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# The Effect of Blue Light on Pilot and Flight Attendant Behavioral Alertness

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## **Summary**

The study aimed to investigate the efficacy of blue light therapy to improve behavioral alertness in flight crew-members. Western Michigan University, College of Aviation, Jeppesen (a Boeing Company), Nature Bright Company, Airline participants, and a leading sleep researcher Schoutens, A.M.C. of FluxPlus, BV, The Netherlands, collaborated to examine whether timed blue light could improve flight crewmember alertness. During the four week study, crewmembers wore actigraph bands to monitor sleep behaviors. Self-assessed levels of sleepiness were recorded using the Karlosinska Sleepiness Scale (KSS), and self-assessed fatigue was measured using the Samn-Perelli (SP) fatigue scale. Participants completed psychomotor vigilance tests (PVT) to measure behavioral alertness. On the third and fourth weeks of the study, participants were exposed to blue light with short wavelength (465nm blue) light therapy. The results show that there was a significant difference in alertness between pre-intervention and post-intervention for each crew member and that 39.1% of the variance is explained by time (pre/post intervention). There is also a significant difference in alertness between flight crew and cabin crew and 49.4% of the variance is explained by position (flight/cabin crew).

Key words: Alertness, Light Therapy, Bright Light, Fatigue, Pilot, Flight Attendant

## **Introduction**

The immediate 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. Fatigue is a threat to aviation safety because of the impairments in alertness and performance it creates. It has significant physiological and performance consequences because it is essential that all flight crewmembers remain alert and contribute to flight safety by their actions, observations, and communications (Strauss, 2006). Dr. Sanjay Patel, a sleep researcher at Brigham and Women's Hospital and Harvard Medical School notes "we should all be concerned that pilots report car crashes due to sleepiness at a rate that is six times greater than that of other workers (Cromie, 2006)." Sleep experts at the National Sleep Foundation (2012) report "the common thread is fatigue, which has caused crewmembers that in cases of emergency were just so numb they couldn't respond instantly to a tragedy at hand." This is evident in several National Transportation Safety Board (NTSB) reports such as the runway overrun during landing by Delta Connection flight 6448, (operated by Shuttle America) where the crew failed to use the thrust reversers and braking system to the maximum effectiveness. According to the NTSB

report (AAR-08-01), “The Captains’ fatigue was said to have affected his ability to effectively plan for the approach and landing, as well as monitor the FO’s approach and landing”(NTSB, 2007).

In another poignant example with a fatigue causation factor proved to be fatal for all onboard, as in the crash of Colgan flight 3407, which crashed in Buffalo, New York, on February 12, 2009. According to the NTSB report (2010), “the pilots’ performance was likely impaired because of fatigue.” The first officer had commuted all night from Seattle on a Fed-EX cargo aircraft and had been awake for 30 hours before the crash. The Captain had also commuted and slept in the crew room before signing-in for the flight. The time spent commuting to work is not included in duty time, which increases the crewmembers ‘time since awake’(Brown and Whitehurst, 2012). Research shows that after 16 hours of ‘time since awake’ performance is similar to someone who is legally drunk (Williamson and Feyer, 2000). Recent fatal accidents have brought out several serious concerns for the Federal Aviation Administration (FAA) and the NTSB, including numerous occurrences of pilots falling asleep while on duty.

These aircraft operated by the autopilot, are at risk for mid- air collisions, running low on fuel, impact into terrain, or being mistaken for hijacked aircraft and possibly intercepted or shot down if no communications are established. Fatigue is not limited to pilots; research has identified key findings concerning fatigue in the pilot and flight attendant occupation, where sleep deprivation and disruption of circadian rhythms were known to occur (Sherry & Philbrick, 2004, and Nesthus & Schroder, 2004). Flight Attendant fatigue continues to be a chronic problem, which can jeopardize safety and security (Brown, 2012).

## **Countermeasures**

These poignant examples point the need for effective preventative and operational fatigue countermeasures. Safety, being the most important objective in aviation, can be improved with effective countermeasures to reduce fatigue related errors (Caldwell et al., 1997).

Countermeasures can be classified in two categories — preventative and operational (Rosenkind et al., 1997).

Preventive strategies: Those used before flying or between flights to reduce the effects of fatigue, sleep loss, and circadian disruption (Caldwell et al., 2009). Proper sleep hygiene, a nap (no longer than 45 minutes) before a flight schedule, hydration, nutrition, exercise, and in some cases —treatment for sleep apnea have been cited as effective preventative strategies for flight crew. These techniques can help to decrease the likelihood of the crewmember starting the trip with a sleep deficit (Rosenkind et al., 1997).

Operational strategies: Used during flights to maintain alertness and performance including controlled timed napping, hydration, bright light, strategic use of caffeine, proper nutrition, short walks when able (flight attendants only) and in seat stretches for pilots. The need of a combination of napping and other countermeasures to improve alertness have been demonstrated

by Garbarino et al., 2004; Gronfier et al., 2007. NASA conducted a pre-planned cockpit rest study for long-haul flights. Results showed that the pilots who had a forty-minute rest period during the flight, increased reaction times by sixteen percent (Graeber R., Rosekind M., Connell, L., and Dinges, D., 1990). The rest group showed a much higher physiological alertness compared to the no-rest group during critical phases of flight (Caldwell et al., 2009).

### **Bright and Blue Light Interventions**

The function of blue light (460nm) to improve alertness and cognitive function “via non-image forming neuropathways has been suggested as a non-pharmacological countermeasure for drowsiness across a range of occupational settings” (Beaven and Ekstrom, 2013). As shown in research conducted by Leger et al., (2008), “bright light could be an effective countermeasure” and warrants further study.

Light Therapy was originally aimed at the treatment of Seasonal Affective Disorder (SAD), winter blues (Subsyndromal Seasonal Affective Disorder S-SAD) and unipolar depression. Intensive ocular light products have recently been applied to people with mood and cognitive problems, shift work fatigue, jet lag and disturbances of the sleep-wake cycle. Light therapy has been used in studies relating to shift [night] workers whom amount to an estimated 270 million workers (Leger et al., 2008). Exact timed bright light is widely recommended to improve the circadian entrainment. It has been demonstrated that single bright light pulses during the shift may be sufficient to entrain the human circadian clock. A review of literature on the acute alerting effect of light shows it to be a potentially useful countermeasure where conditions allow its use. Bright white or blue light treatments may be easy to apply in real aviation occupational settings such as: crew check-in rooms, at home before flight schedule, hotel layovers, air-traffic control break rooms, and possibly aircraft galleys.

Several studies have noted that a combination of countermeasures have a more pronounced effect compared to a single countermeasure (Wright Jr, K., Badia, P., Meyers, B., and Plenzler, 1997). Based on this hypothesis, Léger et al., (2008) designed a preliminary study to test the effects of the 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 (Leger et al., 2008). 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 were reduced by the intervention” (Leger et al., 2008).

In the recent study conducted by Beaven and Ekstrom, (2013), they compared and contrasted the alerting and psychomotor effects of 240 mg of caffeine and a 1-h dose of ~40 lx blue light in a non-athletic population. Twenty-one healthy subjects performed a computer-based psychomotor vigilance test (PVT) before and after each of 4 randomly assigned trial conditions performed on different days: white light/placebo; white light/240 mg caffeine; blue light/placebo; blue

light/240 mg caffeine. The Karolinska Sleepiness Scale (KSS) was used to assess subjective measures of alertness.

Beaven and Ekstrom (2013) reported that both the caffeine only and blue light only conditions enhanced accuracy in a visual reaction test requiring a decision, and an additive effect was observed with respect to the fastest reaction times. However, in a test of executive function, where a distraction was included, caffeine exerted a negative effect on accuracy. Furthermore, the blue light only condition consistently outperformed caffeine when both congruent and incongruent distractions were presented. The visual reactions in the absence of a decision or distraction were also enhanced in the blue light only condition, and this effect was most prominent in the blue-eyed participants.

“Overall, blue light and caffeine demonstrated distinct effects on aspects of psychomotor function and have the potential to positively influence a range of settings where cognitive function and alertness are important” (Beaven and Ekstrom, 2013).

The 1997 study reported by Wright, et al., suggested that the combined treatment of bright light and caffeine provides an effective intervention for enhancing alertness and performance during sleep loss. In the Wright et al., (1997) study, caffeine (200 mg) was administered at 20.00 and 02.00 hours and bright-light exposure (> 2000 lux) was from 20.00 to 08.00 hours each night. The three treatment conditions, compared to the Dim Light-Placebo condition, enhanced night-time performance. Further, the combined treatment of caffeine and all-night bright light (Bright Light-Caffeine) enhanced performance to a larger degree than either the Dim Light-Caffeine or the Bright Light-Placebo condition. Beneficial effects of the treatments on performance were largest during the early morning hours (e.g. after 02.00 hours) when performance in the Dim Light-Placebo group was at its worst. Notably, the Bright Light-Caffeine condition was able to overcome the circadian drop in performance for most tasks measured. Both caffeine conditions improved objective alertness on the Maintenance of Wakefulness Test (Wright et al., 1997).

Interestingly, despite the widespread use of light therapy in competitive sporting environments, the possible impact of blue or bright light therapy (ocular therapy) in aviation has received little attention compared to caffeine. Decreasing fatigue and its associated errors would improve safety and enable operational improvements to meet the business requirements of today’s airlines in lean economic times (Brown, 2010).

Alerting effects of light are tied to its suppression of melatonin, which is ordinarily released in the evening and night. Researchers Cajochen et al. (1999) showed measurable increases in subjective alertness and reductions in slow eye movements, with short wavelength (blue) light appearing to have the greatest alerting effect. There is also evidence that the alerting effects of light are independent of the time of day, leading to the possibility of employing light during the daytime to improve alertness and performance in individuals impaired due to prior sleep deprivation (Cajochen, 2007). Capitalizing on the immediate, direct alerting effects of light for

fatigued flightcrew is particularly useful because the flight-deck environment with its high automation level,” limited opportunities for physical activity or social interaction, steady background noise, and low nighttime light levels creates a setting ripe for boredom, complacency, attention lapses, sleepiness, and performance decrement” (Caldwell, 1997).

Additionally, 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 (Campbell et al., 1990). 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 Cajochen et al., 2009). Exact timed light therapy has proven effective in decreasing the symptoms and length of jet lag for traveling passengers (Czeisler, 1989). Light has been found to effectively align the body clock (circadian phase) of crew-members working the night shift with their work schedules on vessels in maritime settings (BWH, 2010).

Research also suggests that natural light has the same beneficial effects providing the crewmembers have the ability to receive natural light treatment in the operational setting—making makes the use of small, lightweight, portable artificial light units appealing. Adjusting the light level and color temperature is one of a limited number of possible environmental manipulations (Cajochen C. 2007).

## **Blue Light**

Researchers from Brigham and Women’s Hospital (BWH) teamed with George Brainard, Ph.D, professor of neurology at Thomas Jefferson University in Pennsylvania and Harvard Medical School and reported that exposure to short wavelength (460nm) blue light during the biological night directly and immediately improves alertness and performance (BWH, 2006). In the BWH study (2006), subjects exposed to blue light were able to sustain a high level of alertness during the night, and these results suggest that light may be a powerful countermeasure for the negative effects of fatigue for people who work at night (Cromie, 2006). In order to determine which wavelengths of light were most effective in warding off fatigue, the BWH researchers compared the effects of blue light (460 nanometers, nm) with exposure to an equal amount of green light (555 nm) on alertness and performance. The subjects exposed to blue light consistently rated less sleepy, had quicker reaction times, and had fewer lapses of attention during the performance tests. Also, changes in their brain activity patterns indicated a more alert state.

## **The Effect of Blue Light on Pilot and Flight Attendant Behavioral Alertness Study**

This study was funded by the Western Michigan University (Kalamazoo, Michigan, USA) FRAACA award was the first to look at the effects of blue light (460nm) in the occupational setting with flight crew members. The study aimed to investigate the efficacy of blue light therapy to improve alertness in flight crew-members. Western Michigan University, College of Aviation, Jeppesen (a Boeing Company), Nature Bright Company, Airline participants, and a leading sleep researcher Schoutens, A.M.C. of FluxPlus, BV, The Netherlands, collaborated to

examine whether timed blue light could improve flight crewmember alertness and mitigate cognitive fatigue— as seen with gold medal Olympic athletes to improve performance.

## **Methods**

### Subjects

Fourteen flight crew members, males (n=9) and females (n=5), working as pilots or flight attendants, participated in the study under the Western Michigan University HSIRB approved protocol. All participants were nonsmoking, active flight crewmembers. The crewmembers were based in Sweden and maintained flight schedules to the Mediterranean and the Canary Islands, as well as long-haul flights to Thailand, India and Vietnam. Each participant signed an informed consent document and attended a two hour training session on the use of the light and actigraphy band. Each participant was assigned a confidential code and completed the Morningness-Eveningness Questionnaire (MEQ), a self-assessment questionnaire (Horne & Ostberg, 1976), to measure their peak sleepiness and alertness time (diurnal type). The MEQ was used once at the beginning of the testing period to assess the habitual and preferred weekday and weekend clock times of the participants. The MEQ is a 19 item, self-report instrument that consists of questions in which the participant indicated their preference using a 4-point Likert Scale.

During the 30 day study, the crewmembers wore actigraph wrist bands to record sleep/wake behaviors, and recorded self-assessed levels of sleepiness with the Karolinska Sleepiness Scale (KSS) daily. Daily self-assessed fatigue was recorded using the Samn-Perelli Fatigue Scale (SP), and they completed daily psychomotor vigilance tests (PVT). On the third and fourth weeks, the flight crew-members were exposed to blue light (BL) in occupational-based treatment with short wavelength (460nm) light therapy. The occupational setting was inflight during normal long haul flight schedules. Actigraphy wrist bands and the Karolinska Sleepiness Scale (KSS) were used for detection of circadian rhythmicity in neurobehavioral variables. Successful results have been reported in studies with a wide array of subjective measures of alertness and fatigue. The KSS is used to obtain subjective alertness and mood assessed with 9-digit rating scales, and the visual psychomotor vigilance test (PVT) to measure vigilance (response time in milliseconds and lapses).

The first two weeks were recorded as a baseline pre-light intervention, followed by two weeks of daily, 30 minute light intervention followed by the KSS, SP, and PVT recordings, in addition to the control group without light intervention for 30 days.

### **Equipment**

Nature Bright Company provided 20 Square One® rechargeable, portable, lightweight, wake-up lights which weighed less than 2 lbs. The Square One light provides blue ( $\lambda_{\text{max}} = 465 \text{ nm}$ ) light intervention and is currently one the smallest light therapy devices on the market, with an



advanced optical lens and a wakeup light alarm. The Square One (Figure 1.) was selected due to the small portable size, ideal for crewmembers, as it was easy to place in a flight bag, handbag or luggage.

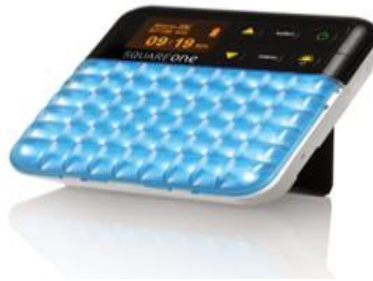


Figure 1. Nature Bright Square One® rechargeable portable light

CamNTEch MotionWatch 8 actigraphy wrist band (Figure 2.), with a tri-axial digital accelerometer was worn for 30 days by all participants. Actigraphy has been used in studies to measure sleep/wake patterns for decades (AASM, 2010). The advantage of actigraphy over traditional polysomnography (PSG) is that actigraphy is non-invasive (a water proof watch band) and can conveniently record continuously for 24-hours per day for days, weeks or even longer.



Figure 2. CamNTEch Motionwatch 8 (Actigraph wrist band)

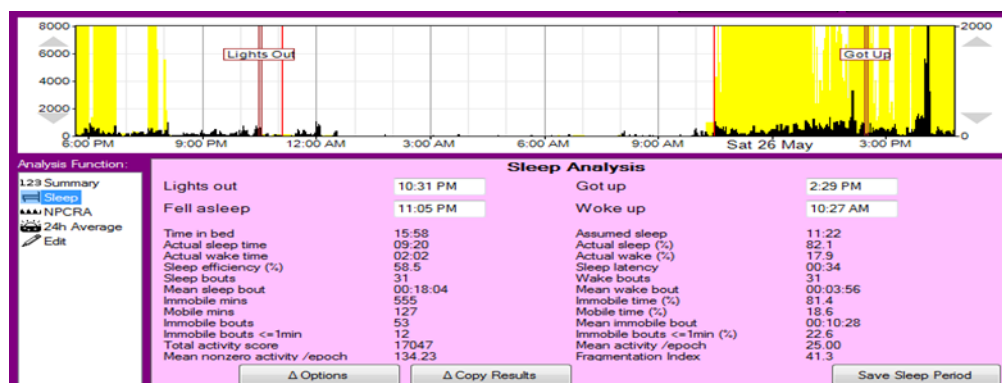


Figure 3. Sleep Analysis Plot –downloaded activity plots (Figure 3.) coupled with specialized software used to quantify the intensity and duration of daily physical activity. This data was analyzed to identify irregular activity patterns for assessment of sleep quality. Individual, daily



sleep efficiency and sleep bouts were used to look for correlations with the KSS, SP, and PVT results. The band also measured the amount of lux each participant was exposed to during the actigraphy period.

### Jeppesen Crew Alert (lite) iOS Application

Data collection was through the (iOS) Boeing Alertness Model (BAM) application called Jeppesen CrewAlert Lite, which can be used anywhere in the world with an Apple iPhone, iPod, or iPad device. The Jeppesen/Boeing CrewAlert (lite) tool was provided to the study with access and data extraction from Jeppesen. The crew alert APP is an easily accessible interface to KSS, PVT and SP scores, integrated with the Boeing BAM model. BAM is a bio-mathematical model of alertness, which has been developed from recent science (Åkerstedt et al., 2004). BAM considers work and sleep schedule, and predicts alertness based on physiology and performance data (Jeppesen, 2013a).

Jeppesen CrewAlert fatigue risk management tool is used for quantifying current fatigue levels connected to certain flights or scheduling patterns initiated by elevated fatigue reports. The data is also being used for investigating the correlation between light effect, the used fatigue model and alertness. Following the data upload de-identified, alertness assessments, is generated along with a visualization of the collected data with alertness predictions side-by-side, in a .csv file for easy correlation and other analysis (Jeppesen, 2013b). The report with crew's scheduled activities was not utilized in this study, as the scope was looking at the effect of light on their KSS, SP, PVT, and sleep data.



Figure 4. Jeppesen Crew Alert Application

## Results

A repeated measures multivariate analysis of variance (MANOVA) was conducted, using IBM SPSS Statistics 20 software, to test the intervention effect of blue light (IV) on both flight and cabin crew alertness, measured by the 4 DVs; KSS, SP, PVTR, and PVTL.

A one-way MANOVA revealed a significant multivariate within-subject main effect for time (pre and post light intervention), Wilks'  $\lambda = .609$ ,  $F(4,55) = 8.843$ ,  $p < .001$ , partial eta squared = .391, and the power to detect the effect was .999. The analysis also revealed a significant multivariate between-subject main effect for position (pilot/flight attendant), Wilks'  $\lambda = .506$ ,  $F(4,55) = 13.429$ ,  $p < .001$ , partial eta squared = .494, and the power to detect the effect was 1.000.

The results show that there was a significant difference in alertness between pre-intervention and post-intervention for each crew member, and that 39.1% of the variance is explained by time (pre/post intervention). There is also a significant difference in alertness between flight crew and cabin crew, and 49.4% of the variance is explained by position (flight/cabin crew).

Figure 5 shows that for the measure Karolinska Sleepiness nine point Scale (KSS), there is a similar intervention effect for both pilots and cabin crew, but there is a difference in the estimated marginal means related to crew position (1 = pilot and 2 = cabin crew). It is clear that both pilots and flight attendants had a decreased self-assessed sleepiness; however, the reason for the difference in the estimated margin of means based on crew position was not evident.

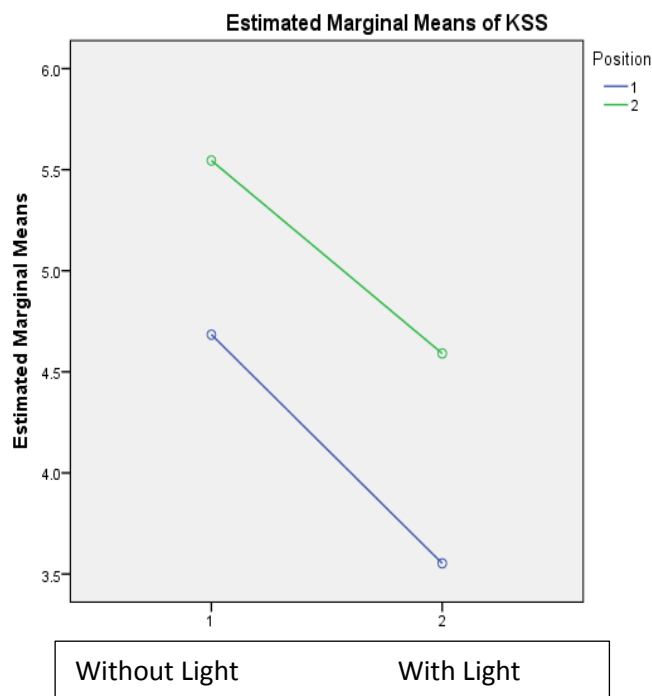


Figure 5 KSS Sleepiness Pre/Post Intervention Marginal Means by Position

The Karolinska Sleepiness Scale (KSS) is a 9-point Likert scale based on a self-reported, subjective assessment of the subject's level of drowsiness at the time (Gillberg et al., 1994) where 1 = extremely alert and 9 = extremely sleepy/fighting sleep. The independent measure derived from the KSS Checklist was self-rated sleepiness. Higher scores indicated a higher level of subjective sleepiness. KSS has been used widely, particularly for describing changes over time within subjects

Figure 6 shows that for the measure Samn-Perelli seven-point fatigue scale (SP), there is a larger intervention effect for cabin crew, but there is still a difference in the estimated marginal means related to crew position pre and post intervention (1 = pilot and 2 = cabin crew).

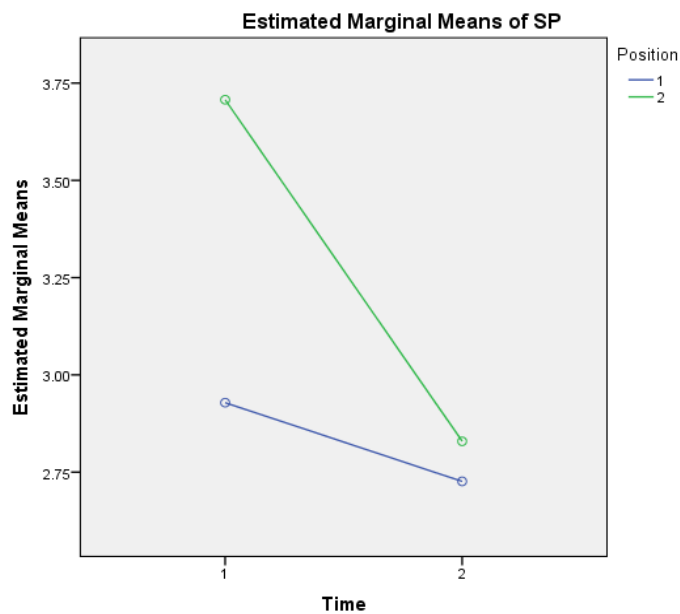


Figure 6. SP Fatigue Scale Pre/Post Intervention Marginal Means by Position

Subjective fatigue was assessed using the Samn-Perelli Fatigue Checklist (Samn & Perelli, 1982). The Samn-Perelli is a 7-point Likert scale, where 1 = fully alert/wide awake and 9 = completely exhausted, unable to function effectively. Higher scores indicated a higher level of subjective fatigue (Samn and Perelli, et al., 1982).

Vigilance was assessed with the Psychomotor Vigilance Test (PVT), a 5-minute iOS visual reaction-time task which evaluates sustained attention (Dinges, et al., 1982). Participants were instructed to respond to the appearance of a visual stimulus by tapping a black bulls-eye target on the iOS screen as quickly as possible. During each 5-min session, visual stimuli appeared at variable intervals of 2–10 s. From each PVT trial, reaction times (RTs) were collected and 2 performance variables, average response time and number of lapses (i.e. failure to respond or RT > 500 msec) were extracted by Jeppesen Crew Alert.

Table 1. shows the intervention means measure psychomotor vigilance test reaction time in milliseconds (PVTR). There is a significant positive intervention effect (reduced reaction time) for the cabin crew, but not significant for pilots. However, there is a difference in the estimated marginal means related to crew position (1 = pilot and 2 = cabin crew). Research suggests individual performance may differ between subjects (Belenky et al, 2003), and can vary with gender and age. Optimal performance on the PVT appears to rely on activation within the sustained attention and within the motor system. According to Wright et al., (1997), PVT can also rely on work schedules, and sleepiness countermeasures such as naps, bright light, and caffeine. Depending on the degree of sleep deprivation, “the fastest RTs on the PVT do not change or change only modestly relative to the well-rested state, and the slowest RTs can lengthen dramatically after sleep deprivation (Blatter et al., 2006).

Table 1. PVTR Pre/Post Intervention Means by Pre and Post Intervention

PVTR_Without Light Mean RT	1 Pilot	369.87
	2 Cabin	438.36
	Total Mean without Light	<b>394.98</b>
PVTR_With Lightt Mean RT	1	348.92
	2	420.36
	Total RT with Light	<b>375.12</b>

Figure 7 shows that for the measure PVTL there is a similar intervention effect for both flight crew and cabin crew, however there is a difference in the estimated marginal means related to crew position (1 = pilot and 2 = cabin crew). Lapses are defined as a failure to react or any reaction exceeding 500 ms, and are often used as the primary outcome measures of PVT performance (Kim, Dinges and Yong, 2007). Research indicates the number of lapses during the psychomotor vigilance task is an objective measure of fatigue (Lee et al., 2010).

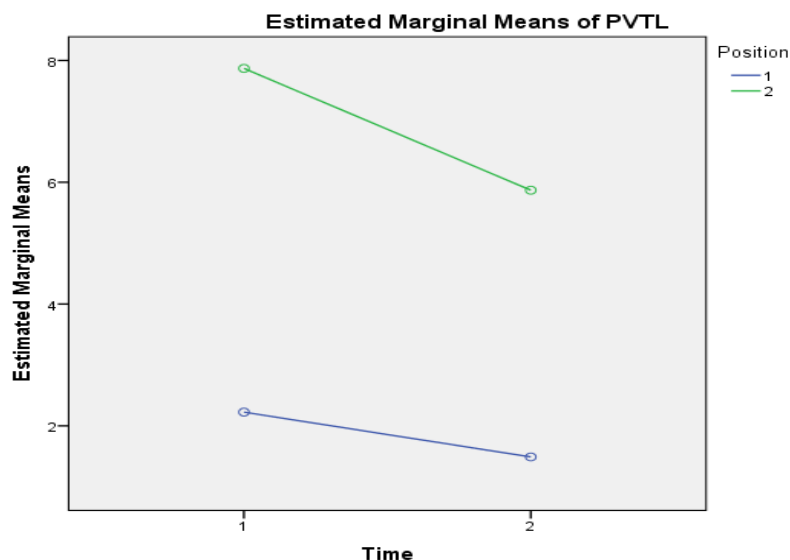


Figure 7. PVTL Pre/Post Intervention Marginal Means by Position

## Further Discussion

Recently, we have seen a flux of light therapy innovations aimed at passengers to improve mood, decrease effects of jet lag and minimize fatigue. Next generation aircraft such as, the B787 and A380, have mood lighting installed to help passengers adjust to new time zones. Paris Charles de Gaulle airport installed three light therapy ‘spaces’ where passengers can enjoy light therapy to fight their jet lag. The benefits of light therapy has extended well beyond aviation, and is used with depression, dermatology, psychiatry, neurology and gerontology and work related issues such as, shiftwork and sports (Dutch Olympic Swimming Team, TVM Ice -skating team, Dutch Olympic Committee). We have also seen light cafes opening in Seattle and Sweden. An energy company in Umeå, northern Sweden, has installed phototherapy lights in the city’s bus stops to combat the short days, lack of sunlight, and residents’ depression.

In addition to individual crewmember portable light units, crewmembers can benefit from innovative ‘light stations’ in crew check-in areas. Such light stations have been placed in the operations area at airlines operating in arctic regions and the student lounge area at Western Michigan University, College of Aviation. Students can bask under light therapy while studying or relaxing in between classes. The desktop 10,000 lux, 17,000 Kelvin UV-Free lights mimics a blue sky. In addition to improved alertness, relief from seasonal effective disorder is also a benefit- particularly in the dark winter months in areas such as Seattle, Norway, Sweden, Canada and Michigan.

Air traffic control is another occupation that could possible benefit from properly timed light. A combination of fast-paced situations, rapidly rotating shiftwork schedules, and constant multitasking certainly makes the controller vulnerable to fatigue on a near-daily basis (Calvaresi-Barr 2009). This issue has recently alerted the public due to various instances of controllers falling asleep while on duty. Certain countermeasures have been taken by both the individual controller and the Federal Aviation Administration (FAA), but both parties are still in the process of determining the best ways to overcoming fatigue on the job. It is likely that the most prominent of these countermeasures is caffeine consumption.

Though many countermeasures have been identified and attempted, there is one countermeasure that tends to be overlooked— light therapy. A study conducted by Kons and Fowler, (2007), within the United States military consisting of thirteen military air traffic and weapon controllers that worked an intense, rotating shift schedule, the study measured “salivary melatonin samples and a computerized cognitive task developed by the military (SynWin), to measure physiological and cognitive fatigue” (Kons and Fowler, 2007). After the light therapy was complete, the results showed that SynWin scores did increase, denoting a suppression of melatonin levels. However, this countermeasure is not widely known among air traffic controllers. Felix Esquibel, a retired controller supervisor, notes “that this therapy does not necessarily have a place in the

facilities just yet.” He also notes that “many controllers would rather stick to basic countermeasures rather than use light therapy”. Regardless, this modern method has proven to be effective, and it could be effective for air traffic controllers as well as pilots and flight attendants. This is an area which requires more study to look at the efficacy of small light units in break rooms.

## **Conclusion**

The results reveal that crewmembers may be able to improve behavioral alertness with the use of bright light interventions as a fatigue countermeasure to improve occupational safety in transportation. A review of literature and results of this study show the acute alerting effect of blue light to be a potentially useful countermeasure to reduce physiological, perceived, and cognitive fatigue, where conditions allow its use. Results garnered can be used to develop innovative light therapies and preventive strategies for industries with shift workers such as aviation, maritime, rail, nuclear and medical.

## **Limitations and Recommendations**

Lack of data from the control group prevented a between group analysis, thus only the data from the treatment group was to analyze within subject effects and between position effects. Further study is recommended to look at the effects of light including short haul operations and pilots operating in areas such as Antarctica with long periods of no daylight, and the air traffic control community.

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