive slowing, short-term memory failures, slowed physical and mental reaction time, rapid and involuntary sleep onsets, decreased cognitive performance, increased subjective sleepiness, and polysomno graphic evidence of increased sleep pressure [1, 8, 11, 15, 9]. Similar problems occur in night-shift maintenance technicians who also often work during their biological night and have an increased risk of errors and injuries.

The "Pilot/Fight Attendant Communication and Joint Training" study sought to identify gaps that impede effective communication and coordination. Respondents included in the study represented 29 countries throughout the world. The countries of origin for the respondents' airlines include Australia, Austria, Belgium, Brussels, Canada, China, Finland, France, Germany, Greece, Hong Kong, Ireland, Italy, Japan, Mauritius, Mexico, New Zealand, Poland, Portugal, Romania, Slovakia, Spain, Switzerland, The Netherlands, Turkey, United States, United Arab Emirates, United Kingdom, and Venezuela.

In this study, 291 flight attendants and pilots were asked if fatigue had ever affected their ability to perform their duties safely (shown in figure 1). Out of the total 291 participants, 68% responded that fatigue would greatly affect their ability to complete their duties safely.

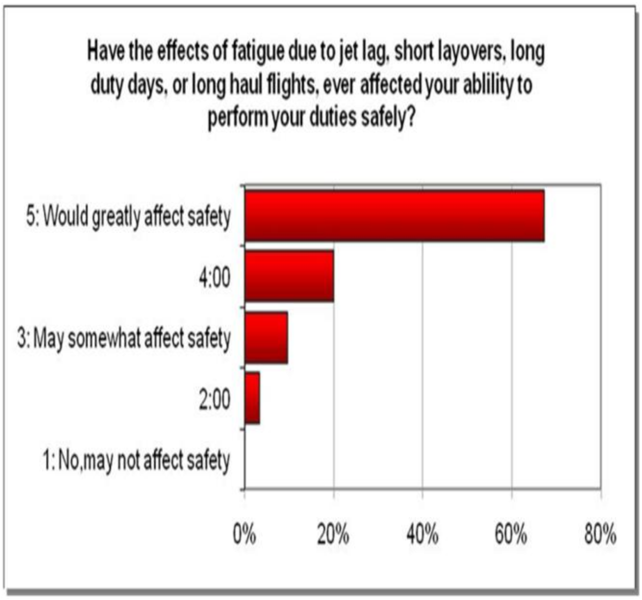

Fig. 1 Fatigue Effects

2.1 Countermeasures

We can use results garnered from previous fatigue studies to suggest potential countermeasures to sleep and circadian issues that flight and cabin crews encounter. Each individual crewmember will benefit from these countermeasures differently and will need to decide which garners the best results for them. This is why education about fatigue and countermeasures is a crucial element of training. In order to maximize the success for each individual crew member, researchers suggest trying different combinations for different periods of time to discover what is the most effective [1, 8, 3].

One of the most crucial countermeasures is the early recognition of fatigue in yourself or other crewmembers. Individuals must recognize fatigue in order to address it. Since it is difficult for people to estimate their own alertness and fatigue levels, objective criteria may help in assessment. Some of the signs that may be caused by fatigue are forgetfulness, poor decision making, slower reaction time, decreased vigilance, communication difficulties, fixation, lethargic, and moodiness [7, 8,11]. If any of these signs are apparent, then the individual can employ an alertness strategy. Alertness strategies can be categorized as follows.

2.1.1 Strategies

Preventive strategies: Those used before flying or between flights to reduce the effects of fatigue, sleep loss, and circadian disruption. These strategies are employed prior to checking-in for a trip, or during layover time. These techniques can help ensure restorative sleep and minimize circadian rhythm interruptions. At home, it is important for crewmembers to get the best possible sleep before flying, getting at least 8 hours of sleep combined with strategic naps, proper hydration, nutrition, and exercise. These techniques can help to decrease the likelihood of the crewmember starting the trip with a sleep deficit. Proactive preventative strategies combined with fatigue risk management systems (FRMS) and the use of scheduling tools can be combined to optimize preventive measures [7,11].

Operational strategies: Used during flights to maintain alertness and performance. It is important to note that the only thing, which can reverse physiological sleepiness, is a sleep period or nap. The need of a combination of napping and other countermeasures to improve alertness has been demonstrated by, Garbarino et al., 2004; Gronfier et al., 2007, in previous research. As shown in research conducted by Leger, et al., bright light could be one of these countermeasures [9], and warrants further study.

Napping affects the homeostatic component of sleepiness, and bright light is widely recommended to improve the circadian entrainment. It has been demonstrated by Hoddes et al., 1973; Hornberger et al., 2000; Horne and Reyner, 1999; Horowitz et al., 2001, that single bright light pulses during the shift may be sufficient to entrain the human circadian clock 1999. Bright light pulses may be easy to apply in real settings in crew rooms, hotel layovers, air-traffic control break rooms, and possibly aircraft galleys. Based on this hypothesis, Leger et al. [9], designed a preliminary study to test the effects of combination of napping and bright light pulses in a pilot group of shift workers. This study used short pulses (10 min) of 5000 lux white light, combined with naps [9].

The key finding in their preliminary study is that the combination of napping and two pulses of bright light are effective in reducing both subjective and objective sleepiness at the wheel at any time of the 24 hour cycle. Both the number and the duration of the episodes of sleepiness are reduced by the intervention. They identified an average 10.7 episodes of sleepiness on the first baseline period versus an average one episode on the second intervention period ($P = 0.013$) and the reduction concerned not only the night shift but also the morning and the afternoon shifts [9].

Strategic caffeine consumption while on duty to increase alertness can be effective, though it is not recommended within several hours before going to sleep, and should only be used when the crewmember feels tired. High-energy drinks should be used strategically with care due to the high sugar content. Staying hydrated and being sensible about nutrition is very important. High protein snacks such as nuts or protein bars can be helpful to stabilize blood glucose levels. Moving, stretching, and periodic exercise (walk about the cabin), may also be beneficial. This is an advantage that flight attendants have over a pilot- the ability to get exercise. Caffeine, activity, artificial indoor lighting, or other stimulation, can mask sleepiness, and help maintain a level of alertness until a crewmember can get sleep. These strategies do not affect the underlying physiological mechanisms of fatigue, but can aid in managing fatigue during operations. Primarily, these short-term strategies help to stave off, or mask underlying physiological sleepiness [1, 3]. It is important to note that, when an individual uses two or more of the countermeasures together, it can produce a "synergistic" approach, maximizing alertness and performance; thereby, increasing safety and productivity.

Melatonin is a naturally occurring hormone produced by the pineal gland in the brain. Since its secretion increases at nighttime, and is correlated with the sleep/wake cycle, melatonin is being studied as a treatment for insomnia. Many companies claim that melatonin fights stress, aging, jet lag, high blood pressure, and immune system deficiencies. As with many herbal countermeasures, not much is known about long-term side effects; so any use of melatonin should be under a medical doctor's supervision, and required airline drug testing policies should be consulted carefully. Melatonin, kava-kava, and valerian root are sold as a dietary supplement and are not approved by the FDA, so they are not regulated for purity [1, 3].

2.1.2 High Lux Lights

Originally aimed at the treatment of seasonal affective disorder (SAD) and winter blues, NatureBright® Photodynamic Therapy (PDT) products have recently been applied to people with mood and cognitive problems, shift work fatigue, jet lag, disturbances of the sleep-wake cycle, and premenstrual syndrome (PMS). These and similar products have been involved in many studies relating to shift (night) workers whom amount to an estimated 270 million workers [1, 8], many of which are flight attendants, pilots, and air traffic controllers.

The February ninth 2006 edition of the Harvard Gazette mentioned the medical school's own research on light therapy, stating that "the eyes are part of a light reception system that can keep you alert when sleep starts to fog your brain" [2]. The Harvard study also suggested that "light may be a powerful countermeasure for the negative effects of fatigue for people who work or study at night" [2]. This is essential for pilots and flight attendants on whom, the safety of hundreds of passengers depend every night.

Researchers have been able to demonstrate that bright light pulses of 10,000 lux, at about 30 minutes a day, were able to help adjust employees to new circadian rhythms [8, 1].The light entering the retina is said to affect neurons in the suprachiasmatic nuclei (SCN) of the hypothalamus, which is the compound that affects circadian light/dark cycles in humans.

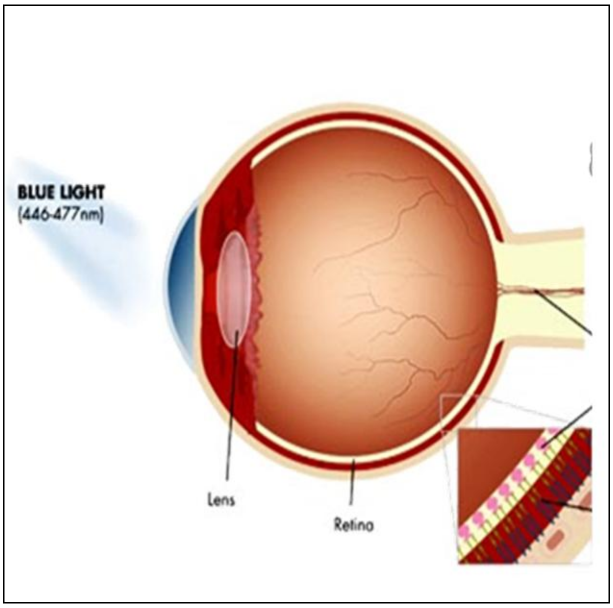

Fig. 2 Light entering the retina

These neurons secrete a chemical called vasopressin, which studies have shown is a neuropeptide involved in synchronizing these cycles. When a person is undergoing bright light therapy, the properly tuned, high lux wavelength of light enters the retina (shown in figure 2) and is thought to re-energize inactive neurons in the SCN. These neurons once again begin secreting vasopressin, (shown in figure 3) allowing the subject to redevelop a normal sleep cycle [1, 4].

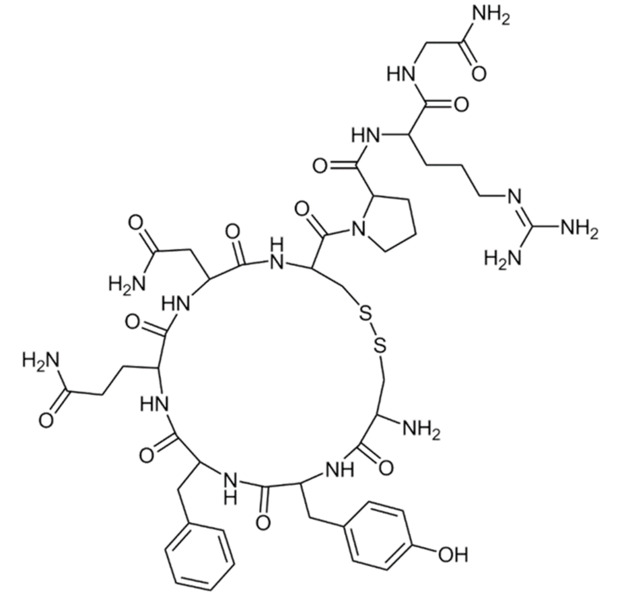

Fig. 3 Chemical Makeup of Vasopressin

Although high lux lights have proven effective in decreasing the symptoms and length of jet lag for traveling passengers, this countermeasure is more difficult for crewmembers with varying schedules. This area requires further research, which must carefully considers circadian phase change, similar to recent studies conducted with green light. Light technology has been found to effectively align the body clock (circadian phase) of crew-members working the night shift with their work schedules on operational vessels in maritime settings [14].

Other studies using 300-400 lux green light lamps have been used for in the development of the U.S. Coast Guard's Crew Endurance Management System. The U.S. Coast Guard Research and Development Center tested the effectiveness of low intensity green lamps for shifting circadian rhythms in order to align the internal body clock of crewmembers on the midnight watch with their work schedule [10].

Researchers from Brigham and Women's Hospital (BWH) and Harvard Medical School found that exposure to short wavelength, or blue light, during the biological night directly and immediately improves alertness and performance [12, 13]. These findings add to the body of evidence that illustrates that there is a novel photoreceptor system that exists in the human eye in addition to that used for sight[10, 13] "Light exposure to this system, particularly blue light, directly reduces sleepiness. Subjects exposed to blue light were able to sustain a high level of alertness during the night when people usually feel most sleepy, and these results suggest that light may be a powerful countermeasure for the negative effects of fatigue for people who work at night" [13].

In order to determine which wavelengths of light were most effective in warding off fatigue, researchers [13] compared the effects of blue light (460 nanometers, nm) with exposure to an equal amount of green light (555 nm) on alertness and performance for six and a half hours during the night. Subjects rated how sleepy they felt on a scale from one to 9, had their reaction times measured and wore electrodes to assess changes in brain activity patterns during the light exposure [10, 13]. The subjects exposed to blue light consistently rated less sleepy, had quicker reaction times, and had fewer lapses of attention during the performance tests compared to those who were exposed to green light. They also had changes in their brain activity patterns that indicated a more alert state. The finding that short-wavelength blue light was more effective indicates that the color vision system is not the primary photoreceptor system used to detect light for these effects as the visual system is most sensitive to the green light exposure used (555 nm) [10, 13].

Until recently, it was thought that the eye was just used to see. Researchers and others [12,10, 13, 15] have shown that it is also used to detect light for other purposes, such as resetting the body clock to the 24-hour day. This photoreceptor system is different from that used in normal vision as it has a different sensitivity to the color of light and is retained in some blind people. However, green light was also found to be capable of provoking non-visual responses to light exposure, although the responses were not always as long lasting [14].

Another study [15] entitled “Field trial of timed bright light exposure for jet lag among airline cabin crew” conducted by the University of Helsinki, where out of 15 participants questioned on 28 flights; the mean estimated effect of bright light was a decrease of 5.3 points on the symptom scale. Volunteer study subjects were cabin crew members on long-haul flights. The subjects filled in a 16-Item Columbia Jet Lag Scale (maximum score 64) before the flight (expected symptoms based on previous flights), on the third day at the destination and again on the third day after returning home. Changes in scores were compared relative to the timed exposure to bright light, and to flights eastwards or westwards, and in summer or winter *[15]*. The study had a very small sampling size using both outdoor sunlight and artificial white lights of 500 lux.

3 Current Research

Dr. Chris Idzikowski from the U.K. Sleep Center, Western Michigan University Professor Lori Brown, and NatureBright® have collaborated on a pilot study designed to research the feasibility of high lux lights to mitigate fatigue and increase alertness for pilots, flight attendants. The study will combine short naps and light therapy in the Chinese long and short haul aviation environment. Some of the light products used in the study are:

Sun Touch Plus® Light and Ion Therapy system: The desktop device emits powerful 10000 Lux Sky Effect light and high-density negative ions. Pilots, flight attendants, and air traffic controllers could consider using short exposure of light therapy in crew-rooms, break areas, and galleys to increase concentration, and alertness.

Sky Effect® lighting: The overhead fluorescent lamp emits bright blue-enriched white light which replaces traditional airport, office, hanger, classroom, and crew-room lighting. Sky Effect lighting can create a therapeutic environment for increased alertness, elevated focus, mood, and calmness. Western Michigan University, College of Aviation has replaced traditional fluorescent overhead lighting with the high lux blue enriched Sky Effect lights with a favorable response from students. Further research is needed to look at the efficacy of these lights in crew-rooms, airports, aircraft galleys, and air traffic control break areas, for calming travel anxiety, and increased staff concentration throughout.

The Blueberry 500®, uses 460 nm blue led’s with features such as a MP3 and motion sensor. At 4.6 inches, this is the smallest multiple function light therapy device on the market, with an advanced optical lens, and a wakeup light alarm and built in MP3 player with down loadable stress reducing meditation song programs.

Figure 4 The Blueberry 500 (Nature Bright BB500®)

At completion of the pilot study, a full research project will be designed to look further at the mitigating effects of neurons secreting vasopressin, allowing the subject to redevelop a normal sleep, reduce fatigue, elevate mood, and increase business productivity through the evaluation of high lux light products combined with preventative and operational strategies such as napping.

To establish baseline crewmembers are asked to log the following information into the online database.

Flight times and SLEEP-Time to bed, Time to fall asleep, Time of awakening, Time of getting up, and naps. (Note the time zone that you are entering the time in).

DAILY (Jet lag)- Note whether you have had problems with fatigue, tiring easily, trouble concentrating, physical clumsiness, decreased waking alertness, trouble with memory, general weakness, lethargy, sleepiness. 0-4 scales for above, 0=nothing, 4=extreme

A circadian baseline is required to establish the feasibility of bright light for reducing jet lag-due the many time zones and erroneous schedules of international crewmembers. After the baseline is determined, the flight attendants will use the BB500® portable light in conjunction with on duty crew rest. Data are collected in an electronic PDA database.

A definitive research project will be designed to look further at the mitigating effects of neurons secreting vasopressin, allowing the subject to redevelop a normal sleep, reduce fatigue, elevate mood, and increase business productivity with blue light. The study will use 200 flight attendant and pilot participants currently employed by three airlines in China. This full-scale project will evaluate the efficacy of portable high lux lights in commercial aviation while examining occupational and personal benefits of light therapy.

4 In summary

Application of these studies may improve alertness in those people who need to sustain attention for long periods such as long distance drivers, pilots, or even astronauts. Blue light exposure for shift-workers could improve safety in dangerous situations that may arise due to the sleepiness experienced when working at night. [10, 13].

The therapeutic effects of blue light still need further investigation, particularly with regard to the safety of long-term exposure. Blue light, if misused, can cause damage to the eye and exposures need to be carefully monitored. With the advent of new, more controllable lighting technologies, we can begin to develop lighting systems designed to maximize the beneficial effects of light for health, increase alertness, and safety.

To address fatigue, we must combine regulations with operational practices, countermeasures, and education. To achieve this further study to evaluate the effects of light exposure on crewmember fatigue would significantly contribute to the limited body of knowledge in this area. Combined research of countermeasures, fatigue education, fatigue risk managements plans, commuting policies, rulemaking and the validation of models in airline operations are imperative to improve transportation safety and productivity, opening up a whole new range of possibilities for using light to improve human health.

References

[1] Brown L and Niehaus J. Countermeasures to Mitigate Effects of Fatigue: to Improve Transportation Safety and Productivity. Conference Proceedings-15th International Symposium on Aviation Psychology, Wright State University, Dayton, Ohio, 2009.

[2] Cromie, W. When the Blues Keep You Awake. Harvard Gazette, p. 2. February 2009.

[3] Fatigue Countermeasures Group. Flight Attendant Fatigue. Human Factors Research and Technology Division, NASA Ames Research Center, 2002.

[4] Forbes D, Morgan DG, Bangma J, Peacock S, and Adamson J. Light Therapy for Managing Sleep, Behavior, and Mood Disturbances in Dementia. Cochrane Database of Systematic Reviews, Issue 2, 2004.

[5] Friend P. Testimony of Patricia A. Friend, International President of the Association of Flight Attendants. CWA-AFL-CIO, Before the Subcommittee on Transportation and Infrastructure, 2006.

[6] House of Representatives. Appropriations Bill, The Departments of Transportation, and Treasury, House Rpt.108-671, 2007.

[7] Hursh S, Redmond D, Johnson M,Thorne D, Belenky G and Balkin T. Fatigue models for applied research in war fighting. Aviation Space and Environmental Medicine, 2004.

[8] Kerin, A. , & A guirre, A. (2005). Improving health, safety, and profits in extended hours operations (shiftwork). Journal of Industrial Health, 43, 201-08, 2008.

[9] Leger, Damien, Philip, Pierre, Jarriault, Philippe, Metlaine, Arnaud, Choudat, and Dominique. Effects of a combination of napping and bright light pulses on shift workers' sleepiness at the wheel: a pilot study. European Sleep Research Society, 2004.

[10] Lockley, SW. Circadian Rhythms: Influence of Light in Humans. Encyclopedia of Neuroscience, vol. 2, pp. 971-988, 2009.

[11] Nesthes D, and Schroder. Flight Attendant fatigue Study, Dot/FAA/AM-07/21, FAA Office of Aerospace, 2004.

[12] Sherry P and Philbrick K. Report on American airlines professional flight attendants fatigue survey. Paper presented at the meeting of the Association of Professional Flight Attendants, Dallas, TX., 2004.

[13] BWH. Blue Light May Fight Fatigue. Brigham and Women's Hospital. Space Daily. 2006.

[14] BWH. Green Light Exposure Can Reset Body Clock Brigham and Women's Hospital Press Release, 2010.

[15] Lahti T, Jukka I, Terttunen, Leppämäki, S, Lönnqvist J, Partonen, T. Field trial of timed bright light exposure for jet lag among airline cabin crew. 2007. Retrieved from: http://ijch.fi/issues/664/664_Lahti.pdf