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ACTIVITY AND LIGHT EXPOSURE PATTERNS IN FLIGHT CREW

A Thesis

Presented to

The Faculty of the Program of Human Factors and Ergonomics

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Raymond Lawrence Oyung

December 2003

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ABSTRACT

ACTIVITY AND LIGHT EXPOSURE PATTERNS IN FLIGHT CREW

by Raymond Lawrence Oyung

Commercial air carrier pilots are commonly faced with operational challenges that occur with flights that oscillate between day and night and span multiple time zones. An examination of 40 pilots flying domestic and international flight operations revealed significant differences that domestic pilots obtain for amount of time in bed overall, at home, during layover, and the second 24 hour period after returning home from trips, than international pilots. Significant differences were also found between light levels obtained by pilots on the ground and during flight operations. The number of time zone crossings was the main predictor of time in bed obtained during layover. These results may provide a step in understanding the extent that sleep loss and circadian disruption occur in flight operations (guiding policy makers on rulemaking), and components that may be integrated into modeling efforts employed to mitigate pilot fatigue and increase flight scheduling efficiency while maximizing safety.

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ACTIVITY AND LIGHT EXPOSURE PATTERNS IN FLIGHT CREW

The National Transportation Safety Board (NTSB) defines accidents as occurrences associated with the operation of an aircraft in which a result of the operation of an aircraft, any person (either inside or outside the aircraft) receives fatal or serious injury or any aircraft receives substantial damage. Substantial damage constitutes damage or structural failure that: (a) negatively affects an aircraft's structural strength, performance, or flying characteristics; or (b) would require significant repair or replacement of the affected component or system not including damage to landing gear, wheels, tires, flaps, aerodynamic fairings, dents or small punctures in the aircraft skin, propeller damage due to contact with the ground, or damage only to a single engine (National Transportation Safety Board, 2003). An estimated 65 to 70% of accidents that occur in the aviation industry are classified as human error accidents (Lauber & Kayton, 1988; McFadden, 2001). During a 14-year period between 1983 and 1996, there were nearly 30,000 human error related aviation accidents (Li, Baker, Grabowski & Rebok, 2001). Of those accidents, 329 were major air carrier crashes consisting of domestic and flag operations in which 53% involved fatalities and 40% occurred at night. A major commercial air carrier is an organization with annual revenues over US\$1 billion (McFadden, 2001). Domestic operations consist of any scheduled operation in turbojet-powered airplanes, with nine or more passenger seats, or weighing more than 7,500 lb, and fly within and between the 48 contiguous states, territories, or possessions of the United States. Flag operations consist of any scheduled operation in turbojet-powered airplanes, with nine or more passenger seats, or weighing more than 7,500 lb, and fly:

(a) within the United States; (b) between the United States and another country; or (c) between countries outside of the United States (Federal Aviation Administration, 2003b).

To err on the optimistic side, one would have a 2.5 better chance of winning a state lottery, in which the odds of winning are 1 in 5.2 million, than being involved in an aviation accident (Barnett, 2000). Aviation accidents are rare events (McFadden, 1996). Although rare, 1988 estimates on the cost of a single major civil aviation accident was in the range of US\$500 million in total financial losses (Lauber & Kayton, 1988). For reference, the average list price of various Boeing aircraft as of 2002 is listed in Table 1. More recent insurance estimates for each air carrier accident fatality estimate payments that range up to US\$3 million, as this is the current assessed value of human life (Office of the Secretary of Transportation, 2002). For this reason, large international air carriers usually carry insurance policies that will cover up to US\$2 billion per aircraft loss (Bannister, n.d.). As an example, a Boeing 747-300 aircraft registered to Korean Air Company, Ltd. crashed into mountains 3 miles from the destination airport killing 228 of 254 passengers and crewmembers aboard. The aircraft was destroyed by impact into the terrain and the post-crash fire. Cost of the hull loss (i.e. aircraft damaged beyond repair, destroyed, or missing) was approximately US\$155 million (Roberts, 1999). Korean Air carried a liability limit of at least US\$1 billion (Shapiro, 1997). A contributing factor (i.e. elements of an accident that further explain or supplement probable cause) to the accident reported by the NTSB was the captain's fatigue (National Transportation Safety Board, 2000). Fatigue is defined in the present study as sleep loss and circadian rhythms

disruption in which a circadian disruption is an intrinsic or extrinsic disturbance in the circadian rhythm.

The definition of human error in flight operations allows for a broad interpretation of accident causation. The Federal Aviation Administration (FAA) supports the Aviation Safety Reporting System (ASRS) operated by the National Aeronautics and Space Administration (NASA) to collect voluntary, anonymous reports concerning deficiencies that may occur in the aviation system. The purpose of the ASRS is to evaluate the aviation system, and correct potential hazards that could affect the safety of flight operations (incidents) before they become accidents (FAA, 2002).

What is the prevalence of fatigue in flight operations and what are the factors associated with it? Probable cause as defined by the NTSB is the cause-and-effect relationship in an accident sequence about which something can be done to prevent the recurrence of a similar accident, and it was concluded in an NTSB accident report, that for the first time, fatigue was the probable cause in an aviation accident (NTSB, 1994).

Of all reports stored in the ASRS database, 21% have been related to general fatigue (e.g., "I had been scheduled for more than 7 hrs of flt time and almost 10 hrs on duty.") However, when fatigue was explicitly mentioned in report narratives (e.g., "We were tired due to a long day with delays..."), this figure drops to 3.8% (Federal Register, 1995; Battelle Memorial Institute, 1998). Since the late 1980's there have been several fatigue-related aviation accidents encompassing 289 fatalities, 75 serious injuries, 111 minor injuries, and 47 uninjured persons within 12 accident events. The NTSB defines serious injuries as the result of one or more of the following conditions: (a) requires

hospitalization for more than 48 hr, commencing within 7 days from the date the injury was received; (b) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (c) involves lacerations that cause severe hemorrhages, nerve, muscle, or tendon damage; (d) involves injury to any internal organ; or (e) involves second or third degree burns, or any burns affecting more than 5% of the body surface. Minor injuries are those that are not fatal or serious (NTSB, 2003). These aviation accidents include the controlled flight into terrain of Korean Air Flight 801; the in-flight upset of China Airlines Flight 006 in which 2 people were severely injured (NTSB, 1999); and an accident involving American Airlines Flight 1420 in which 11 people perished (NTSB, 2002). In 1999, the NTSB issued a safety report outlining 70 fatigue-related recommendations based on accident investigations and studies encompassing all modes of transportation. In each of the aviation cases, crew fatigue from long duty periods and/or circadian factors had been implicated. Duty periods vary by different airline standard operating procedures, but are commonly specified as 1.5 to 2 hr before until 0.5 to 1 hr after an international flight, and 1 hr before until 0.25 to 0.5 hr after a domestic flight.

Also, there is evidence that a number of high-profile catastrophes (e.g., the grounding of the Exxon Valdez, the explosion of the space shuttle Challenger, and the partial meltdown at Three Mile Island) were at least partially attributable to human fatigue associated with night operations (Mitler, Carskadon, Czeisler, Dement, Dinges & Graeber, 1988; NTSB, 1990).

If long duty days and circadian components were identified by the NTSB as fatigue factors, then an examination of the aviation duty regulations, their interaction with sleep loss and circadian rhythms, and current research examining fatigue in aviation seems appropriate.

Regulations and Policy

Currently, commercial air carrier pilots who fly under the Federal Aviation Regulations (FAR) Part 121.543 are required to stay at their assigned duty station with seat belts fastened at all times with the exceptions that the absence is: (a) necessary to perform other duties related to the operation of the aircraft; (b) related to physiological needs; or (c) required to take a rest break as long as relief is provided by another qualified crewmember (FAA, 2003d). In addition, crewmembers operate under specific flight and duty time limits. Flight time defined here begins when an airplane moves under its own power for the purpose of flight and ends when it comes to rest at the end of that flight (FAA, 2003a). FAR Part 121.471 states that no pilot flying domestic operations may fly more than 100 hr per calendar month, 30 hr per seven consecutive days and 8 hr between required rest periods with the following rest requirements: (a) 9 consecutive hr of rest if scheduled flight time is less than 8 hr; (b) 10 consecutive hr of rest if scheduled flight time is 8 hr or more, but less than 9 hr; or (c) 11 consecutive hr of rest if scheduled flight time is more than 9 hr (FAA, 2003c). Pilots may not be on duty more than 16 hr per 24-hr period, fly a maximum of 8 hr in a single duty period, and after every flight arrival must be able to look back and find a minimum 8 hr actual rest period during the previous 24 hr period (Air Link Safety, 2002). A scientific working group consisting of scientists

and subject matter experts conducted extensive research in the aviation environment and has published a set of guidelines for duty and rest scheduling in order to address issues concerning 24 hr global aviation operations (Dinges, Graeber, Rosekind, Samel & Wegmann, 1996). Flight and duty time limitation periods are absent in the document for monthly or annual guidelines as scientific data do not exist on the cumulative effects of fatigue in aviation operations. Flight and duty time regulations differ by country and are based on many factors, which are implemented by some countries, and absent in other countries' policies. These factors include: (a) flight time, (b) duty time, (c) preceding rest, (d) time of day, (e) night flight, (f) night sleep, (g) time zones, (h) number of flight segments (one departure to destination equals one flight segment), (i) number of pilots, (j) augmentation (additional pilots to relieve pilots on duty during flight operations), (k) flight range, and (l) aircraft type. How these factors are combined or absent from regulations of different countries is complex, but underlying reasons may be more operationally-based than scientifically-based (Wegmann, Conrad & Klein, 1983). One aim of the current study is to explore this issue and determine the extent of fatigue that may occur over time in domestic and flag operations. Another aim is to examine factors such as duty time and flight time in predicting the amount of time in bed (TIB) that can be obtained by pilots during layover. Time in bed for the present study begins when lights are turned off and eyes are closed to initiate sleep until final wakeup accompanied by a departure from the sleep facility.

The current study proposes to collect the activity and light exposure of commercial air carrier pilots during a month of flight activity. Trip patterns consist of the

first flight that originates at the domicile airport until the last flight that ends at the domicile airport and may span one to several days. A domicile is the airport at which a pilot reports to work for each assigned flight. Also, trip patterns may or may not be combined with sleep periods that occur in locations other than the pilot's home (layover sleep). A comparison of: (a) the amount of time in bed at home, during layover, and surrounding the first 72 hr upon returning home from trip patterns, (b) flight and duty schedules of domestic and flag operation pilots specific to the prediction of layover time in bed; and (c) the amount of light exposure during the day, at night, on the ground, and during flight operations will be analyzed through the use of an activity monitor, light sensor, an activity log, and questionnaires.

It is hypothesized that total time in bed away from home will be less than time in bed at home. The amount of obtainable time in bed may be based to some extent on social factors, but a driving factor is most likely based on a pilot's flight schedules, and these schedules are related to seniority number. In general, commercial air carrier pilots are given a seniority number based on their date of hire. This number decreases (seniority number 1 being most senior) as other pilots in the company retire or are terminated from the company. Pilots will thus obtain a lower seniority number over time. Pilots choose their flight schedules for a given month based on their seniority number. The most senior pilots pick their schedules first. Therefore, pilots with the least seniority must choose their flight schedules based on the remaining available routes. A typical scenario occurs when senior pilots choose condensed flight schedules with 7 to 10 day trip patterns away from home in order to maximize the number of days off duty at home.

The home may vary in distance from the domicile where the pilot is stationed for work. Junior peers may have more demanding schedules that scatter flights throughout the scheduling period that encompasses highly variable flight schedules, and time of day of each flight. In addition, more senior pilots who generally fly the longer international routes will have opportunities for rest during those flights in on-board crew rest facilities. Less senior pilots, who generally fly domestic shorter routes will not have these opportunities, available rest facilities, or regulations that allow for rest opportunities. Unless a crewmember is taking a rest period, and a qualified pilot provides appropriate relief, commercial air carrier pilots that operate under FAR Part 121 regulations are not specifically sanctioned to nap when on duty (FAA, 2003d). It has already been shown that pilots attempt to maintain a daytime schedule no matter what time zone they are currently located. They also have extended periods of partitioned sleep (brief sleep periods that may occur several times throughout a given 24 hr period) with short periods of sleep obtained after a flight in order to maintain the local daytime schedule during flights consisting of single trip patterns (Lowden & Akerstedt, 1998, 1999; Samel, Wegmann, Vejvoda, Drescher, Gundel, Manzey et al., 1997). This study will explore the dynamics of pilot behavior, sleep loss, and circadian rhythm patterns over 40 days (5 days prior until 5 days after 1 month of flight activity) to uncover cumulative effects of fatigue that may occur due to flight operations. Time in bed at home will be assessed after each trip pattern to determine the time required for recovery as measured by actigraphy and activity logs. At present, no study has examined the effect of flight schedules on pilot fatigue over a 40-day period.

Sleep Loss

Some background on the factors associated with fatigue should be addressed.

One of the earliest studies on sleep deprivation was published in 1896 in which 3 participants were sleep deprived for 90 hr and were found to have both motor and cognitive deficits (Patrick & Gilbert, 1896). Over 20 years later, Nathaniel Kleitman, conducted 60 and 114 hr sleep deprivation studies. He and his colleagues found that motor and cognitive performance was characterized by slow response times and increased errors intermixed with normal baseline responses. Eugene Aserinsky was a graduate student of Dr. Kleitman conducting research on the slow eye movements of children during the transition from wake to sleep as measured by EEG (i.e. sleep onset; Chokroverty, 1995). Aserinsky used electrooculography (EOG) to measure the electrical activity during sleep onset. Later these studies moved to the data collection of slow eye movements in adults. Electrodes were attached to the outer canthus of each eye, and connected to a polygraph machine that would record this activity. The polygraph machine would be turned on and off periodically during participant recordings to collect the slow eye movement activity. Occasionally, the slow eye movements changed to fast eye movements. Although it was first thought to be a malfunction of the equipment, a light placed on the sleeping participant to try to understand the source of EOG artifact showed that the eyelids were closed, but the eyes were moving rapidly. The current theory at the time was that the brain was inactive during sleep, as if the brain turned off during this period prior to wakefulness. This accidental discovery in 1952 is the basis of what would later be labeled REM sleep (Aserinsky, 2003; Dement, 1999).

Another medical student joined Kleitman's lab at the University of Chicago during this time, and in 1953, William Dement conducted all-night electroencephalography (EEG) recordings to collect information on events that occur during sleep. The observed waveforms displayed distinct periods of slow and fast activity, and this activity pattern was similar in all participants. So it was discovered that the brain does not simply shut off at night, but is quite active during this period (Dement, 2000).

Thus a human sleep structure was discovered, and criteria were developed to delineate the various aspects of sleep. Sleep is defined by the *stages* of non-REM sleep and REM sleep based on EEG, EOG, and electromyography (EMG) characteristics. The non-REM stages of sleep are categorized as light or deep sleep. Light sleep is defined as Stage 1 and Stage 2 sleep. Stage 1 sleep is characterized by low voltage, mixed frequency EEG consisting of 2 to 7 cycle per second waveforms without REM activity that often occurs during the transition between wakefulness and sleep, or following body movements during sleep. Stage 2 sleep is characterized by EEG consisting of: (a) 12 to 14 cycles per second; (b) sleep spindles greater than 0.5 sec with 6 to 7 waves within the 0.5 sec period; and (c) clearly defined negative sharp waveforms usually greater than 0.5 sec (K complex waves) on a low voltage, mixed frequency background. Deep sleep consists of Stage 3 and Stage 4 sleep. Stage 3 sleep is characterized by high amplitude, slow wave activity that is less than or equal to 2 cycles per second with an amplitude greater than 75 μ V from peak to peak of the waveform between 6 to 15 sec in duration. Stage 4 sleep is characterized by similar criteria for Stage 3 sleep with the exception that

the waveform duration must be greater than 15 sec. Finally, REM sleep is characterized by low voltage, mixed frequency brain activity combined with occasional periods of rapid eye movements and low amplitude muscle activity (Rechtschaffen & Kales, 1968).

These are the origins of sleep research and have since initiated a multitude of questions that drive an extensive amount of sleep and circadian rhythm research. This introduction will briefly describe: (a) sleep deprivation and age related factors; (b) aspects of the circadian rhythm including morningness-eveningness preference, light, and melatonin; and (c) the factors of sleep loss and circadian rhythms in flight operations.

Many studies have examined the effects of total sleep deprivation, but what happens to subsequent alertness after partial sleep deprivation? Carskadon and Dement (1981) examined the effects of partial sleep deprivation of 5 hr sleep, which was half the amount of sleep the study participants needed to feel well rested as determined by baseline data collection. The 7-day protocol to examine daytime sleepiness found that: (a) cumulative sleep loss is directly related to cumulative increased sleepiness during waking hours, (b) participants' subjective levels of sleepiness leveled off after the fourth day of sleep deprivation, and (c) recovery to baseline levels of alertness occurred after one night of unrestricted sleep. During sleep restricted to 5 hr per night for 1 week, Dinges, Pack, Williams, Gillen, Powell, Ott et al. (1997) examined the effects of cumulative sleep loss on daytime neurobehavioral functioning, as measured by a sustained simple reaction time (RT) task (Dinges & Powell, 1985), working memory task and cognitive throughput task, and found that: (a) cumulative sleep loss is directly related to cumulative increased sleepiness during waking hours (as was found by Carskadon &

Dement); (b) participants' performance based on a sustained simple RT task leveled off between sleep deprivation days 2 and 6 suggesting a possible step-wise function (i.e., adaptation) to sleep deprivation; and (c) 2 days were required to recover alertness to baseline levels. Also, this simple RT measure showed clear effects of sleep loss whereas others (probed recall memory to evaluate working memory and a 1 min serial addition task to measure cognitive throughput) failed to indicate any effects of sleep deprivation. This finding addresses the need to carefully determine the performance measures used in experiments that will be sensitive to the question under examination.

The effects of sleep loss on simple neurobehavioral performance have been described in an 88 hr sleep deprivation and 88 hr partial sleep deprivation protocol in which performance, as measured on a sustained simple RT task, was assessed every 2 hr over the course of each 88 hr period (Doran, Van Dongen & Dinges, 2001). Doran et al. found increasing between-participant variability as sleep loss increased suggesting that some individuals are more vulnerable to neurobehavioral impairment than others. It was also discovered that this performance variability started after 18 hr of wakefulness in which short, fast reaction times were commingled with errors of omission (the failure to do something) and errors of commission (performing an act incorrectly). An example of an error of omission is not initiating a response during a simple reaction time task when a stimulus is presented (lapse), and an error of commission is initiating a response during a simple reaction time task in the absence of a stimulus presentation (false start).

In addition to the performance decrements associated with full and partial sleep deprivation, performance deficits were found to occur whether sleep was restricted to the

first half of the night or the second half of the night and these deficits seem to be a function of sleep loss and not composition (quantity of NREM and REM periods) of sleep (Tilley & Wilkinson, 1984).

Recent partial sleep deprivation studies by Van Dongen, Maislin, Mullington, and Dinges (2003) to examine partial sleep deprivation in a dose-response method of 4, 6, or 8 hr of sleep opportunity over 14 consecutive days concluded that sleep restricted to 6 hr or less resulted in similar performance deficits that occur after 48 hr of total sleep deprivation. Belenky, Wesensten, Thorne, Thomas, Sing, Redmond et al. (2003) during a similar partial sleep deprivation study of 3, 5, 7, or 9 hr of sleep opportunity over 7 days concluded that the brain adapts to sleep restriction of 5 or 7 hr of total time in bed although performance stabilizes at a level below baseline in which three consecutive 8 hr time in bed periods were provided (recovery sleep), and performance after 3 hr of time in bed declined throughout the 7-day partial sleep deprivation protocol period.

Based on these studies, it seems that sleep loss can lead to safety risks. However, results of a recent survey study with survivors of cancer patients concluded that sleeping 8 hr or more may increase mortality risk compared with sleeping 7 hr or less (Kripke, Garkinkel, Wingard, Klauber & Marler, 2002). The findings do have limitations such as sampling methods used, type of questions asked, and other interpretations of the survey results and thus warrants further investigation (National Sleep Foundation, 2002). With these partial and cumulative sleep loss laboratory experiments as a foundation, how does the accumulation of fatigue affect recovery sleep at home over one month of flight activity?

Age Factors

Age has been examined in laboratory studies related to changes in sleep stages, sleep deprivation, and recovery performance after sleep deprivation. In a study of sleep deprivation in a group of older males (55-71 years), performance declined on an auditory RT task as sleep loss increased throughout a 64 hr protocol. Baseline levels of performance returned after one unrestricted night of recovery sleep, but subjective sleepiness did not return to baseline levels until the second night of recovery sleep (Bonnet, 1985). Brendel, Reynolds, Jennings, Hoch, Monk, Berman et al. (1990) examined sleep, mood, and performance in response to 24 hr of sleep deprivation in the old-old (80-89 years) compared to younger individuals (20-29 years). The elderly were found to have lower sleep efficiency and more awakenings. However, there were no differences in time to fall asleep and the elderly had greater mood stability. Young participant performance was affected to a larger extent by sleep deprivation than the elderly participants as measured on a Mackworth Clock Test (Mackworth, 1948). A visual RT task was used to avoid confounds due to hearing loss. Also, mood was more aggravated due to acute sleep loss in the young participants.

Does this mean that older people need less sleep than young people to maintain levels of vigilance? This is an area requiring further investigation. Kramer, Kerkhof, and Hofman (1999) investigated age-related differences in the variability in sleep-wake patterns across days of older men (59-74 years) by comparing them to a group of young men (18-26 years). Based only on sleep logs and actigraphy (gross motor activity over time), elderly participants had more stable and relatively advanced sleep-wake patterns

(arose from bed and went to bed earlier) than younger participants. This was suggested to be an adaptive response to age-related changes because elderly participants reported higher levels of alertness during the day than the younger participants. Age-related characteristics found during this study include the following in older men: (a) deep sleep decreases; (b) number and duration of awakenings increase; (c) length of sleep decreases; (d) overall daytime alertness levels decrease; (e) circadian amplitude diminishes on the temperature rhythm (increasing core body temperature is associated with wakefulness); and (f) advanced circadian phase (leading to earlier sleep and wake times). The following section provides an overview of circadian concepts and relevant research findings.

Circadian Rhythms

It has been determined that nearly all organisms on Earth possess an internal mechanism that entrains with the 24 hr light-dark cycle in a sinusoidal fashion. In humans, this rhythm is on average 24.18 hr in length (Czeisler & Wright, 1999; Czeisler, Duffy, Shanahan, Brown, Mitchell, Rimmer et al., 1999). This rhythm is characterized by a sinusoidal pattern and possesses: (a) an amplitude which is one half the value from peak to trough; (b) an acrophase defined as the point of the curve at which the maximum value occurs; and (c) a nadir defined as the minimum point on the curve (Campbell, Gillin, Kripke, Erikson & Clopton, 1989). This structure is referred as a circadian rhythm and originates from Latin: *circ* meaning about; and *dies* meaning day. Various rhythms in the human body follow this cycle including core body temperature, plasma melatonin, and plasma cortisol, all of which rise and fall during the 24 hr period (Colquhoun, 1971).

The rise and fall of the circadian rhythm is associated with increasing and decreasing levels of alertness throughout the 24 hr period in which the low points of the period (moving toward the nadir) are characterized by subjective sleepiness and performance decrements (Kleitman, 1963).

So with differences in the rise and fall of circadian rhythms across 24 hr periods, what would happen when environmental and temporal cues are eliminated? Circadian rhythms have been shown to oscillate at their own intrinsic period that shifts in phase towards an advanced (earlier) or delayed (later) direction (Doran et al., 2001). Horne and Östberg (1976) attempted to measure the characteristics of individual differences of the circadian rhythm and the tendency for some individuals to have an intrinsic phase advance (morning-type) whereas others have an intrinsic phase delay (evening-type). Research findings seem to indicate that these differences result from genetic variation (Singer & Lewy, 1999). However, the question has been raised that questionnaires used to measure morningness and eveningness must be sensitive to the population under study. When published, the Horne and Östberg questionnaire did not provide the statistical analyses documenting the internal consistency of their instrument, but was validated resulting in good internal consistency and reliability (Smith, Reilly & Midkiff, 1989). Duffy and Czeisler (2002), in a study of age-related changes to circadian rhythms and diurnal preference in an elderly population ($M = 67.4$, $SD = 3.2$ years), found no correlation of core body temperature and results from a widely used morningness-eveningness questionnaire. Brown (1993) developed a morningness-eveningness

questionnaire that is less complex, easier to understand, shorter in length, and sensitive to a shift-working environment in contrast to the Horne-Östberg questionnaire.

The entrainment to the Earth's light-dark cycle provides individuals with a mechanism to maintain a normalized schedule. The connection between the external light-dark cycle and the internal mechanism that controls circadian rhythms has been postulated to originate from the eyes. Photoc information is sent through the retinal ganglion cells of the eyes to a hypothalamic tract, through a cell column of the spinal cord to the mechanism (commonly called the circadian pacemaker or circadian clock) in the suprachiasmatic nucleus (SCN; Czeisler & Wright, 1999). This photic information is also sent to the pineal gland via cervical ganglia. The pineal gland excretes a hormone linked to sleepiness called melatonin and is sensitive to environmental light conditions. Melatonin is suppressed in the presence of light (Brainard, Richardson, King, Mathews & Reiter, 1983). When light is presented at a specific time in a specific quantity and duration, it has the ability to shift the circadian rhythm to an earlier or later time in addition to suppressing melatonin. For example, a 6.5 hr pulse of light approximately 500 lx in the angle of gaze in a carefully controlled laboratory environment will delay the circadian rhythm (in the direction of more eveningness traits) to a later time and suppress the secretion of melatonin (Zeitzer, Dijk, Kronauer, Brown & Czeisler, 2000).

If melatonin has the ability to promote sleepiness, and a specific duration and intensity of light suppresses melatonin and can shift the circadian cycle to more eveningness, then what other characteristics of light may affect the rhythm? Humans seem particularly sensitive to light in the range of 500 nm (Wurtmann, 1975). Horne,

Donlon, and Arendt (1991) examined the effects of green light for the nighttime suppression of melatonin. However, there were no significant differences between 5 and 10 min pulses of green light or 10 min pulses of red-green alternating light (2,000 lx) every hour during a 36 hr sleep deprivation protocol. Although the peak in melatonin secretion was suppressed, the 24 hr total output was not changed. Perhaps 10 min was too short in duration to have an effect. It has been suggested that the duration and intensity of light has an inverse relationship (e.g., light intensity may be reduced when the duration of light exposure is increased). For example, melatonin suppression has been shown to occur with a 30 min pulse of full spectrum light at 393 lx, or a 120 min pulse of full spectrum light at 285 lx (Aoki, Yamada, Ozeki, Yamane & Kato, 1998). Also, half the maximum alerting response to a 6.5 hr pulse of bright light (9,100 lx) was obtained with light subjectively at 180 lx and physiologically through EEG at 90 lx for the same duration (Cajochen, Zeitzer, Czeisler & Dijk, 2000). It is important to note with all these studies that the timing of light exposure must be precise in order to have a significant effect on melatonin suppression or phase shifting, and the environmental settings must be highly controlled.

Other factors that may alter melatonin output or shift circadian phase include: (a) mild exercise, which may cause phase delays in the circadian temperature rhythm (Eastman, Hoese, Youngstedt & Liu, 1995); (b) timing of the sleep-wake cycle, knowledge of clock time, and social cues (Middleton, Arendt & Stone, 1996); (c) women's use of oral contraceptives, which increases melatonin levels and the temperature rhythm (Wright & Badia, 1999); and (d) caffeine use in combination with

bright light (1,000 lx) or alone, which reduces melatonin output and delays the decrease in the temperature rhythm (Wright, Badia, Myers, Plenzler & Hakel, 1997). For these reasons, data were collected to examine the levels of exercise, medication and caffeine consumption during the 40-day period, which will be examined in future research.

The factors of gender and age have also been examined in circadian research. Healthy elderly participants (65-81 years) were observed to have melatonin output similar to healthy young participants (18-30 years). Since these participants were not taking any medications on a regular basis it is important to emphasize that the melatonin output of elderly with any medical conditions and use of melatonin suppressing medications (e.g., aspirin, nonsteroidal anti-inflammatory chemicals) may have different results. Elderly women tend to exhibit temperature rhythms slightly higher in amplitude combined with a more rapid rise and descent of the rhythm, and an earlier temperature acrophase than elderly men. Thus, elderly women reported significantly shorter sleep duration, earlier wake time, and less quality sleep (Zeitzer, Daniels, Duffy, Klerman, Shanahan, Dijk et al. 1999).

Studies have also been conducted to determine if circadian entrainment could occur through methods other than the eyes. Campbell and Murphy (1998), demonstrated that one 3 hr pulse of 13,000 lx light to the back of the knee was able to phase shift the circadian rhythms of core body temperature and melatonin. This conclusion was challenged and could not be replicated. Hebert, Martin, and Eastman (1999) found that a 3 hr pulse of bright light (1,000 lx) at the angle of gaze suppressed melatonin secretion, but the same duration of 13,000 lx light behind the knee or dim light (10-20 lx) at the

angle of gaze could not suppress melatonin in 16 healthy, young participants ($M = 26$). Wright and Czeisler (2002) also attempted to replicate Campbell and Murphy's finding without success.

To summarize, factors demonstrated to affect circadian rhythms and their influence on fatigue are as follows: (a) a rise in the temperature rhythm may be linked to increased alertness; (b) melatonin is linked to drowsiness and some suppression occurs with light as low as 100 lx whereas full suppression is dependent on timing and duration of the light pulse; (c) light levels as low as 90 lx provided at the correct time in the temperature rhythm for a specific duration will shift the circadian phase and increase subjective and physiological alertness. This exploratory study will examine environmental light exposure by comparing average levels of light that domestic and flag operation pilots are exposed to during the day, at night, and when on the ground as compared to light exposure during flight operations.

Sleep and Circadian Rhythm Factors Associated with Flight Operations

The nature of aviation operations requires pilots to fly sporadic schedules that are often combined with multiple time zone changes. Extended duty times (work shifts that exceed 8 hr) are already common in aviation. Gander, Gregory, Graeber, Connell, Miller, and Rosekind (1998a) found that one sample of pilots involved in *short-haul* trips (flight time average 4.5 hr) worked an average duty of 10.6 hr per day over 3 to 5 day trip patterns. Another sample of *long-haul* pilots worked an average duty of 9.8 hr per day with an average total period of wakefulness of 20 hr per day over 5 to 9 day trip patterns (Gander, Gregory, Miller, Graeber, Connell & Rosekind, 1998b). Rosekind, Graeber,

Dinges, Connell, Rountree, Spinweber et al. (1994) reported that the duty times of pilots during a series of transpacific flights ranged from 8.4 to 14.8 hr per day. Samel et al. (1997) reported through EEG and subjective report that pilot fatigue increases progressively as a function of flight length.

Simulator and field studies that focused on domestic and flag operation flights found that pilots were especially vulnerable to cognitive lapses or *microsleeps* (brief periods of sensory disconnection from the external environment). These uncontrollable sleep periods measured by alpha, theta, and slow rolling eye movements (SEMs) interfere with wakefulness. Neri, Oyung, Colletti, Mallis, and Dinges (2002) found significant increases in microsleep events greater than 2 to 4 sec in duration during a 6 hr nighttime simulated flight between 0200 and 0800. Inadvertent sleep during the flight also increased through the night. During a field study of transpacific flights balanced with eastward, westward, night, and day flights, Rosekind et al. (1994) found a substantial increase in slow-wave EEG activity and SEMs during 3-crew international flights, with pilots being affected more by the night flights than the day flights. Wright and McGown (2001) also found that sleepiness was prevalent in pilots on international flights during both daytime and nighttime flights, and that sleep occurred more frequently during the late night departure flights. Samel et al. (1997) found similar evidence that pilots inadvertently slept during 9 to 10 hr night flights in 2-crew operations in which sleep away from home (layover sleep) occurred during the day.

Eastbound flights have been found to be more challenging than westbound flights due to the circadian nature of a phase advance toward a slightly shorter period less than

24 hr when sleep may be attempted, and the inability of the body to synchronize to local night and not initiate or maintain sleep (Gander et al., 1998b; Klein, Wegmann, Athanassenas, Hohlweck & Kuklinski, 1976; Lowden & Akerstedt, 1998, 1999; Rosekind et al., 1994).

Age has also been addressed in determining if age-related changes in sleep and circadian rhythm characteristics could be observed in a pilot population. Younger pilots (20-30 years) were significantly more evening-type than older pilots (40-60 years). Older pilots were shown to have more disturbed sleep after one transmeridian flight and averaged 3.5 hr more sleep loss than younger pilots (Gander, Nguyen, Rosekind & Connell, 1993).

Gender has been examined in a 40 hr sustained wakefulness protocol and was found to have no significant effects on helicopter flight performance (straight and level flight, turns, descents, climbs and other flight maneuvers) during simulated flights (Caldwell & LeDuc, 1998).

The majority of these studies measure sleep loss and circadian rhythm disruption: (a) physiologically through EEG, EOG, electromyography (EMG), core body and oral temperature, blood, saliva, and heart rate; (b) objectively through actigraphy, head movement; and (c) subjectively through questionnaires, sleep logs, mood scales, visual analog scales, and sleepiness scales. This study examined 40 days of flight operations with actigraphy, an environmental light sensor, and subjective instruments including an electronic activity log and various questionnaires.

The goals of the present study were: (a) to determine the prevalence of fatigue in flight operations by comparing flight type (domestic, flag operations), and flight position (captain, first officer) on average time in bed at home compared to average time in bed away from home, in addition to average time in bed for the first 72 hr after returning home from trip patterns; (b) to determine predictors of time in bed during layover based on number or trip patterns for the protocol period, number of flight segments per trip pattern, actual duty time, flight time, time zones crossed per flight segment, age, morningness-eveningness preference, and sleep disorders; and (c) to examine the amount of light exposure that pilots receive during the day and night in addition to determining the amount of light exposure present on the ground and during flight operations for domestic and flag flight operations and captains and first officers positions.

METHODS

Participants

A total of 40 pilots were recruited. A sample size of 50 is required with the expectation of a large effect size at $\alpha = .05$, and six independent variables for multiple regression analyses. However, some of the research questions may involve only four independent variables, which would require a sample size of 42 participants for similar power and effect size (Cohen, 1992). Participants were recruited by several methods including: (a) flyers posted at commercial air carrier flight operations department bulletin boards, scientific conferences, and industry workshops; (b) email disseminated by air carrier organizations through company email servers with approval by company management and/or pilot union groups (i.e. Air Transport Association, Air Line Pilots

Association); (c) email disseminated by Aviation Medical Examiners or posted on-line through organizational web sites; and (d) telephone and email contact with air carrier representatives from U.S. major commercial air carriers, their regional affiliates, in addition to non-U.S. flag operation commercial air carriers.

Pilots were accepted for participation if they met the following criteria: (a) possessed an active Air Transport Pilot (ATP) license; (b) currently flew for a passenger air carrier defined by 14 Code of Federal Regulations Part 121 Operating Requirements: Domestic, Flag, and Supplemental Operations; and (c) would be flying a regular schedule (line pilot schedule) during the protocol period. A regular (line) schedule consists of flights that do not involve reserve duty or conversion line flights during the scheduling cycle. This requirement is to ensure that the pilots participating in the study do not have sporadic flight schedules interspersed with a significant amount of time off between flights, which are uncharacteristic of those pilots who fly a regular schedule. Reserve duty is based on contractual agreements between the pilot union and the air carrier who employ those pilots designating time periods within the scheduling cycle (usually 30 days) that requires the pilot to report for duty on short notice (usually within 2 hours of notification) to fill vacancies that occur during the regular flight operations of their commercial air carriers. Events that may occur requiring a reserve pilot to fill vacancies could, for example, be due to a line pilot's illness, weather that may delay a flight, or aircraft mechanical problems. Conversion line schedules consist of the collection of flights that are left after all regular line pilots have received their choice of flights during a scheduling period.

Participation was voluntary and no form of monetary compensation was provided. However, each participant received a NASA *Z Team* baseball cap (Washed Twill Cap, Lands' End, Dodgeville, Wisconsin) and NASA *Z Team* stickers for their participation.

Equipment

An activity monitor, worn continuously on the non-dominant wrist (Actiwatch-64, Mini Mitter Co., Inc., Bend, Oregon) was employed to collect total time in bed during each sleep period, wakefulness prior to each sleep period, and time of day or night that each sleep period occurred throughout the 40-day protocol (see Appendix B). The activity monitor collects activity units by means of an accelerometer and records a summation of this activity within a specified epoch length (interval). The accelerometer possesses characteristics of piezo-electricity and generates a voltage based on the amplitude and speed of device motion, which is then stored in a memory chip located within the device. The more movement that occurs through the activity monitor, the larger the voltage, and the greater the resultant activity count. The device has been validated by demonstrating that it correctly identifies sleep on an epoch-to-epoch comparison of EEG (Ancoli-Israel, Cole, Alessi, Chambers, Moorcroft & Pollak, 2003; Chang, Kushida, Palombini, Carrillo, Hindman, Hong et al., 1999). EEG data are examined and scored at 30 sec epochs while activity monitor epoch lengths can be set from 0.25 sec to 5 min epochs. Participants were instructed to press an event marker located on the face of the activity monitor before each sleep period at *lights out* when ready to initiate sleep, and again when arising from each sleep period as a means of providing a validation marker to obtain accurate total time in bed. The device was set to Coordinated Universal Time (UTC), which is kept using

atomic clocks that are accurate to approximately one nanosecond (billionth of a second) per day, and is the basis of the worldwide system of civilian time (National Institute of Standards and Technology, U.S. Naval Observatory, 2003).

A light sensor, worn around the neck on a clip secured to the shirt, tie, or jacket (Actiwatch-L, Mini Mitter Co., Inc., Bend, Oregon) approximately 4 in. below the neck, collected illuminance (lux) in the surrounding environment (see Appendix B). This distance was chosen to keep the light sensor as close to the eyes as possible without being intrusive to the participants, and also far enough below the chin to avoid any shadowing that may occur by the lower jaw or chin structures. Time was also set to UTC in the light sensing device.

The activity monitor and light sensor were initialized to specific start date, time, and epoch length. An epoch defined for these devices is the period of time units of activity or illuminance are collected over a selected time interval, and resultant data stored in memory. Activity was measured at a sampling rate of 32 Hz and summed over 2 min epochs. The illuminance data was collected by a photo-sensor located in the center of the device worn around the neck. Illumination was sampled every second, and averaged over 5 min epochs. Through technological advances, activity and light data can be collected up to 90 and 75 days respectively. Once the devices are initialized, they continue to collect data until the data storage capacity is full or the battery power has been depleted (see Table 2). Data loss occurs once power is drained from the battery. Manufacturer projected battery life for the activity monitor and light collection is approximately six months.

Participants completed a 63-item background questionnaire developed at NASA Ames Research Center by the Fatigue Countermeasures Group (see Appendix C) to collect demographic, sleep history, flight, duty, and fatigue (before, during, and after flight) information. This information provided descriptive data to compare and contrast each group (domestic, flag operation pilots) in addition to comparing the group in the present study with participants in other aviation-related field research studies to determine proximal similarity to other pilot populations, which would improve external validity. All questionnaires were completed at the participant's discretion during the protocol period. Estimated time to complete all protocol questionnaires was 75 min.

A sleep disorders scale (Multivariable Apnea Prediction and Sleep Symptom Frequency [SleepMAP] Form, University of Pennsylvania Center for Sleep and Respiratory Neurobiology) was completed (see Appendix D) to obtain information on potential sleep-related disorders that could be factors in assessing pilot fatigue. The questionnaire was developed as a diagnostic tool to measure relative sleep apnea risk (Maislin, Pack, Kribbs, Smith, Schwartz, Kline et al., 1995). Sleep apnea is a breathing disorder characterized by multiple respiratory interruptions that occur during sleep, which may last a few seconds to a couple minutes per occurrence. The 19-item form includes demographic questions concerning birth date, gender, weight, and height. The remaining 14 items measure sleep apnea risk on a six-point scale. Internal consistency reliability coefficients (Cronbach's alphas) were established for apnea, difficulty sleeping, excessive daytime sleepiness, and narcolepsy symptoms at 0.89, 0.71, 0.76, and 0.66 respectively. The SleepMAP instrument was used as one of the variables that may

predict the average amount of time in bed obtained during layover. Little information is available on the prevalence of sleep disorders in commercial air carrier pilot populations (Air Safety, 2001).

Two scales of morningness-eveningness preference were completed to examine the extent of circadian preference among domestic and flag operation pilots. Horne and Östberg (1976) developed a 19-item Morningness-Eveningness Questionnaire (MEQ; see Appendix E) that has been validated extensively in student populations, and has become the most widely used device to measure morning or evening preference (Chelminski, Petros, Plaud & Ferraro, 1997). The scores are interpreted as follows: (a) 70-86 = *definitely morning*; (b) 59-69 = *moderately morning*; (c) 42-58 = *neither*; (d) 31-41 = *moderately evening*; and (e) 16-30 = *definitely evening*. Smith et al. (1989) evaluated the MEQ and determined the internal consistency and reliability coefficient (Cronbach's alpha) as 0.82. However, validation of this scale based on a younger population has received critical attention, and it has been suggested that the device should be used only with young adults (Duffy & Czeisler, 2002). For this reason, the 13-item Basic Language Morningness (BALM) Scale (see Appendix F) was also administered, which has been developed specifically for a variety of working environments such as those in manufacturing and air traffic control operations (Brown, 1993). Internal consistency reliability coefficients (Cronbach's alpha's) were established for shift workers and day workers as 0.88 and 0.91 respectively. The scores are interpreted as follows: (a) 53-55 = *extreme morning*; (b) 49-52 = *strong morning*; (c) 45-48 = *moderate morning*; (d) 42-44

= *mild morning*; (e) 27-41 = *neither*; (f) 24-26 = *mild evening*; (g) 20-23 = *moderate evening*; (h) 16-19 = *strong evening*; and (i) 13-15 = *extreme evening*.

The morningness-eveningness data was used to determine if this characteristic can predict the prevalence of preference that may underlie a pilot's flight schedule. Do pilots self-select for certain types of flight schedules based on their morningness-eveningness preference?

A Palm Pilot-based electronic activity log (Palm Vx, Palm, Inc., Milpitas, California; see Appendix B) was developed using off-the-shelf database software (Satellite Forms 4.2, Pumatech, Inc., San Jose, California). A folding rigid case (RhinoSkin Aluminum Slider Hard Case, Saunders and Saunders Mfg Co. Inc., Readfield, Maine) was employed to protect each Palm Pilot from potential drop or crush damage. A charging cradle was supplied to re-charge the Palm Pilot, which contains a built-in lithium power supply (connecting the Palm Pilot to the charging cradle is the only method to restore battery power to the device). A 50 W voltage converter was also provided to pilots flying international routes during the protocol period in order to charge the Palm Pilots when on travel to avert any over-voltage damage that may occur due to different electricity currents of various countries (50 W Foreign Travel Voltage Converter 273-1412, Radio Shack, Fort Worth, Texas). Information collected by the activity log included: (a) flight and duty schedules, (b) layover activity, (c) sleep quantity and quality, (d) medication use, (e) alcohol and caffeine consumption, (f) exercise frequency and duration, and (g) light exposure. The information was also used to compare and reconcile the actigraphy data for possible data interpretation issues (see

Appendix G). It has been demonstrated that actigraphic data combined with activity log data provide a more accurate assessment of sleep/wake activity (Ancoli-Israel et al., 2003; Eissa, Poffenbarger & Portman, 2001; Mizuma & Sakamoto, 1998; Wilson, Watson & Currie, 1998). The Palm Pilot system time was also set to UTC and participants were instructed to enter all information in the activity log with UTC in order to synchronize time for data from the activity monitor, light sensor, and activity log. A pop-up window displayed the current UTC time in the activity log during data entry to increase accuracy and decrease participant workload in needing to calculate UTC from the time zone of their current location.

For convenience, and to provide participants flying through multiple time zones some time management assistance in entering accurate time information into the activity log, a world time clock application installed on the Palm Pilot could be programmed by participants to display up to four different regional times, and efficiently compare time at any geographic location with UTC (Clock+ 3.6, Bitware Australia Pty. Ltd., Manuka, Australian Capital Territories, Australia). A note pad application built into the Palm Pilot could be used for comments that did not fit into any activity log category (e.g. “up from 0130 to 0330 due to fire alarm in the layover hotel”).

Procedure

Approval to conduct the present study was granted by the San Jose State University (see Appendix H) and NASA Ames Research Center Human Research Institutional Review Boards. Once potential participants were provided with information regarding the study, and agreed to participate, they were divided into two groups within

an ex post facto quasi-experimental design. One group was composed of participants who actively flew domestic operations for the United States or non-U.S. flag carriers. The other group was composed of participants who actively flew flag operations for the United States or other non-U.S. flag carriers. After receipt of informed consent (see Appendix I), each participant was contacted by phone to collect pre-study demographic information (age, home time zone, caffeine consumption per day, etc.), flight information (aircraft seniority, type aircraft flown, crew position, etc.), and sleep history information (amount of sleep to feel well rested, average amount of sleep obtained in the past week, etc.) to balance the domestic, and flag operation pilot groups. If contact was not possible via telephone, a pre-study questionnaire was sent via email or fax (see Appendix J). Participants were issued a unique number that separated their personal information from any collected data. Confidentiality was maintained for each participant based on the guidelines of the San Jose State University Institutional Review Board, and NASA Ames Policy Directive APD 7170.1 for the protection of human research participants (National Aeronautics and Space Administration, 2001).

Participant data were then entered into a database for protocol coordination (FileMaker Pro 4.0, FileMaker, Inc., Santa Clara, California), to store contact information, company information (company name, aircraft type, aircraft position), equipment issuance, tracking numbers for shipping, pre-study information, and other pertinent notes or comments. The database linking participants to their participant identification numbers was destroyed at the end of data collection to ensure participant confidentiality.

All interaction with the participants was conducted remotely. Materials, equipment, and instructions necessary to complete the protocol were contained in a package and sent to the designated address provided by each participant several days prior to the study start date. All communication was conducted via phone, fax, and/or email. The contents of the package sent to each participant are listed in Table 3. A series of email messages were sent to each participant: (a) prior to study commencement for orientation and to remind them of the procedures for data collection; (b) midway through the protocol to maintain contact, provide assistance when necessary, and disseminate useful information provided by other participants to streamline data collection procedures; (c) 7 days prior to the end of the 40-day protocol to provide information on the procedures for returning equipment to the Fatigue Countermeasures Group laboratory at NASA Ames Research Center; and (d) at the end of the protocol period to extend a note of gratitude for taking part in the research study, and to coordinate a convenient time to debrief, answer any questions, and address any comments or concerns. In order to assist each participant regarding the procedures and operation of the equipment at the beginning of the protocol, a Frequently Asked Questions (FAQ) list was sent via email to address the most commonly asked questions collected from previous participants (see Appendix K). Most questions pertained to the use of the Palm Pilot-based electronic activity log, and proper use of the activity monitor and light sensor.

Each participant wore the activity monitor continuously for 40 days including 5 days prior to the regular flight schedule cycle and 5 days after the flight schedule cycle to collect daily time in bed periods, and overall sleep-wake cycle data. This information

was: (a) compared between domestic and flag operation groups to determine the extent of fatigue that may have occurred during the protocol period; (b) used to conduct a hierarchical multiple regression analysis to predict amount of time in bed that may be obtained during layover; and (c) to be used later in models that may predict alertness. A sports watch-type band was installed on the activity monitor to increase comfort and reduce potential morbidity threats (participant drop out rate) due to skin irritation (19mm black water watch band, Chisco, Salt Lake City, Utah).

The light sensor was worn around the neck using a nylon lanyard during the entire 40-day protocol, but was removed during sleep periods to avoid obstructions to the light sensor from blankets, bed covers, or body position while sleeping. Participants were instructed to place the light sensor around the neck again after each sleep period. Environmental light data provided: (a) the illuminance that occurred throughout the protocol period; (b) another source to validate the total time in bed; and (c) data that may be used to model alertness based on different timing, intensity, and duration of light introduced at different locations of an individual's circadian phase.

Participants entered information into the activity log throughout the data collection period, and were asked to enter events into the activity log as often as possible at the time events occurred. However, during flight, it was emphasized that flight operation safety is paramount, and participants were instructed to enter information into the activity log at the earliest convenience after required flight duties were completed.

The background, SleepMAP, and morningness-eveningness questionnaires were completed anytime prior to returning the equipment and materials back to the Fatigue

Countermeasures Group lab at NASA Ames Research Center. If data were missing from any questionnaires after they were returned to the lab, then forms were either sent back for completion, or verbatim questions were sent via email to the participants requesting a response to complete missing items.

Participants were allowed to contact the principle investigator at any time during the study for any reason. Once the study was completed, participants would use an enclosed express service air waybill to send the equipment and questionnaires back to NASA Ames Research Center for post data collection processing, storage, and data analysis. A debrief interview followed at the participant's earliest convenience after the completion of the protocol to obtain feedback concerning problems, comments, and suggestions surrounding the study. Also, a thank you letter was sent to each participant after their respective package of equipment and materials was received (see Appendix L). The activity log was revised (based on participant comments) during the early stages of data collection to modify the order of questions that were presented to a more operationally logical order that was more meaningful to participants when they entered information.

Data Reduction

All analyses were conducted using a commercial statistical package (SPSS for Microsoft Windows XP version 11.01, SPSS, Inc., Chicago, Illinois).

Demographics. Demographic variables from the pre-study interview, and background questionnaire were entered into a FileMaker Pro 4.0 database and exported into Microsoft Excel 2001 for the Macintosh computer (Microsoft, Inc., Seattle,

Washington). Participants were divided into domestic and flag operation groups. Means were extracted from the actigraphy file for: (a) total mean time in bed; (b) mean time in bed (layover only); (c) mean time in bed (home sleep only); and (d) the first three 24 hr sleep periods after returning home from trip patterns for each participant.

Two participants did not properly complete the MEQ and BALM, and were not included in the multiple regression analyses. One participant did not completely fill out the SleepMAP and was not included in the multiple regression analyses.

A total of nine participants were excluded from the study for various reasons. Four participants were excluded from the protocol due to health issues (cold, flu, pneumonia). One participant was excluded due to personal reasons (death in the family). One pilot was excluded due to involvement in a motor vehicle accident. One participant was excluded due to transition training into a different aircraft partway through the protocol. Two participants were excluded due to protocol non-compliance (no activity and/or light data) beyond the first week of the protocol.

Means were calculated from data extracted by the activity logs for: (a) number of trip patterns flown over the protocol period, (b) average number of flight segments per trip pattern, (c) average time zone crossing per duty period, (d) duty time, and (e) flight time per flight segment.

Actigraphy data. Actigraphy data extraction was performed using Actiware Sleep 3.3 (Mini Mitter, Co., Inc., Bend, Oregon) to obtain total time in bed. The time that lights were turned off to initiate sleep in addition to wake up/out of bed times were identified using the following criteria: (a) the presence of an actigraph event marker; (b) activity log

entry for pre- and post-sleep periods; or (c) estimate based on 3 min prior to no activity period greater than 10 min in length until 3 min after activity periods greater than 50 activity units.

Each sleep period was coded based on the location (sleep at home; during layover away from home; during the first, second, and third 24 hr period at home after returning from trip patterns; or rest obtained in on-board crew rest facilities in the aircraft). Time in bed periods were validated by pre- and post-ground sleep activity log entries provided by the participants. Layover sleep was validated by activity log entries, and flight operation information from activity log entries and company flight schedules if provided by participants. In-flight sleep was validated by pre- and post-in-flight sleep activity log entries as well as flight schedules if provided by the participant. The method of sleep and wake up time for each sleep period was notated based on the source of identification (event marker press, activity log entry, or estimate when either event marker or activity log entry were not available).

Data were exported into a Microsoft Excel spreadsheet and transposed with participant identification numbers along rows, and actigraphy variables across columns. Times were converted into decimal numbers for analysis. Several pilots took the activity monitor off consistently at night, and donned the device upon awakening thus instead of deleting those participants, only total time in bed was extracted from the activity monitor. In addition, the accuracy of other sleep actigraphy variables such as sleep latency (the time period between *lights out* and ready for sleep until sleep onset) and sleep efficiency (the index of the amount of time in bed spent sleeping) as compared to EEG may be a

function of the study question, time of day, and other factors such as age (Reid & Dawson, 1999).

Flight operational data. Flight operation variables were extracted from the duty entries of the activity log or printed flight schedules if provided by the participant. Activity log files were downloaded from the Palm Pilot into Satellite Forms 4.2, and stored as Access 2002 files (Microsoft, Inc., Seattle, Washington). Access data were then transferred to Microsoft Excel 2002 for Windows XP Pro.

Macros were used to format and sort the data into a usable format in order to validate actigraphy time in bed periods as well as flight periods. Macros were used to extract the following variables for the multiple regression correlation analysis: (a) scheduled duty start time; (b) scheduled duty end time; (c) actual duty end time; (d) duty time per flight segment; (e) departure airport and time zone; (f) arrival airport and time zone; (g) trip pattern count per protocol period; (h) flight segment count per trip pattern; (i) number and direction of time zones crossed; (j) block out time, which occurs when an aircraft departs the Jetway or ramp from an airport terminal prior to flight; (k) block in time, which occurs when an aircraft arrives at the Jetway or ramp of an airport terminal after flight; (l) flight time per flight segment; and (m) deadhead flights (participant non-revenue flights taken as a passenger; not on-duty).

Duty time was based on scheduled start time minus actual duty end time if available. Otherwise duty time was considered scheduled start time minus scheduled duty end time. If no duty times were available, or duty periods seem to be entered in error, duty start and end times were extrapolated from block out and block in time by the

following criteria: (a) for domestic flights, duty begins 1 hr before the first flight segment of the day (or night) starting a 24 hr period and ends 15 min after the end of the last flight segment of the day (or night) prior to the subsequent sleep period on the ground; and (b) for international flights, duty begins 2 hr before the flight segment of the day (or night) and ends 30 min after the end of the last flight segment of the day (or night). Missing pieces of duty time information from the activity log occurred in 203 of 1283 entries (15.8% of the dataset). If block out or block in times were omitted/missing from the activity logs, or time entries for a city pair seemed to be in error based on illogical flight times for given city pairs (e.g., SFO to LAX, flight time entered by a participant equals 6.3 hr for a flight that would on average require 1.3 hr barring weather, traffic, or other possible delays), an average of other exact departure and destination city pair flight durations flown by the participant during the protocol period would be used. Missing block in or block out information occurred in 60 of 1283 entries (4.7% of the data set). If time information was incomplete for a city pair that was flown only once during the protocol period, then the published flight schedule for that city pair was used based on the pilot's affiliated company's public web site airline schedule. This procedure occurred with 45 of 1283 entries (3.5% of the dataset). Duty time, flight time, trips per protocol period, and legs per trip entries were screened for outliers, missing data, and anomalous entries using SAS version 8.02 (SPSS, Inc., Chicago, Illinois).

Light data. Light data were examined using Actiware Sleep 3.3 (Mini Mitter, Co., Inc., Bend, Oregon), and a data reduction program written in PHP (Personal Home Pages) to extract light data periods by start date, start time, end date, and end time. The

PHP program extracted the light data for the entire protocol period, and start/end time and date information matched flight periods for each participant from block out of the departure airport through block in to the arrival airport. Data were coded to indicate day and night during the protocol period in addition to light exposure on the ground, and during flight operations. Local block in and block out times were computed, and sunrise and sunset times were determined for each departure and arrival airport based on the local time zone. Each block out to block in period was then coded to identify day or night flights. Deadhead flights were omitted, and flights that traversed through both night and day were coded separately.

Sunrise and sunset information was extracted from the U.S. Naval Observatory, Astronomical Applications Department at <http://aa.usno.navy.mil/>. When international airport latitude longitude information was needed to calculate sunrise, and sunset times at non-U.S. airports, coordinates were obtained from AR Group, Inc. Air Routing International Airport Locator at <http://www.ar-group.com/>.

The coded definition of day and night flight was based on the criteria issued by FAR Part 1, Section 1.1 General Definitions, which defines night as the time between the end of evening civil twilight and the beginning of morning civil twilight, as published in the American Air Almanac, converted to local time. Civil twilight is defined as the beginning of morning until the end of evening when the center of the Sun is 6 degrees below the horizon (U.S. Naval Observatory, 2003). The U.S. Naval Observatory is the parent organization of the U.S. Nautical Almanac Office, which publishes the American Air Almanac.

RESULTS

Descriptive Statistics

Table 4 displays descriptive statistics. Participants were current ATP certificated pilots who were actively flying for an FAR Part 121 commercial passenger air carrier, or non-U.S. equivalent Part 121 commercial passenger air carrier in domestic or flag operations ($N = 40$).

As a group, participants were 42.90 years old ($SD = 10.50$, range = 26.70-59.70) with 92.5% male, and 7.5% female encompassing 21 domestic, and 19 flag operation pilots consisting of 22 captains, and 18 first officers. Total flight experience was 11,792.64 hr ($SD = 7,243.30$, range = 3,000-29,500).

The domestic pilot participants ($n = 21$) were 37.99 years old ($SD = 9.13$, range = 26.70-59.70) with 90.5% male, and 9.5% female consisting of 13 captains and 8 first officers. These pilots flew on average 16.81 trip patterns ($SD = 5.19$, range 2-24) during the protocol period consisting of 2.81 flight segments per trip pattern ($SD = 0.85$, range 1.56-4.60), 0.97 time zones per flight segment ($SD = 0.77$, 0-2.30) consisting of 9.61 hr duty time ($SD = 1.50$, range 6.74-14.15), and 4.66 hr flight time ($SD = 0.83$, range 3.40-6.20). Total flight experience was 8,728.10 hr ($SD = 5,323.40$, range 3,000-22,000). Total time in bed was 7.96 hr ($SD = 0.89$, range = 5.88-9.51) consisting on average 7.97 hr time in bed at home ($SD = 0.89$, range = 5.85-9.74), and 7.86 hr time in bed away from home (layover; $SD = 0.92$, range = 5.95-9.87). The first 72 hr time in bed periods after returning home from trip patterns were 7.90 hr ($SD = 1.26$, range 5.97-10.31), 8.14 hr ($SD = 1.06$, range 6.02-10.13), and 7.85 hr ($SD = 1.49$, range = 4.05-10.60) respectively.

The flag operation pilot participants ($n = 19$) were 48.33 years old ($SD = 9.33$, range = 32.93-59.33) with 94.7% male, and 5.3% female consisting of 9 captains and 10 first officers. These pilots flew on average 9.31 trip patterns ($SD = 3.28$, range 4-15) during the protocol period consisting of 1.04 flight segments per trip pattern ($SD = 0.07$, range 1.00-1.27), 6.97 time zones per flight segment ($SD = 5.06$, range = 1-18) consisting of 11.99 hr duty time ($SD = 2.29$, range 8.05-16.02), and 9.73 hr flight time ($SD = 2.02$, range 6.20-14.00). Total flight experience was 15,179.76 hr ($SD = 7,689.01$, range = 5,500-29,500). Total time in bed was 6.67 hr ($SD = 0.78$, range = 5.43-8.05) consisting on average 7.30 hr time in bed at home ($SD = 0.89$, range = 5.96-9.25), and 6.87 hr time in bed during layover ($SD = 1.21$, range = 3.77-8.57). The first 72 hr time in bed periods after returning home from trip patterns were 6.92 hr ($SD = 1.82$, range 2.77-9.47), 7.41 hr ($SD = 1.13$, range 6.08-9.74), and 8.27 hr ($SD = 1.22$, range = 5.23-10.23) respectively.

As expected, domestic pilots flew more trip patterns per month, more legs per trip pattern, crossed fewer time zones per trip pattern, encompassing less duty and flight time than flag operation pilots. Domestic pilots obtained more time in bed on average than their flag operation colleagues irrespective of time in bed at home, away from home, or during the first 48 hr period after returning home from trip patterns.

Analysis of Variance

A comparison of overall time in bed for flight type and flight position. A series of analyses were conducted in order to determine the potential for the development of fatigue in flight operations for domestic and flag operations and flight position.

A two-factor between-subjects analysis of variance (ANOVA) was conducted comparing total time in bed (dependent variable) of domestic and flag operation pilots, and captain and first officer positions (independent variables) in order to compare the differences present in overall time in bed across the 40-day protocol. The analysis showed a main effect for type of flight operation (domestic, flag), $F(1,36) = 24.89, p < .001$. All subsequent analyses are considered significant at $p < .05$.

Domestic pilots obtained significantly more time in bed overall ($M = 7.96$) than flag operation pilots ($M = 6.67$). However, there was no overall difference in the time in bed obtained by captains ($M = 7.31$), or first officers ($M = 7.39$), $F(1,36) = 1.03, p = .32$, and no interaction was present, $F(1,36) = .70, p = .41$.

A comparison of layover sleep and home sleep. A three-factor (2 x 2 x 2; flight type by flight position by sleep location) mixed factorial design ANOVA was conducted with a between-subjects factor of flight type (domestic, flag operation) and between-subjects factor of flight position (captain, first officer) as independent variables, and within-subjects independent variable of sleep location (average home sleep, average layover sleep) to compare time in bed at home versus time in bed during layover.

Overall analyses showed a two-way interaction effect between sleep location and flight position, $F(1,36) = 5.14, p < .05$. Simple comparisons analyses to examine the interaction of sleep location and position was significant, $F(1,36) = 9.60, p < .01$. Captains obtain less time in bed during layover ($M = 7.15$) than at home ($M = 7.70$). A three-way interaction effect between sleep location by flight type and position, $F(1,36) = 4.69, p < .05$ was also obtained. Further simple comparisons indicate that flag operation

captains obtain less time in bed during layover ($M = 6.42$) as compared to the time in bed at home ($M = 7.55$), $F(1,36) = 13.14$, $p = .001$ (see Figure 1). In addition, simple comparisons on sleep location for domestic and flag operation first officers was significant, $F(1,36) = 8.20$, $p < .01$. Domestic first officers obtain more time in bed at home ($M = 8.28$) than flag operation first officers ($M = 7.08$; see Figure 2). Also, simple comparisons on sleep location for domestic and flag operation captains was significant, $F(1,36) = 7.60$, $p < .01$. Domestic captains obtain more time in bed ($M = 7.66$) during layover than flag operation captains ($M = 6.42$; see Figure 3).

A two-factor ANOVA was conducted to test for differences between flight type and flight group to determine if the significant differences between the two and three-way interactions comparing layover and home time in bed were the result of any pre-existing conditions. Participants were asked between one week and one month prior to beginning the study protocol, "How much sleep did you obtain on average in the past week?" This average sleep value was identified as a baseline value to determine if any pre-existing differences were present between flight type and flight position. No main effects were present by group, $F(1,36) = .19$, $p = .67$, by position $F(1,36) = 1.52$, $p = .23$, and the interaction of group by position was also not significant, $F(1,36) = .64$, $p = .43$. Therefore, any significant differences can be inferred as differences in the flight schedules and not due to any pre-existing condition of flight type or position.

A comparison of each recovery sleep period for flight type and flight position. Two-factor ANOVAs were conducted comparing each 24 hr recovery period (dependent variable) for flight type and position (independent variables) to determine if any

differences occurred within the first 72 hr of time in bed after returning home from trip patterns. The first 24 hr period, $F(1,36) = 3.85$, $p = .057$, and third 24 hr period, $F(1,36) = 1.58$, $p = .22$, were not significantly different.

A significant difference was obtained for the second 24 hr sleep period after returning home from trip patterns. The overall analysis showed a main effect of flight type, $F(1,36) = 6.21$, $p < .05$. There was no main effect for position, $F(1,36) = .40$, $p = .53$. A significant interaction effect between flight type, and position was obtained, $F(1,36) = 5.88$, $p < .05$, $R^2 = .24$. In order to determine the source, and nature of the significant interaction effect, simple comparison analyses were conducted to examine the effect of flight type (domestic, flag), and flight position (captain, first officer) on the amount of time in bed during the second 24 hr period. The simple comparison of flight type for the first officer position was significant, $F(1,36) = 10.82$, $p < .01$. The simple comparison of time in bed for captains was not significant, $F(1,36) = 0$, $p = 1.0$. First officers flying domestic operations obtained more time in bed ($M = 8.77$) than first officers flying flag operations ($M = 7.13$). The time in bed was similar for captains regardless of domestic ($M = 7.75$), or flag ($M = 7.73$) operations. Additionally, domestic captains ($M = 7.75$) and domestic first officers ($M = 8.77$) obtained similar time in bed during the second 24 hr period of sleep at home.

A comparison of layover sleep and the first three sleep periods at home. A three-factor ($2 \times 2 \times 4$; flight group by flight position by sleep location) mixed factorial design ANOVA was conducted with a between-subjects factor of type of flight (domestic, flag) and between-subjects factor of flight position (captain, first officer) as independent

variables, and the within-subjects independent variable of sleep location (average layover sleep, average recovery sleep period 1, recovery sleep period 2, recovery sleep period 3) to compare differences in layover time in bed, and the first three 24 hr time in bed periods after returning home from trip patterns.

Mauchly's sphericity test indicated that the main effect of sleep location violates the sphericity assumption, $W = 17.81, p < .01$. Therefore, any main effect or interaction would be adjusted with the Greenhouse-Geisser method for degrees of freedom correction. Overall analysis showed a main effect of flight type, $F(1,36) = 7.26, p < .05$. Domestic pilots obtained more time in bed during the first 24 hr recovery ($M = 7.90$), second 24 hr recovery ($M = 8.14$), third 24 hr recovery ($M = 8.10$), and layover ($M = 7.86$) periods combined than flag operation pilots ($M = 6.92, 7.41, 7.59$, and 6.87 respectively). All other main effects and interactions for layover time in bed, and any recovery sleep period were not significant.

Although separate two-factor ANOVAs resulted in a significant difference between domestic first officers and flag first officers for time in bed during the second 24 hr recovery period, this significant difference was not found in the three-factor ANOVA. This absence of significant findings may be due to the inclusion of error variance from the first and third recovery period, and average layover time in bed, which could potentially mask any significant findings.

Age related factor on flight type and flight position. Could these results be affected by age? A two-factor ANOVA was conducted to determine if an interaction existed for type of flight operation and position as the independent variables, and age as the

dependent variable. The overall analysis indicated a main effect of flight type, $F(1,36) = 16.08, p < .001, R^2 = .42$, and flight position, $F(1,36) = 6.08, p < .05$. A significant interaction effect between flight type and position was also obtained, $F(1,36) = 4.39, p < .05$. In order to determine the source, and nature of the significant interaction effect, simple comparison analyses were conducted examining the effect of flight type on captain and first officer positions.

The simple comparison for flight type for the captain position was significant, $F(1,36) = 18.10, p < .001$. Captains flying flag operations ($M = 54.78$) were older than captains flying domestically ($M = 38.37$). The simple comparison for flight type for the first officer position was not significant, $F(1,36) = 1.21, p = .28$. First officers flying domestic operations ($M = 37.37$), and flag operations ($M = 42.52$) were similar in age. In addition, captains ($M = 38.37$), and first officers ($M = 37.37$) as a group were similar in age in domestic flight operations, but captains ($M = 54.78$) were older than first officers ($M = 42.52$) employed in flag operations.

Multiple Regression

A series of analyses were conducted toward the prediction of average time in bed during layover including morningness-eveningness, sleep disorders, and flight operational variables. The morningness-eveningness questionnaires were examined to determine which of the questionnaires better predicted group membership for flight type. Both the morningness-eveningness and the sleep disorders questionnaires were also examined to eliminate variable redundancies prior to conducting the main hierarchical regression analysis in predicting average layover time in bed.

Morningness-eveningness. A Pearson correlation coefficient was conducted to determine the relationship between the two morningness-eveningness questionnaires to see if the Basic Language Morningness (BALM) Scale was more applicable to a commercial air carrier pilot population than the more widely used Horne-Östberg Morningness-Eveningness Questionnaire (MEQ). The instruments are highly correlated, $r = .91, p < .01$.

A direct discriminant analysis was conducted to determine whether the MEQ and the BALM scale could distinguish between domestic and flag operation pilots. The overall relationship between the two morningness-eveningness questionnaires, and the two groups was statistically significant, $\lambda = .84, \chi^2(2, N = 40) = 6.30, p < .05$, with the predictor variables accounting for 16% of the variance between groups.

Table 5 presents the standardized discriminant function coefficients and structure coefficients to identify the predictor variables contributing to the significant relationship. The largest standardized coefficient was the MEQ (.99). To determine the nature of the relationship between the predictor variables and the two groups, Table 6 shows descriptive statistics and univariate F-ratios. Based on these results, the MEQ described domestic pilots as having *neither morning nor evening* preference ($M = 51.35$), whereas flag operation pilots were described as having a *moderately morning* preference ($M = 60.06$). The BALM Scale described the domestic pilots as having *neither morning nor evening* preference ($M = 36.90$), whereas flag operation pilots were described as having a *mild morning* preference ($M = 43.00$).

The predictor variables were able to correctly classify membership between domestic and flag operation pilots with an overall hit rate of 63.2%. Predicted group membership for the domestic and flag operation pilots were 65.0% and 35.0% respectively. Based on a classification assumption of equal prior probability of membership (50%), the MEQ and BALM Scale seem to be able to determine domestic and flag operation pilot morningness-eveningness preference equally well.

A standard multiple regression would have been conducted on the BALM Scale and MEQ ability to predict average layover time in bed in order to uncover possible relationships between morningness-eveningness preference and the amount of time in bed that may be obtained during layover, but Pearson correlation coefficients indicated that both morningness-eveningness preference instruments are highly correlated with each other (see Table 7). Predictor variables should not correlate with each other in order to account for as much variance as possible in the criterion variable. Therefore, the standard multiple regression was not conducted due to the multicollinearity nature of the predictor variables. However, due to the fact that the MEQ had the greatest weight (importance) to distinguish between groups (i.e. the relationship to flight type and accounting for variance overlap), the MEQ was entered into the final hierarchical regression.

Sleep disorders. A standard multiple regression was conducted with five sleep disorder predictors (restless leg syndrome, sleep apnea, difficulty sleeping, excessive daytime sleepiness, and narcolepsy) to determine which of the five variables best predicts average layover time in bed. Restless leg syndrome is an intrinsic sleep disorder characterized by an intense urge to move the legs and may be accompanied by a tingling

sensation. Symptoms occur periodically and may intensify in the evening or nighttime hours. Onset occurs during rest, and relief is usually in the form of moving the legs or walking (Montplaisir, Nicolas, Godbout & Walters, 2000). Narcolepsy is an insomnia disorder associated with the central nervous system that is characterized by recurrent and uncontrollable sleep of short duration that may occur suddenly during any moment of the day or night, and is usually accompanied by falls (cataplexy; Guilleminault & Anagnos, 2000).

Correlation coefficients for each predictor were examined (see Table 8).

Correlations were flagged with values $\geq .70$ because high positive correlations among predictors provide an indication that variables are redundant, which inflate error term size and weaken the analysis (Tabachnick & Fidell, 2001). The excessive daytime sleepiness and apnea variables were highly correlated with the restless leg variable, and therefore were omitted from further analyses. All other variables possessed weak correlations with average layover sleep and with each other. The overall relationship among the independent sleep disorders variables and amount of layover time in bed was not significant, $R^2 = .12$, $F(5,33) = .86$, $p = .51$. Thus, none of the sleep disorder variables were added to the final hierarchical multiple regression correlation.

Predicting layover time in bed. A hierarchical multiple regression was conducted with five flight operational predictor predictors (average mean flight time per trip pattern, average mean duty time per trip pattern, average time zone crossings per flight segment, average number of flight segments per trip pattern, and total number of trip patterns during the protocol period), and two physiological variables (age, morningness-

eveningness preference) to predict the criterion variable of average amount of time in bed during layover. Correlation coefficients were examined for each variable (see Table 9). Average flight time was highly correlated with average flight segments, average time zones crossed, and average mean duty time. Therefore, average flight time was omitted from further analyses.

The overall relationship of the flight operational variables used to predict time in bed during layover was significant, $R^2 = .34$, $F(6,31) = 2.64$, $p < .05$. Only the average number of time zone crossings per flight segment was important in predicting the amount of layover time in bed (see Table 10). The greater the number of time zones crossed, the shorter the obtained amount of layover time in bed. Age and MEQ were not significant, and did not provide a significant relationship above and beyond the flight operational variables toward predicting average layover time in bed.

Light Analysis

A comparison of light exposure during the day and night by flight type and position.

A three-factor mixed factorial ANOVA was conducted to examine the effects of flight type, position, and time of light exposure (day or night). Flight type and position were between-subjects variables, and time of light exposure was a within-subjects variable. Overall analysis showed no main effect or interaction between night and day light exposure for either domestic and flag operation types, or captains and first officer positions.

A comparison of light exposure on the ground and during flight operations by flight type and position. A similar three-factor (2 x 2 x 2; flight type by flight position by light exposure location) mixed factorial design ANOVA was conducted with a between-subjects factor of type of flight (domestic, flag operation), and between-subjects factor of flight position (captain, first officer) as independent variables, and within-subjects independent variable of light exposure location (ground, flight) to compare differences of average light exposure on the ground and during flight operations.

Overall analysis showed an interaction between light exposure on the ground and in-flight by flight type, and flight position, $F(1,36) = 7.99, p < .01$ (see Figures 4 & 5). Simple comparison analyses were conducted to examine the interaction of light exposure location by flight type and flight position. Domestic first officers obtain less exposure to light on the ground ($M = 549.01$) than during flight operations ($M = 619.17$; see Figures 4 & 5). There seemed to be differences of light exposure greater than 100 lx between the domestic pilots ($M = 619.19$) and flag operation pilots ($M = 514.83$) on the ground, and the domestic pilots ($M = 649.26$) and flag operation pilots ($M = 507.95$) during flight operations, but these differences were not significant, and were most likely due to the large variability in the data (see Table 11). No other main effects or interactions were statistically significant.

Summary Results

Overall, domestic pilots obtained more time in bed than flag operation pilots over the 40-day protocol. When examining time in bed periods more specifically, domestic pilots obtained more time in bed than flag operation pilots at home as well as time in bed

at layover hotels. After returning home from trip patterns, domestic and flag operation pilots obtained similar amounts of time in bed for the first and third successive 24 hr sleep periods. During the second 24 hr sleep period however, domestic first officers obtained more time in bed than flag operation first officers, domestic captains, and flag operation captains.

A difference in flight position was also found between average time in bed at home, and average time in bed obtained at layover hotels. Captains obtained less time in bed during layover than at home. More specifically: (a) flag operation captains obtained significantly less time in bed during layover than at home; (b) domestic first officers obtained more time in bed at home than flag operation first officers; and (c) domestic captains obtained more time in bed during layover than flag operation captains.

Morningness-eveningness preference instruments were able to equally predict group membership between domestic and flag operations. However, MEQ and age were not significant variables in the hierarchical multiple regression. The average number of time zones crossed per flight segment was the only significant predictor of the amount of time in bed at layover hotels such that the more time zones that were crossed during flight operations, the less time in bed was obtained during layover.

Finally, although there was no significant difference between the light exposure obtained during the day or night for flight type or position, domestic first officers seem to have more light exposure during flight operations than on the ground.

DISCUSSION

The monitoring of flight crew with the use of an activity monitor and subjective log is not unique. Buck, Tobler, and Borbely (1989) wished to determine if wrist actigraphy could measure sleep quality in flight crews during north-south, transatlantic and transpacific flights of 6 to 11 days in duration covering 5 baseline periods before trip patterns through 5 recovery periods after trip patterns spanning 1 to 17 time zones. Although data collection epochs (intervals) were 7.5 min, assessments were possible in comparing layover and recovery sleep. Layover periods were reported on average as 8.13 hr. However, recovery periods were only reported by percent differences compared to baseline periods, and baseline means were not reported.

This study explored the sleep-wake activity, duty and flight schedules, and light exposure over a period of 40 days in domestic and flag operation flight crew. No literature was available on the examination of flight crew to obtain an understanding of sleep, wake, light exposure, and flight schedules over extended periods of time. Thus, this exploratory study has shown that the monitoring of flight crew through use of actigraphy and an activity log is possible to determine time in bed for 40 days of flight activity for domestic and flag operation pilots.

Some research has been conducted concerning the amount of sleep obtained by pilots during layover. A team of researchers from Asia, Europe, and the United States carried out a series of studies of flight crew on eastbound and westbound international flights to subjectively (via questionnaires), objectively (via sleep latency test), and physiologically (via EEG, respiration, leg movement, and heart rate) determine the

amount of sleep obtained during layover. Dement, Seidel, Cohen, Bliwise & Carskadon (1986) found that older pilots obtained less total sleep time (the actual time asleep minus wake time within a rest period as measured by EEG; Chokroverty, 1995) than younger pilots in a sample of 12 pilots and seven flight engineers on flights from San Francisco to London and San Francisco to Tokyo. Total sleep time was found to be 6.59 hr during sleep in the home time zone, and 6.07 hr during the first layover sleep period.

Sasaki, Kurosaki, Mori & Endo (1986) examined six captains and six flight engineers during flights between San Francisco and Tokyo, and found that these flight crew obtained 7.78 hr time in bed within the home time zone consisting of 7.19 hr total sleep time. During layover, these pilots obtained 6.28 hr time in bed consisting of 5.41 hr total sleep time.

Nicholson, Pascoe, Spencer, Stone, and Green (1986) examined 13 pilots during flights between San Francisco and London, and determined that the pilots were obtaining 7.42 hr total sleep time at home, and 7.26 hr total sleep time during layover.

Wegmann, Gundel, Naumann, Samel, Schwartz, and Vejvoda (1986) examined 12 flight crewmembers operating between California and Frankfurt, and found that these pilots obtained 7.96 hr time in bed consisting of 7.19 hr total sleep time at home. During the westbound trip from Frankfurt to San Francisco or Los Angeles, the flight crew obtained 9.18 hr time in bed consisting of 7.83 hr total sleep time. During the eastbound flights from San Francisco and Los Angeles to Frankfurt, the pilots obtained 6.10 hr time in bed consisting of 5.45 hr total sleep time.

The findings from Dement et al., Sasaki et al., Nicholson et al., and Wegmann et al. are consistent with the present study, which demonstrated that aircrew obtained less time in bed during layover than time in bed at home. The analysis of self-reported baseline sleep provided evidence to conclude that the differences found for the amount of time in bed are not due to any pre-existing differences between flight type and position. Also, the findings from the present study provide a unique contribution to past literature that examined trip patterns spanning 3 to 20 days by expanding the results from previous studies that can now be generalized out to 40 days. Future analyses could be conducted to compare any differences that may have occurred between eastbound and westbound flights in the present study to obtain more insight into the differences relating to home and layover time in bed periods.

When examining time in bed after returning home from trip patterns, the present study showed that domestic first officers obtained more time in bed than flag operation first officers on the second recovery period. Domestic pilots as a group obtained on average 7.96 hr time in bed whereas flag operation pilots obtained on average 7.53 hr time in bed for the first 72 hr period after returning home from trip patterns respectively. Similar results of recovery periods for flag operation pilots were obtained during recovery sleep from a study of aircrew flying polar routes between Europe and Asia (Spencer, Stone, Rogers & Nicholson, 1991). Three sets of flight crew operating four different flag routes obtained on average 6.23 hr of recovery sleep for the first three recovery periods after returning home from trip patterns as measured by EEG.

Although a main effect of group was the only significant finding comparing layover and recovery sleep in the present study, heterogeneity of variance due to unequal sample sizes for the repeated measure of layover time in bed and/or the number of available recovery periods may address a portion of this issue. Some pilots were able to obtain only one or two sleep periods after returning home from a trip pattern before they were required to leave to fly a new trip pattern the subsequent 24 to 48 hr.

Although age was not a significant predictor of the time in bed obtained during layover, analyses showed that the domestic captains, domestic first officers, and flag operation first officers were all similar in age. A different result may have occurred if there was more variation in participant age.

A significant relationship does exist among age, type of flight, and flight position. Why pilots cluster into the different flight type or position categories is a separate question. Domestic first officers would definitely be the youngest group, and flag operation captains would be the oldest group because these groups are linked to seniority, which is specifically linked to time employed by an airline. Whether domestic captains and flag operation first officers self-select into those groups could be due to domestic captains wishing to stay closer to home, or not wishing to fly multiple time zone routes. Flag operation first officers may want to engage in the economic benefits of flying larger aircraft farther distances, and not requiring to be the final authority and responsibility for the safe operation of every flight. These reasons however, are solely speculation. Determining whether there is a self-selecting nature towards the direction age groups fall

within flight type or position would require further data collection to look at that specific question.

Morningness-eveningness preference was able to predict type of flight operation, but was unable to predict amount of time in bed during layover above and beyond the flight operation predictor variable of time zone crossings per flight segment. Sasaki et al. (1986) found a morningness-eveningness component when tracking changes to sleep-wake patterns during flight operations. This group of pilots appeared to have influences of morningness-eveningness preference as shown on a daytime sleepiness measure and a modified Horne-Östberg MEQ. The pilots that were scored as more morning-type experienced more daytime sleepiness. Gander et al. (1993) found within a military and commercial flight crew population of *short haul*, *long haul*, and overnight cargo pilots ($N = 91$) that: (a) the younger pilots (20-30 years) were more evening-type; (b) the temperature rhythm (a marker of the circadian rhythm) nadir occurred later in the younger pilots than the older pilots (30-40 and 40-50 years); (c) the amplitude of the temperature rhythm declined with increasing age; and (d) based on a multiple regression of factors contributing to the variance in sleep loss, the most important predictors of sleep loss were local time of temperature minima (circadian phase) and circadian amplitude such that the greater average daily percentage of sleep loss was associated with individuals who experience earlier baseline temperature minima (advanced circadian phase) and lower rhythm amplitude. Although accounting for only 5% of the variance, results from the multiple regression also indicated that individuals with a morningness preference experienced an earlier occurrence of the temperature minimum.

In the present study, flag captains were significantly older than other pilots, and flag operation pilots were characterized by a *moderately morning* preference. Consistent with the prediction of sleep loss from Gander et al. (1993), flag captains were also found to obtain the least amount of layover time in bed. Further investigation may provide insight on methods to optimize pilot flight schedules, or provide pilots with a tool to predict trip patterns that may be more appropriate based on their morningness-eveningness preference.

The sleep disorders index was not able to predict the time in bed during layover. Commercial air carrier pilots are required to undergo, and must pass flight physicals that are performed every six months by an FAA Aero Medical Examiner in order to maintain flight privileges. The literature is scarce in this regard. Although it has been stated anecdotally that some pilots have been diagnosed with sleep apnea, and have successfully managed this condition, there is very little information on the prevalence of sleep disorders in this community. Narcolepsy would most likely be screened out during a flight physical as this disorder is one of the more severe sleep disorders, but others may go unnoticed (i.e. apnea, excessive daytime sleepiness, restless leg syndrome, difficulty sleeping).

Flight operations during this study of 40 days of flight activity were similar to the flight characteristics of other studies. Gander et al. (1998a) showed that *short haul* pilots flew an average of 5.10 flight segments with each flight averaging 4.50 hr within a 10.70 hr average duty period. In comparison, the domestic pilots in this study flew an average of 2.81 flight segments with each flight averaging 4.66 hr within a 9.61 hr average duty

period. *Long haul* pilots (Gander et al., 1998b) flew an average of 1.2 flight segments. Each flight segment was 6.90 hr on average within a 10.30 hr average duty period. The flag operation pilots during this 40-day protocol flew an average of 1.04 flight segments with an average of 9.73 hr flight time within an 11.99 hr average duty period.

The flight operational variables selected to predict time in bed during layover were obtained from several sources including the regulations from several countries' aviation regulations for flight and duty time limitations (Wegmann et al., 1983). Beyond the obvious note that the variables are moderately correlated with each other, several suppressor variables were present in the hierarchical multiple regression (number of trip patterns per month, average duty time per trip, and MEQ). Suppressor variables are more highly correlated with other independent variables than with the dependent variable accounting for more variance in the independent variables than the dependent variable. Suppressor variables are identified by: (a) $t < \beta$; (b) t and β that possess opposite values (positive/negative) for a given independent variable; (c) opposite values (positive/negative) from zero order to partial correlation for a given variable; or (d) the decreasing progression from zero order to partial correlation values. These suppressor variables may have caused some independent variables to be significantly correlated with the dependent variable of average layover time in bed individually, but not significant when combined with other independent variables. Modeling efforts in this area would be worthy of investigation to determine which combinations of flight parameters may be able to best predict not only the possible amount of time in bed during home, layover, or recovery sleep periods, but (also) waking performance.

Fatigue is a complex issue in the aviation industry and various methods to mitigate fatigue on the flight deck have been explored. It has been shown that the use of strategic napping on the flight deck is an effective countermeasure in alertness management (Rosekind et al., 1994). Since this finding was released, napping on the flight deck has been implemented at several non-U.S. flag commercial air carriers but is not currently sanctioned on U.S. commercial air carriers. No formal action has been taken by the FAA to provide guidance on its use. Until these issues are resolved concerning pilot napping on the flight deck, other measures must be explored to manage fatigue in the U.S. commercial aviation industry. One study has been conducted to examine the efficacy of activity breaks as a fatigue management tool for commercial flight crews (Neri et al., 2002).

Another approach that is at the forefront in efforts to mitigate flight crew fatigue is modeling. Researchers at Brooks Air Force Base (United States of America), Walter Reed Army Institute of Research (United States of America), University of Southern Australia (Australia), University of Zurich (Germany), Karolinska Institute (Stockholm), Harvard University (United States of America), and other commercial entities are looking at different methods to provide commercial air carriers and other aviation organizations with an approach to enhance safety in the management, scheduling, and operations of flight crew and other resources. Models to predict alertness are based on a variety of factors including circadian rhythms, sleep homeostat, sleep inertia, light exposure, cognitive throughput, rest-activity cycles, work schedules, and subjective alertness. The sleep homeostat is a brain mechanism that regulates daily amounts of sleep. The process

ensures that the proper amount of sleep an individual needs is obtained by increasing the tendency to fall asleep in direct proportion to the increasing size of sleep loss (Dement, 1997). Sleep inertia is the transitional state from sleep to wake characterized by low arousal, but normal vigilance and dissipates gradually over a period up to several hours (Tassi, Bonnefond, Hoeft, Eschenlauer, Muzetand, 2003). Each model uses its own set of these aforementioned variables and some models are based on a derivative of these variables. Some of the models have been validated from laboratory studies extrapolating shift work data into a model that could be used as a first step to transition the information into an aviation environment.

One of the first models examining the prediction of alertness in humans used subjective alertness data of shift workers to provide insight into the feasibility of such a tool (Folkard, Akerstedt, Macdonald, Tucker & Spencer, 1999). Another model was based on subjective alertness and objective performance of locomotive engineers (Dawson & Fletcher, 2001). The factors used in other models are selected on the bases of research on sleep propensity and regulation (sleep deprivation), forced desynchrony (constant routine) studies, and effects of light on the circadian system (Van Dongen & Dinges, 2001). A constant routine protocol is designed to investigate endogenous circadian rhythms without environmental and behavioral *masking* that may be due to varying environmental light levels, temperature and humidity fluctuations, exercise, food intake, postural changes, and ability to sleep (Czeisler, Kronauer, Allan, Duffy, Jewett, Brown, et al 1989). Recent work by Van Dongen and Dinges (2003) showed potentially

new interactions between the homeostatic and circadian components of sleep to predict alertness during wakefulness.

Focusing on the aviation environment, one model has used field data on a limited number of commercial pilots during an east-west trip schedule (Gundel & Spencer, 1992). More specifically, studies have been conducted to collect actigraphy, core body temperature, and subjective report data from pilots on flight schedules eastward, westward, over polar routes, domestically, and internationally. These field studies encompassed 3 to 18 day trip patterns (Dement et al., 1986; Gander et al., 1998a, 1998b; Lowden & Akerstedt 1998, 1999; Rosekind et al., 1994; Samel et al., 1997; Spencer et al., 1991).

Survey data have been collected that provide a good foundation that describe the sleep-wake patterns in short haul and long haul flight operations, but little information is available on the use of light exposure as a method for properly shifting the circadian rhythms in flight crew, which could be especially beneficial for crews that traverse multiple time zones. Light has been demonstrated to be a significant method for shifting the circadian rhythm in humans (Jewett & Kronauer, 1999). Babkoff, French, Whitmore, and Sutherlin (2002) examined the effects of a 1 hr light exposure (3,000 lx) period, and 200 mg doses of caffeine pills in a four-way design (light and caffeine; light and no caffeine; no light and caffeine; and no light and no caffeine) constant routine during a simulated night shift. If light was used in a particular condition, it was provided at the peak time of melatonin secretion. It was determined that both the 1 hr bright light exposure period provided at the peak of melatonin secretion and the one dose of caffeine

increased alertness throughout the rest of the simulated night shift. If only light exposure was provided, then performance increased directly after the 1 hr pulse was administered, but gradually increased sleepiness and decreased performance throughout the rest of the shift. Also, Bolvin, Duffy, Kronauer, and Czeisler (1996) determined that relatively low intensity indoor room light (about 180 lx) was able to significantly phase advance the human circadian clock.

It has been determined in the present study that: (a) captains obtain less time in bed during layover than at home; (b) more specifically, flag operation captains obtain less time in bed during layover than domestic captains; (c) flag captains are significantly older than other pilots; and (d) flag operation pilots are characterized by a moderately morningness preference. Other studies have suggested that: (a) older pilots are characterized by more morningness than eveningness preference, and morningness preference is associated with an advanced circadian phase; (b) older pilots experience an advanced circadian phase, which is associated with average daily sleep loss; and (c) light provided at a certain time of the circadian cycle with proper intensity for a specific duration can be used to significantly shift circadian phase. The present study demonstrates that there are sufficient sources of light on the flight deck during the day and night with ample intensity that may be used to shift the circadian rhythm and potentially provide pilots with an alerting effect. The limitation of the duration this light may be used is limited to the operational requirements that pilots must maintain an appropriate amount of light (or darkness) to safely conduct flight operations. Field study research into the dose response relationship of light exposure (both intensity and

duration) and additive effects of other countermeasures such as caffeine, naps, and rest breaks may provide pilots (especially captains) a set of tools that may be used in various situations to decrease sleepiness, increase alertness, and ultimately increase the safety factor prior to as well as when conducting commercial air carrier operations. The examination of light over 40 days in a commercial air carrier pilot population provides a first step towards this goal.

It is difficult to interpret the reason why average light levels were similar during the day and at night as well as the light exposure that was obtained when participants were on the ground and when they were engaged in flight operations. The variability of the data may have equalized any differences between day and night, or light exposure on the ground and during flight operations. It must be noted that with any field study, it is impossible to control for compliance issues with use of any equipment (in this case, the proper use of the light sensor). Although participants were instructed explicitly on the use of the light sensor during the protocol period (see Appendixes J, L & O), in addition to being provided a section in the activity log to record times when the activity monitor or light sensor were removed, it may not be possible to determine from the raw data when the light sensor was removed and separated from the participant. For example, it would not be possible to determine with certainty that the light sensor was removed and separated from a participant, or if the participant may have been taking a nap in a dark or low light area, watching a film at a movie theater, or taking part in some other event during civil twilight hours when low light levels were present in the data unless the event was recorded in the activity log. Future analyses to determine the source of the

variability may include separating light data for each participant by each day of the protocol period. This exercise may also uncover why domestic first officers are exposed to significantly more light during flight operations than during their time on the ground.

One field study examining the light exposure during a transpacific flight on one commercial air carrier westbound and eastbound during both day and night flights between the United States and Japan showed that light levels were 1,513 lx and 1.05 lx during daytime and nighttime flight operations respectively (Rodriguez, Oyung, Barger, Mallis & Jewett, 2002). Light levels on the ground ($M = 642$, $SD = 80$) were somewhat similar to light levels on the ground recorded in the present study, but again, the variability must further be examined ($M = 569.62$, $SD = 301.43$).

Overall, domestic pilots obtain more time in bed than flag pilots, and this period extends to both the amount of time in bed at home and the amount of time in bed during layover. Although all pilots obtained about the same amount of time in bed during the first 72 hr of sleep opportunity after returning home from trip patterns, it seems that the domestic first officers obtain the most time in bed after returning home from trip patterns on the second 24 hr sleep opportunity period. It is important to note that time in bed does not equal time asleep. Belenky et al. (2003) and Van Dongen et al. (2003) conducted parallel studies on a dose-response curve of varying amounts of time in bed and the cost in neurobehavioral performance associated with the amount of time in bed in 1 hr increments from 3 to 9 hr. Specific to recovery sleep, Belenky et al. (2003) reported that 3 days of recovery sleep was insufficient to restore performance on a psychomotor vigilance task to baseline levels for those participants subjected to 5 or 7 hr total time in

bed for the 7 consecutive days of partial sleep deprivation. Although time in bed and actual sleep time are clearly related, it is important to note that total time in bed does not equal the total amount of sleep obtained, but only the opportunity to sleep. Total sleep time was reported as 7.93 hr, 6.28 hr, 4.66 hr, and 2.87 hr for the 9, 7, 5, and 3 hr time in bed groups. Thus, a limitation of this study is the inability to determine the amount of time participants are actually asleep at home, during layover, or during any recovery periods.

Flag operators fly more time zones per flight segment, which has been determined to be a significant predictor of the amount of average layover time in bed in that the more time zones that are crossed during flight operations, the less time in bed may be obtained during layover. In addition, flag operation captains are older than their flag operation first officer colleagues or domestic pilots of either position.

Simulation of these variables, and their interaction with each other surrounding sleep loss and circadian rhythm disruption may assist in the specification of issues pertinent to commercial air carrier safety, and provide a better understanding of how napping, the proper use of light, or other countermeasures may be applied in the aviation environment to expand on the safety factor.

An overall goal of this study was to examine the sleep/wake cycles and light exposure of commercial air carrier pilots in order to determine the extent of sleep loss and circadian disruption that may occur over 40 days of flight activity. Results objectively show that participants were on average in bed between 6.67 and 8.27 hr throughout the protocol period at home, during layover, and during the first 72 hr after

returning home after trip patterns. Do these numbers fully convey the level of fatigue experienced by pilots during flight operations? The impact of flight activity on sleep loss and circadian rhythm disruption has also been measured subjectively. Two items were presented to participants from the NASA Background Questionnaire as follows: (a) "Have you ever nodded off during a flight?" and (b) "Have you ever been on a flight where arrangements were made for one of the pilots to nap in their cockpit seat during the leg?" Rosekind, Co, Gregory, and Miller (2000) found that the two most common suggestions from corporate pilots to reduce fatigue in corporate aviation were to set flight, duty and rest limits, and improve scheduling. Corporate pilots operate under a different set of FARs (Part 91; general aviation) that do not specify flight, duty, or rest limits. However, participants reported: (a) flying on average 13.8 trips per month consisting of 35.2 flight hours per typical month; (b) having a 9.9 hr typical duty period; (c) flying 3.2 flight segments per typical duty day; and (d) crossing three or fewer time zones per flight during 95% of typical flights. Of 1,488 respondents, 71% reported having "nodded off" during a flight whereas 39% reported that arrangements were made for one crewmember to nap in the cockpit seat during a flight segment.

Regional pilots operating under Part 121 and 135 (commuter and on demand operations) have also responded to these same items in a separate survey (Co et al., 2000). These regional pilots reported: (a) flying on average 18.3 trips per month consisting of 81.3 flight hours per typical month; (b) having an average typical duty period of 11.2 hr; and (c) flying 3.2 flight segments per typical duty day. Eighty percent of these regional pilots ($N = 1,424$) reported nodding off during a flight whereas 56%

reported that arrangements were made for one pilot to nap in the cockpit seat during a flight segment.

In the present study, 85.7% of domestic pilots and 94.7% of flag operation pilots reported nodding off during a flight whereas 76.2% of domestic pilots and 94.7% of flag operation pilots made arrangements for one pilot to sleep in the cockpit seat during a flight segment. It must be noted that these survey results are subjectively based, and must be evaluated with this in mind. In addition, there is also a sampling limitation due to the self-selecting nature of the survey studies mentioned and the present study's quasi-experimental design. Nevertheless, the findings do bring to surface an issue that must be addressed in order to determine the impact of fatigue, sleep loss, and circadian rhythm disruption over extended periods of time, and find ways to identify countermeasures that pilots may use before, during and after flight operations to increase aviation system safety for everyone in the air as well as for those of us on the ground.

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Dear Raymond,

You have permission to include a copy of the Multivariable Apnea prediction and Sleep Symptom Frequency (MAP) Form in your thesis, but be certain to cite on the inclusion the published paper from which this scale can be found.

Sincerely,

David F. Dinges, Ph.D.
Professor and Chief

FROM : Sleep Lab

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26 NOV. 2003 01:34PM P1

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From: Prof. Jim Horne
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Date: 26 November 2003

Number of pages (inc. cover sheet): 1

Dear Ray

I give you permission to use the Horne-Osteberg Morningness-eveningness Questionnaire for scholarly purposes.

Regards

Jim Horne

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Raymond Oyung
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Dear Raymond,

You have permission to include a copy of the Basic Language Morningness (BALM) Scale in your thesis entitled "Activity and Light Exposure Patterns in Flight Crew."

Sincerely,

Frederick Brown, Ph.D.
Associate Professor of Psychology
Cognitive/ Health Psychology

Appendix A
Tables and Figures.

Table 1.
Average Boeing Aircraft List Prices for FY2002

Model	Price
717	37.5
737-800	61.0
747-400	198.0
767-300ER	121.5
777-300ER	217.5

Note. All values are in millions of U.S. dollars.

Source: Aviation Today. Retrieved August 7, 2003 at

<http://www.aviationtoday.com/VIP/values/value081202a.htm>

Table 2.
Activity Monitor and Light Sensor Storage Capacity Based on Device Type and Epoch
Length

	Epoch length (min)				
	0.25	0.50	1.00	2.00	5.00
	Storage capacity (days)				
Actiwatch-64K	11.3	22.7	45.4	90.8	
Actiwatch-L	3.7	7.5	15.1	30.2	75.7

Table 3.
Contents of Each Package Sent to Study Participants

1. Introduction letter (see Appendix M)
 2. Verification of study Participation letter for airport security (see Appendix N)
 3. Certificate of Registration Customs Form 4457 (pilots flying international routes only)
 4. NASA Background Questionnaire (see Appendix C)
 5. Multivariable Apnea Prediction and Sleep Symptom Frequency Form (SleepMAP; see Appendix D)
 6. Preference Questionnaire (MEQ; see Appendix E)
 7. Basic Language Morningness Scale (BALM; see Appendix F)
 8. Activity log instruction manual (see Appendix O)
 9. Activity monitor and light sensor instruction manual (see Appendix P)
 10. 50 W foreign travel voltage converter instructions
 (pilots flying international routes only)
 11. Actiwatch-64
 12. Actiwatch-L
 13. Palm Pilot Vx
 14. Palm Pilot charging cradle
 15. 50 W foreign travel voltage converter (pilots flying international routes only)
 16. NASA *Z Team* baseball cap
 17. NASA *Z Team* stickers
 18. Business cards with Principal Investigator contact information
 19. Express service air waybill to return equipment to NASA Ames Research Center
-

Table 4.
Descriptives Overall and by Flight Type (N = 40)

Variable		Overall	Domestic	Flag
Age	Mean	42.90	37.99	48.33
	SD	10.50	9.13	9.33
	N	40	21	19
Gender				
male	n	37	19	18
	%	92.50	47.50	45.00
female	n	3	2	1
	%	7.50	5.00	2.50
Position				
captain	n	21	13	9
first officer	n	19	8	10
Flight Ops				
trips/month	Mean	13.25	16.81	9.31
	SD	5.76	5.19	3.28
legs/trip	Mean	1.97	2.81	1.04
	SD	1.08	.85	0.07
time zones	Mean	3.82	0.97	6.97
	SD	4.62	0.77	5.06
duty time (hr)	Mean	10.21	9.61	11.99
	SD	2.55	1.50	2.29
flight time (hr)	Mean	7.07	4.66	9.73
	SD	2.97	0.83	2.02
Sleep (time in bed; hr)				
overall	Mean	7.35	7.96	6.67
	SD	1.05	0.89	0.78
home	Mean	7.65	7.97	7.30
	SD	0.95	0.89	0.89
layover	Mean	7.39	7.86	6.87
	SD	1.17	0.82	1.21
recovery 1	Mean	7.43	7.90	6.92
	SD	1.61	1.26	1.82
recovery 2	Mean	7.79	8.14	7.41
	SD	1.14	1.06	1.13
recovery 3	Mean	8.06	7.85	8.27
	SD	1.36	1.49	1.22

Note. legs/trip (flight segments per trip)

Figure 1. Two-way Interaction of Sleep Location for Domestic and Flag Operation Captains.

Note. Error bars represent standard error of the mean.

Figure 2. Two-way Interaction of the Average Time in Bed at Home for Flight Type and Position.

Note. Error bars represent standard error of the mean.

Figure 3. Two-way Interaction of Sleep Location for Flight Type and Position.

Note. Error bars represent standard error of the mean.

Table 5.
Standardized Discriminant Function Coefficients and Structure Matrix for Morningness-Eveningness Preference by Domestic and Flag Operation Pilots (N = 38)

	Standardized discriminant func.	Structure matrix
BALM	-.25	.83
MEQ	1.21	.99

Note. BALM (Basic Language Morningness Questionnaire)
 MEQ (Horne-Östberg Morningness-Eveningness Questionnaire)

Table 6.
Descriptives and Univariate F-ratios for Flight Type and Morningness-Eveningness Preference (N = 38)

Variable		BALM	MEQ
Domestic	Mean	36.90	51.35
	SD	9.45	11.52
Flag operations	Mean	43.00	60.06
	SD	7.20	8.28
Wilks' Lambda		.88	.84
<i>F</i>		4.92	7.01
<i>df</i>		1,36	1,36
<i>p</i>		.03	.01

Note. BALM (Basic Language Morningness Questionnaire)
 MEQ (Horne-Östberg Morningness-Eveningness Questionnaire)

Table 7.
Correlation Matrix of Morningness-Eveningness Variables on Layover Time in Bed

(N = 38)

	Layover	BALM	MEQ
Layover	1.00		
BALM	-.03	1.00	
MEQ	-.08	.91***	1.00
Mean	7.36	39.79	55.47
SD	1.17	8.90	10.91

Note. *** $p < .001$.

BALM (Basic Language Morningness Questionnaire)

MEQ (Horne-Östberg Morningness-Eveningness Questionnaire)

Table 8.
Correlation Matrix of Sleep Disorder Variables (N = 39)

	Layover	Restless leg	Apnea	Diff slp	Excess day slp	Narcolepsy
Layover	1.00					
Restless leg	-.07	1.00				
Apnea	.04	.81***	1.00			
Diff slp	-.28*	-.05	.07	1.00		
Excess day slp	-.16	.71***	.70***	.40**	1.00	
Narcolepsy	-.04	.10	.40	-.02	.03	1.00
Mean	7.39	.31	.53	1.42	.84	.15
SD	1.17	.25	.55	.63	.47	.26

Note. * $p < .05$ ** $p < .01$ *** $p < .001$.

Diff slp (difficulty sleeping)

Excess day slp (excessive daytime sleepiness)

Table 9.
Correlation Matrix with Flight Operational Variables (N = 38)

	Layover	# trips	# legs	Time zones	Duty time	Flight time	Age	MEQ
Layover	1.00							
# trips	.30*	1.00						
# legs	.35*	.66***	1.00					
Time zones	-.57***	-.54***	-.60***	1.00				
Duty time	-.39**	-.65***	-.57***	.69***	1.00			
Flight time	-.45**	-.67***	-.76***	.79***	.87***	1.00		
Age	-.38**	-.37*	-.49**	.61***	.37*	.54***	1.00	
MEQ	-.06	-.19	-.56***	.25	.16	.33*	.17	1.00
Mean	7.36	13.26	1.99	3.89	10.27	7.14	42.40	55.47
SD	1.17	5.91	1.10	4.72	2.59	3.00	10.48	10.91

Note. * $p < .05$ ** $p < .01$ *** $p < .001$.

trips (average number of trip patterns for the protocol period)

legs (average number of flight segments per trip pattern)

Time zones (average number of time zones crossed per trip pattern)

Table 10.
*Summary of Hierarchical Regression for Variables Predicting Time in Bed During
 Layover (N = 40)*

	β	t	Zero-order	Partial	sr^2
# trips	-.06	-.26	.30	-.05	-.04
# flight segments	.14	.53	.35	.09	.08
# time zones crossed	-.55	-2.25*	-.57	-.37	-.33
Duty time	.03	.11	-.39	.02	.02
Age	-.04	-.19	-.38	-.03	-.03
MEQ	.15	.80	-.06	.14	.12

Note. Step 1. $R = .58$; $R^2 = .34$; $R^2_{adj} = .21$; $\Delta R^2 = .02$.

Significant standardized coefficients are in bold; * $p < .05$.

Figure 4. Two-way Interaction of Light Location for Domestic Captain and First Officer Positions.

Note. Error bars represent standard error of the mean.

Figure 5. Two-way Interaction of Light Location for Domestic and Flag Operation First Officers.

Note. Error bars represent standard error of the mean.

Table 11.
Descriptives for Light Exposure on the Ground and During Flight Operations by Flight
Type and Position (N = 40)

Light exposure		Domestic		Flag	
location (lux)		captain	first officer	captain	first officer
Ground	Mean	662.37	549.01	471.20	554.09
	SD	323.57	326.92	315.64	244.29
In-flight	Mean	667.77	619.17	507.81	508.08
	SD	292.89	354.66	369.05	224.91

Appendix B

Activity Monitor, Light Sensor, and Activity Log

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Appendix C

Background Questionnaire

The background questionnaire was developed by the Fatigue Countermeasures Group at NASA Ames Research Center, Moffett Field, California, and adapted from a survey study on sleep quantity and quality of augmented long-haul flight crews in on-board crew rest facilities (Rosekind, Miller, Gregory & Dinges, 2000), and a survey study of fatigue factors in regional airline operations (Co, Gregory, Johnson, Rosekind, 1999).

Background Questionnaire

Fatigue Countermeasures Program
Human Factors Research and Technology Division
NASA Ames Research Center
Moffett Field, CA
2002

BACKGROUND QUESTIONNAIRE

This background questionnaire is being provided to all those who have agreed to participate in the study, Activity and Light Exposure Patterns in Flight Crew.

DO NOT WRITE YOUR NAME ON THIS SURVEY.

This will ensure anonymity for you and your company.

This survey will be administered to as many as 40 subjects and will be held in the strictest confidence.

For research purposes only

We very much appreciate your participation.

GENERAL SURVEY DIRECTIONS:

I. Please answer all questions, and please be as accurate as possible. All information is confidential and anonymous.

II. Please mark boxes and lines as follows:

Small boxes should get a checkmark or an "x": ☐ ⇔ √ or X

Large boxes should get a number:

⇔

Lines should get text:

 kids

III. Watch for special instructions relating to a question or set of questions.

A. GENERAL

1. Gender?

☐ male ☐ female

2. If male, skip to question #4.
Do you use oral contraceptives?

☐ yes ☐ no

3. If yes to question #2,
How long have you used them?

yr mo

4. Age?

yr

5. Weight?

lb

6. Height?

ft in

7. In what time zone relative to UTC
do you live?

hrs (specify + or -)

8. Do you have a bed partner or room-
mate?

☐ yes ☐ no

9. According to him or her, or to your knowledge, how often in the past 3 months have you had:
- | | never | less than
once/week | 1-2 times/
week | 3-4 times/
week |
|---|--------------------------|--------------------------|--------------------------|--------------------------|
| a. loud snoring | ☐ | ☐ | ☐ | ☐ |
| b. long pauses between breaths while sleeping | ☐ | ☐ | ☐ | ☐ |
| c. legs twitching or jerking | ☐ | ☐ | ☐ | ☐ |
| d. episodes of disorientation or confusion during sleep | ☐ | ☐ | ☐ | ☐ |
| e. other sleep problems, please describe | | | | |

10. What is your usual amount/frequency of caffeine consumption? (Enter number of cups of coffee/cafeinated soft drinks)

	daily	weekly
	<input type="text"/>	<input type="text"/>

11. What is your usual smoking frequency? (Enter number of packs of cigarettes)

	daily	weekly
	<input type="text"/>	<input type="text"/>

12. What is your usual amount/frequency of alcohol consumption? (Enter number of drinks: where 1 drink = one 1.5 oz of liquor, one glass of wine, or one 12 oz beer)

	daily	weekly
	<input type="text"/>	<input type="text"/>

13. Do you exercise on a regular bases?
If no, skip to **Section B.**

	yes	no
	☐	☐

14. How often do you exercise?

	less than once/week	1-2 times/ week	3-4 times/ week	over 4 times/ week
	☐	☐	☐	☐

a. List type(s) of exercise you do:

B. SLEEPING AT HOME

Based on an average night of sleep at home (at least 2 days after your return home following a trip), please give one best answer to each of the following questions. Use your local 24-hour clock.

15. On average, how many nights of sleep do you get at home between trips? nights
16. On your days off duty, what time do you usually go to bed?
time, 24-hr clock
17. On your days off duty, how long after going to bed do you usually fall asleep? hr and min
18. When sleeping at home, how many times on average do you wake up? times
19. If you wake during the night, what most often awakens you?
(Check **ONLY** one answer.)
☐ bathroom	☐ can't sleep
☐ children/spouse	☐ noise
☐ other	
20. If you wake during the night, on average, how long does it take you to go back to sleep? hr and min
21. When sleeping at home, what is the amount of total sleep you get on average? hr and min
22. On your days off duty, what time do you usually get out of bed?
time, 24-hr clock

23. On average, how much sleep per 24 hr day have you obtained during the past 30 days? hr and min

24. How much sleep per 24 hr day do you usually need to feel fully alert for the day? hr and min

25. Do you consider yourself a morning person or evening person? ☐ morning person ☐ evening person

26. At what time of day do you feel most alert? (please shade/circle your alert times below)

27. How often do you take a nap at home? (If "never," skip to #29.)

never	rarely	sometimes	often	very often
1-10 /yr	1-3 /mo	1-4 /wk	5-7 /wk	
☐	☐	☐	☐	☐

28. On average, how long are your naps? hr and min

29. When sleeping at home, how often do you have problems getting to sleep?

never	rarely	sometimes	often	very often
1-10 /yr	1-3 /mo	1-4 /wk	5-7 /wk	
☐	☐	☐	☐	☐

30. How often do you take medication to help you sleep? (If "never," skip to #33.)

never	rarely	sometimes	often	very often
1-10 /yr	1-3 /mo	1-4 /wk	5-7 /wk	
☐	☐	☐	☐	☐

31. If you take medication to help you sleep, please specify the medication and dose. name: _____ dose: _____

32. Rate the effectiveness of the medication.
not at all effective			moderately effective		very effective
☐	☐	☐	☐	☐	☐
33. How often do you use alcohol to help you sleep?
never
1-10 /yr.	rarely
1-3 /mo.	sometimes
1-4 /wk	often
5-7 /wk	very often
☐	☐	☐	☐	☐
34. Overall, what kind of sleeper are you?
very poor	poor	good	very good
☐	☐	☐	☐

C. FLYING INFORMATION

35. How many total flight hours have you logged in your lifetime? hrs

36. What is your flight deck position?

Capt	F/O
☐	☐

37. What aircraft do you fly? _____

38. For monthly bidding purposes, what is your relative seniority number on this aircraft?

39. How many pilots are on the bid list for this aircraft?

Answer questions 36-37 according to the flying done **ONLY** for your commercial aviation job **within the past year**.

40. How many hours of night ops did you fly in a month?
(based on FAR §61.57)

<input type="text"/> hr	<input type="text"/> hr	<input type="text"/> hr
typical	fewest	most

41. In general, how would you rate your level of alertness under the following conditions?

	always alert/ fatigue never a problem	usually alert/ very infrequent problem w/fatigue	sometimes alert/ intermittent problem w/fatigue	not frequently alert/ often times problem w/fatigue
a. daytime (0600-1800)	☐	☐	☐	☐
b. nighttime (1800-0600)	☐	☐	☐	☐

D. DUTY

Please answer the following questions **using your logbook or pay sheet**, according to the flying done **ONLY** for your aviation job within the past year.

42. How many duty days did you fly in a month?
____	days	____	days	____	days
	typical		fewest		most
43. What was your number of actual flight hours per month?
____	hr	____	hr	____	hr
	typical		fewest		most
44. How many flight segments did you fly in a duty day?
____		____		____	
	typical		fewest		most
45. How much time did you have on the ground between flights (time between blocking in and out)?
____	hr	____	hr	____	hr
	typical		fewest		most
46. During the past month, how many times did you report for duty during each of the following time periods?
____	0000-0359 hr	____	0800-1159 hr	____	1600-1959 hr
____	0400-0759 hr	____	1200-1559 hr	____	2000-2359 hr

47. In a typical month, on how many duty days did your actual flying time fall into each range?

<8 hr

8-12 hr

>12 hr

48. What was the duration of your duty day? typical: hr and min
shortest: hr and min
longest: hr and min

49. What was the longest duty day you have had in your flying career?

hr

and

min

50. If you had your own choice to schedule your duty day, what time would you pick to work your shift? (24 hr clock)

begin

end

51. How much sleep do you usually obtain before a scheduled flight?

hr and

min

52. How many hours before a flight do you usually get this sleep?

hr and

min

53. In a typical month, how many flights involved time-zone changes of the following magnitudes?

flights

0-3 zones

flights

4-6 zones

flights

over 6 zones

E. FATIGUE

54. In what ways does fatigue affect your flight performance?

55. When your flight performance is affected by fatigue, which phase of flight performance is most affected? (Choose only **ONE** answer.)

☐ taxi	☐ descent
☐ takeoff	☐ approach/landing
☐ enroute	

56. List in rank order three strategies (for each heading) that you use to cope with fatigue.

PRETRIP:

1. _____
2. _____
3. _____

IN-FLIGHT:

1. _____
2. _____
3. _____

POSTTRIP:

1. _____
2. _____
3. _____

57. What three changes would you make to reduce fatigue in commercial operations? List the most important first.

1. _____
2. _____
3. _____

58. Have you ever "nodded off" during a flight? (If "no," skip to #60.) ☐ yes ☐ no
59. If this has occurred more than once, on what percentage of flights in a typical month does it occur? % flights in typical mo
60. Have you ever been on a flight where arrangements were made for one of the pilots to nap in their cockpit seat during the leg? ☐ yes ☐ no
61. In a typical month, on what percentage of flights does this occur? % flights in typical mo
62. Has fatigue ever prevented you from flying a scheduled trip? ☐ yes ☐ no
63. For the following question:
- Check the box that represents **the extent to which each factor affects your fatigue level on duty.**
 - Then, in the far right column, write the number that corresponds to how frequently you experience each factor (based on the Frequency Scale below).
 - In the "Comments" section at the end of this question, please elaborate on any factors as needed.

Frequency Scale				
0=never	1=very rarely (1-10/yr)	2=sometimes (1-3/mo)	3=often (1-4/wk)	4=very often (5-7/wk)

- | | | not at all
frequency | slightly | moderately | seriously | |
|----|----------------------------|--------------------------|--------------------------|--------------------------|--------------------------|----------------------|
| a) | Moderate/severe turbulence | ☐ | ☐ | ☐ | ☐ | <input type="text"/> |
| b) | Icing | ☐ | ☐ | ☐ | ☐ | <input type="text"/> |

c)	- ATC interactions	☐	☐	☐	☐	<input type="text"/>
d)	Interacting w/ other co employees	☐	☐	☐	☐	<input type="text"/>
e)	Time zone changes	☐	☐	☐	☐	<input type="text"/>
f)	Company scheduling practices	☐	☐	☐	☐	<input type="text"/>
g)	Time of day of operation	☐	☐	☐	☐	<input type="text"/>
h)	Early morning departures	☐	☐	☐	☐	<input type="text"/>
i)	Late night arrivals	☐	☐	☐	☐	<input type="text"/>
j)	FAR flight/duty/rest limitations	☐	☐	☐	☐	<input type="text"/>
k)	Sudden scheduling changes	☐	☐	☐	☐	<input type="text"/>
l)	Heavy workload	☐	☐	☐	☐	<input type="text"/>
m)	Company mgmt responsibilities	☐	☐	☐	☐	<input type="text"/>
n)	Dehydration	☐	☐	☐	☐	<input type="text"/>
o)	Illness	☐	☐	☐	☐	<input type="text"/>
p)	Emotional stress	☐	☐	☐	☐	<input type="text"/>
q)	Sleep loss	☐	☐	☐	☐	<input type="text"/>
r)	Boredom	☐	☐	☐	☐	<input type="text"/>
s)	Age	☐	☐	☐	☐	<input type="text"/>
t)	Other (specify)	☐	☐	☐	☐	<input type="text"/>

Comments detailing any of the above factors (Use the back of this page if necessary):

Appendix D

Multivariable Apnea Prediction and Sleep Symptom Frequency (MAP) Form

The Multivariable Apnea Prediction (MAP) Index and computing tools were developed by the Human Assessment and Biostatistics Core of the Center for Sleep and Respiratory Biology, University of Pennsylvania Medical Center. Form dated 10/16/00 version 3.1. Research was supported by the SCOR in Cardiopulmonary Disorders in Sleep (HL42236-08) and then by the SCOR for the Neurobiology of Sleep and Sleep Apnea (P50 HL-60287). Maislin, G., Pack, A.I., Kribbs, N.B., Smith, P.L., Schwartz, A.R., Kline, L.R., et al. (1995). A survey screen for prediction of apnea. *Sleep*, 18, 158-66.

**MULTIVARIABLE APNEA PREDICTION AND
SLEEP SYMPTOM FREQUENCY (MAP) FORM
UNIVERSITY OF PENNSYLVANIA
CENTER FOR SLEEP AND RESPIRATORY NEUROBIOLOGY**

I agree to allow my answers in this MAP questionnaire to be used for research purposes. My understanding is that, if the answers are so used, my identity will be kept confidential.

Signed _____

Print Name _____

Print phone number _____

What is today's date? Month _____ Day _____ Year _____

When were you born? Month _____ Day _____ Year _____

What is your gender? Male _____ Female _____

What is your weight? Pounds _____

What is your height? Feet _____ Inches _____

The following questions refer to your behavior while sleeping, trying to sleep, or while feeling sleepy. Please fill in one circle for each question. During the last month have you had, or have been told about the following?

	Never	Rarely, less than once a week	1-2 times per week	3-4 times per week	5-7 times per week	Don't Know
Loud Snoring	☐	☐	☐	☐	☐	☐
Your legs feel jumpy or jerk	☐	☐	☐	☐	☐	☐
Difficulty falling asleep	☐	☐	☐	☐	☐	☐
Frequent awakenings	☐	☐	☐	☐	☐	☐
Snorting or Gasping	☐	☐	☐	☐	☐	☐

	Never	Rarely, less than once a week	1-2 times per week	3-4 times per week	5-7 times per week	Don't Know
Falling asleep when at work	0	0	0	0	0	0
Frequent tossing, turning, or thrashing	0	0	0	0	0	0
Your breathing, stops or you struggle for breath	0	0	0	0	0	0
Any snoring	0	0	0	0	0	0
Excessive sleepiness during the day	0	0	0	0	0	0
Morning Headaches	0	0	0	0	0	0
Falling asleep while driving	0	0	0	0	0	0
Awaken feeling paralyzed, unable to move for short periods	0	0	0	0	0	0
Find yourself in a vivid dreamlike state when falling asleep or awakening even though you know you're awake	0	0	0	0	0	0

Appendix E

Horne-Östberg Morningness-Eveningness Questionnaire

Reprinted with permission by Dr. Jim Horne, Director of Loughborough Sleep
Research Centre, Department of Human Sciences, Loughborough University,
Leicestershire, United Kingdom.

1. For this section, please read each question very carefully before answering each question.
2. Answer ALL questions.
3. Answer questions in numerical order.
4. Each question should be answered independently of others. DO NOT go back and check your answers.
5. All questions have a selection of answers. For each question, place a cross alongside ONE answer only. Some questions have a scale instead of a selection of answers. Place a cross at the appropriate point along the scale.
6. Please answer each question as honestly as possible. Both your answers and the results will be kept in strict confidence.
7. Please feel free to make any comments in the margin for each question.

1. Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?

2. Considering only your own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your evening?

3. If there is a specific time at which you have to get up in the morning, to what extent are you dependent on being woken up by an alarm clock?	Not at all dependent.....	☐
	Slightly dependent.....	☐
	Fairly dependent.....	☐
	Very dependent.....	☐
4. Assuming adequate environmental conditions, how easy do you find getting up in the morning?	Not at all easy.....	☐
	Not very easy.....	☐
	Fairly easy.....	☐
	Very easy.....	☐
5. How alert do you feel during the first half hour after having woken in the morning?	Not at all alert.....	☐
	Slightly alert.....	☐
	Fairly alert.....	☐
	Very alert.....	☐

6. How is your appetite during the first half-hour after having woken in the morning?	Very poor.....
Fairly poor.....
Fairly good.....
Very good.....	☐
☐
☐
☐
7. During the first half-hour after having woken in the morning, how tired do you feel?	Very tired.....
Fairly tired.....
Fairly refreshed.....
Very refreshed.....	☐
☐
☐
☐
8. When you have no commitments the next day, at what time do you go to bed compared to your usual bedtime?	Seldom or never later.....
Less than one hour later.....
1 – 2 hours later.....
More than two hours later.....	☐
☐
☐
☐
9. You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is between 7.00 – 8.00 AM. Bearing in mind nothing else but your own “feeling best” rhythm, how do you think you would perform?	Would be on good form.....
Would be on reasonable form.....
Would find it difficult.....
Would find it very difficult.....	☐
☐
☐
☐

10. At what time in the evening do you feel tired and as a result in need of sleep?

11. You wish to be at your peak performance for a test, which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day and considering only your own "feeling best" rhythm which ONE of the four testing times would you choose?

8.00 – 10.00 AM.....
11.00 – 1.00 PM.....
3.00 – 5.00 PM.....
7.00 – 9.00 PM.....

12. If you went to bed at 11.00 PM at what level of tiredness would you be?

Not at all tired.....
A little tired.....
Fairly tired.....
Very tired.....

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which ONE of the following events are you most likely to experience?

Will wake up at usual time and will NOT fall asleep.....
Will wake up at usual time and will doze thereafter.....
Will wake up at usual time but will fall asleep again.....
Will NOT wake up until later than usual.....

14. One night you have to remain awake between 4.00 – 6.00 AM in order to carry out a night watch. You have no commitments the next day. Which ONE of the following alternatives will suit you best?

Would NOT go to bed until watch was over.....

Would take a nap before and sleep after.....

Would take a good sleep before and nap after.....

Would take ALL sleep before watch.

15. You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your own “feeling best” rhythm which ONE of the following times would you choose?

8.00 – 10.00 AM.....

11.00 – 1.00 PM.....

3.00 – 5.00 PM.....

7.00 – 9.00 PM.....

16. You have decided to engage in hard physical exercise. A friend suggests that you do this for one hour twice a week and the best time for him is between 10.00 – 11.00 PM. Bearing in mind nothing else but your own “feeling best” rhythm how well do you think you would perform?

Would be on good form.....

Would be on reasonable form.....

Would find it difficult.....

Would find it very difficult.....

-
- A horizontal timeline representing a 24-hour day. It consists of 24 empty square boxes arranged in a single row. Below the boxes, the numbers 1 through 24 are printed, corresponding to each box. The word "MIDNIGHT" is printed below the first box (1), the word "NOON" is printed below the 12th box (12), and the word "MIDNIGHT" is printed below the 24th box (24).

-

- Definitely a "morning" type.....
 Rather more a "morning" type
 than an "evening" type.....
 Rather more an "evening" type
 than a "morning" type.....
 Definitely an "evening" type.....

Appendix F

Basic Language Morningness (BALM) Scale

Reprinted with permission by Dr. Frederick Brown, Associate Professor of Psychology, College of the Liberal Arts, The Pennsylvania State University, University Park, Pennsylvania.

BASIC LANGUAGE MORNINGNESS (BALM) SCALE

The Pennsylvania State University Psychobiological Rhythms Laboratory

****IMPORTANT INSTRUCTIONS****

Answer the following questions *as if you did not work, and did not have to take care of any children, or other people, or animals, or anything, and that your time was your own and you are free to set your own schedule, like being on a restful vacation.* For every question please mark (X) the one answer that would fit you the best.

1. Thinking only of your own "feeling best" times of day, what time would you get up if you were completely free to plan your day?

_____ 5:00-6:30 in the morning
_____ 6:30-7:45 in the morning
_____ 7:45-9:45 in the morning
_____ 9:45-11:00 in the morning
_____ 11:00 morning – 12:00 noon

2. Thinking only of your own "feeling best" times of day, what time would you go to bed if you were completely free to plan your evening?

_____ 8:00-9:00 in the evening
_____ 9:00-10:15 in the evening
_____ 10:15 evening – 12:30 night
_____ 12:30-1:45 at night
_____ 1:45-3:00 at night

3. Under free time conditions, how easy do you find getting up in the morning?

_____ Not at all easy
_____ Slightly easy
_____ Fairly easy
_____ Very easy

4. If you go to sleep at night at a regular time, how wide awake do you feel during the first half hour after getting up in the morning?

_____ Not at all wide awake
_____ Slightly wide awake
_____ Fairly wide awake
_____ Very wide awake

5. If you go to sleep at night at a regular time, during the first half hour after getting up in the morning, how tired or rested do you feel?

_____ Very tired
_____ Fairly tired
_____ Fairly refreshed
_____ Very refreshed

6. In your free time you have decided to do some physical exercise. A friend says do this one hour twice a week and the best time is 7:00-8:00 in the morning. Thinking of nothing else but your own "feeling best" times, how do you think you would do at that time?

_____ Would be in very good form
_____ Would be in pretty good form
_____ Would find it difficult
_____ Would find it very difficult

7. Suppose you have nothing but free time, at what time in the evening do you feel tired and need to get some sleep?

_____ 8:00-9:00 in the evening
_____ 9:00-10:15 in the evening
_____ 10:15 evening – 12:30 at night
_____ 12:30-1:45 at night
_____ 1:45-3:00 at night

8. You want to be at your top performance for a test (for a job promotion, for example) which you know is going to take two hours and will completely tire you out mentally. You are completely free to plan your day. Thinking only of your own "feeling best" times, which ONE of the four testing times would you choose?

_____ 8:00-10:00 in the morning
_____ 11:00 morning – 1:00 in the afternoon
_____ 3:00-5:00 in the afternoon
_____ 7:00-9:00 in the evening

9. "Morning people" wake up early and are wide awake fast, but then feel tired in the evenings and like to go to bed before it gets late. "Evening people" take some time before they get going in the mornings, but like to stay up late at night. Which ONE of these types do you think you are?

☐ For sure a morning type
☐ More a morning than an evening type
☐ More an evening than a morning type
☐ For sure an evening type

10. When would you like to get up (if you have a full day's work—8 hours—ahead of you, for example) if you were completely free to set your work time?

☐ Before 6:30 in the morning
☐ 6:30-7:30 in the morning
☐ 7:30-8:30 in the morning
☐ 8:30 or later in the morning

11. Suppose that you did not work, but you still always had to get up at 6:00 in the morning. What do you think it would be like for you?

☐ Very difficult and unpleasant
☐ Rather difficult and unpleasant
☐ A little unpleasant but no great problem
☐ Easy and not unpleasant

12. If you could go to sleep at a regular time every night, how much time would it take to "clear your head" in the morning after getting up from a night's sleep?

☐ 0-10 minutes
☐ 11-20 minutes
☐ 21-40 minutes
☐ More than 40 minutes

1. If you were free to set your time, please mark how much you would be a morning or evening *active* person.

☐ Very much early morning active (wide awake mornings and tired evening)
☐ Somewhat morning active
☐ Somewhat evening active
☐ Very much evening active (tired mornings and wide awake evenings)

Appendix G

Activity Log

The activity log was developed by the Fatigue Countermeasures Group at NASA Ames Research Center, Moffett, Field, California, and was adapted from the NASA AIRLOG, which is an early generation electronic sleep/wake diary (Rosekind, Smith, Gregory & Miller, 1996). Activity log items were also adapted from a survey study of sleep quantity and quality in on-board crew rest facilities on international flights (Rosekind, et al., 2000).

Activity Log

Menu

- Actiwatch
- Aircraft Lighting
- Beverage
- Duty
- Exercise
- Meal
- Medications
- Review Log
- Sleep
- Sleepiness Scale
- Sunglasses

Activity Log

☐ Sleep	☐ Duty
☐ Meal	☐ Aircraft Lighting
☐ Beverage	☐ Sunglasses
☐ Medication	☐ Actiwatch
☐ Exercise	
	☐ Review

Main Menu

The Activity Log is used to tell a story of the events that will occur over the 40-day period of this protocol. In order to obtain the most accurate information during this period, it is extremely important to enter as much information as you can as close in time that the event(s) occur.

Information to be entered into the log include:

- Sleep (while on the ground and in-flight)
- Duty (flight information, workload ratings, use of aircraft lighting)
- Activities including meals, beverages, medications, exercise, sunglass usage, and times when Actiwatch or light monitor are removed and put back on

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Activity Log

Menu

- Actiwatch
- Aircraft Lighting
- Beverage
- Duty
- Exercise
- Meal
- Medications
- Review Log
- Sleep
- Sleepiness Scale
- Sunglasses

Actiwatch

▪ Wrist:

ON: _____ OFF: _____

▪ Neck:

ON: _____ OFF: _____

▪ Date: _____

DONE

Main Menu / Actiwatch

Fill this out each time you put on or remove either of the Actiwatch devices. However, the Actiwatch with the light sensor monitor around the neck is taken off each night and placed next to the bed in close proximity (less than 1 meter) from the head with sensor facing the ceiling. This event does not have to be entered. The activity monitor and light sensor should stay on except as noted below.

- Actiwatch and Light sensor: remove if the device may become wet or submerged in water.

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Activity Log

Menu

- Actiwatch
- Aircraft Lighting
- Beverage
- Duty
- Exercise
- Meal
- Medications
- Review Log
- Sleep
- Sleepiness Scale
- Sunglasses

Main Menu / Aircraft Lighting

Aircraft Lighting

▪ Screens/Shades:

ON: _____ OFF: _____

▪ Storm Lights:

ON: _____ OFF: _____

▪ Map Lights:

ON: _____ OFF: _____

▪ In Flight Sunrise:

▪ In Flight Sunset:

▪ Date:

DONE

Fill this out as best as possible when aircraft lighting is turned on, changed, or is turned off. This information is especially important for night flight operations. Also important is to note the timing of in-flight sunrise and sunset.

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Activity Log

Main Menu / Beverage

Menu

- Actiwatch
- Aircraft Lighting
- Beverage
- Duty
- Exercise
- Meal
- Medications
- Review Log
- Sleep
- Sleepiness Scale
- Sunglasses

Beverages

- Quantity: _____ oz/ml
- Type: ▾
Other: _____
- Time: _____
- Date: _____

DONE

Fill this out after each beverage consumed.

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Activity Log

Menu

- Actiwatch
- Aircraft Lighting
- Beverage
- Duty
- Exercise
- Meal
- Medications
- Review Log
- Sleep
- Sleepiness Scale
- Sunglasses

Main Menu / Duty Log

Selecting "Duty" will take you to a sub menu where you will start a new entry "New", continue with the last entry "Last", or "Exit". Contents of Duty include the following:

- Leg Information
- Flight Phase Ratings
- Performance

Flight safety is paramount. Only enter this information when it is operationally feasible. For participants flying multiple legs/segments in a duty day (short haul, domestic, etc. operations).

- Enter scheduled duty start and end time only for the first leg/segment of the day
- Enter actual duty end time on the last leg/segment of the day

Duty Information

Would you like to start a **NEW** entry, continue your **LAST** entry, or **EXIT**?

NEW

LAST

EXIT

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Activity Log

Menu

- Actiwatch
- Aircraft Lighting
- Beverage
- Duty
- Exercise
- Meal
- Medications
- Review Log
- Sleep
- Sleepiness Scale
- Sunglasses

[Main Menu / Duty Log](#)

Duty Time Log

Item 1/29

Scheduled duty start time:

Scheduled duty end time:

NEXT

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Activity Log

Menu

- Actiwatch
- Aircraft Lighting
- Beverage
- Duty
- Exercise
- Meal
- Medications
- Review Log
- Sleep
- Sleepiness Scale
- Sunglasses

Main Menu / Duty Log

Depart Airport

Item 2/29

Flight from: _____

Flight to: _____

Item 3/29

Leg number: ▾

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Item 4/29

Block out: _____

Item 5/29

Select your status:
▼

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Take Off - TOC

Item 6/29

Choose your task.

Flight to: ▾

Item 7/29

Describe the weather.

Flight to: ▾

Other: _____

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Main Menu / Duty Log

Item 8/29

**What is the temperature
(Celsius)?**

Departure: _____

Item 9/29

**What is the dewpoint
(Celsius)?**

Departure: _____

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Take Off - TOC

Item 10/29

1 = LOW 9 = HIGH

	Block Out to TOC
Workload	▼
Fatigue	▼
Boredom	▼
Sleepiness	▼

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Item 11/29

* Rate the following using the following 9 point scale.

1 = reduced 9 = increased

How did ATC performance during clearance, taxi, take-off, and departure affect your workload? -

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Item 12/29

Route (waypoints):

Item 13/29

Choose your task.

Cruise: ~**BACK****NEXT**Download the Activity Log user manual. [[pdf](#)] - [[word](#)]

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Item 14/29

Describe the weather.

Cruise: ▾

Other: _____

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TOC - TOD

Item 15/29

1 = LOW 9 = HIGH

	TOC to TOD
Workload	▼
Fatigue	▼
Boredom	▼
Sleepiness	▼

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Item 16/29

* Rate the following using the following 9 point scale.

1 = reduced 9 = increased

How did crew coordination and communication during flight affect your workload? ▾

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Item 17/29

* Rate the following using the following 9 point scale.

1 = reduced 9 = increased

How did cabin crew performance during flight affect your workload?

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Item 18/29

Choose your task.

Landing: ▾

Item 19/29

Describe the weather.

Landing: ▾

Other: _____

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Item 20/29

**What is the temperature
(Celsius)?**

Arival: _____

Item 21/29

**What is the dewpoint
(Celsius)?**

Arival: _____

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Main Menu / Duty Log

Item 22/29

**Please list any unexpected
operational events during
duty here.**

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Main Menu / Duty Log

TOD - Landing

Item 23/29

1 = LOW 9 = HIGH

	TOD to Block In
Workload	▼
Fatigue	▼
Boredom	▼
Sleepiness	▼

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Item 24/29

1 = reduced 9 = increased

**How did ATC performance
during approach and landing
affect your workload?**

Item 25/29

**List any physical symptoms
you had during duty.**

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Item 26/29

* Rate the following using the following 9 point scale.

1 = Low 9 = High

How much were you preoccupied by personal issues during duty?

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Arrive Airport

Item 27/29

Block In: _____

Item 28/29

Actual duty end time: _____

Item 29/29

Date: _____

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Main Menu / Exercise

Exercise

- Date: _____
- Type: ▾
Other: _____
- Duration: __:__ (hr:min)
and
- Type: ▾
Other: _____
- Duration: __:__ (hr:min)

DONE

Fill this out after exercising.

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[Main Menu / Meal](#)

Meals

▪ Type:

- ☐ Meat ☐ Seafood ☐ Fruit
☐ Vegies ☐ Grain ☐ Other
☐ Dairy ☐ Starch

▪ Time: _____

▪ Date: _____

DONE

Of all the events, this entry is the most important to fill out when the meal occurs (for example, after dinner has been ordered at a restaurant) because a 9-point subjective sleepiness scale is administered with each meal. Press "DONE" to view the Sleepiness Scale.

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Medications

	Med 1	Med 2
▪ Type:	_____	_____
▪ Quantity:	_____	_____
▪ Dose:	_____	_____
▪ More:	_____	
▪ Time:	_____	
▪ Date:	_____	
<div style="border: 1px solid black; padding: 2px 10px;">DONE</div>		

Fill this out after taking any type(s) of medication.

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Survey Review

Select Survey

☐ Pre Ground Sleep	☐ Sleep Scale
☐ Post Ground Sleep	☐ Meal
☐ Pre In-Flight Sleep	☐ Beverage
☐ Post In-Flight Sleep	☐ Actiwatch
☐ Aircraft Lighting	☐ Medication
☐ Duty	☐ Sunglasses
	☐ Exercise

MENU

Use this to amend any of the prior events or to complete an event that was exited prematurely. Events are ordered by date (not time).

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Main Menu / Review / Pre Ground Sleep Review

Pre Ground Sleep Review

Select Day

Review

DONE

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Post Ground Sleep Review

Select Day

Review

DONE

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Main Menu / Review / Pre In Flight Sleep Review

Pre In Flight Sleep Review

Select Day

Review

DONE

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Post In Flight Sleep Review

Select Day

Review

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Aircraft Lighting Review

Select Day

Review

DONE

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Duty Review

Select Day

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Sleep Scale Review

Select Day

Review

DONE

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Meal Review

Select Day

Review

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Main Menu / Sleepiness Scale

Sleep Scale

- ☐ 1-Very Alert
- ☐ 2
- ☐ 3-Normal
- ☐ 4
- ☐ 5-Neither alert nor sleepy
- ☐ 6
- ☐ 7-Sleepy
- ☐ 8
- ☐ 9-Very Sleepy, fighting sleep

**Indicate your
Sleepiness for the
last 5 minutes**

This survey is linked to the meal, duty, and sleep surveys. You should not have to actively select this survey. After completing the above survey sections, you will automatically be brought to the sleep scale survey.

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Beverage Review

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Medication Review

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Sunglasses Review

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Exercise Review

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Sleep Log

☐ Ground Sleep☐ In Flight Sleep

Selecting "Sleep" will take you to a sub menu where you will choose from "Ground Sleep" and "In Flight Sleep".

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Main Menu / Sleep / In Flight Sleep

In Flight Sleep

☐ Pre-Bunk☐ Post-Bunk

Selecting "In Flight Sleep" you will go to another sub menu where you will choose Pre or Post Bunk.

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Main Menu / Sleep / In Flight Sleep / Pre In Flight Sleep

Pre-In Flight Sleep

▪ Where do you plan to sleep?

If other, please elaborate

▪ Lights out time? ▪ Date:

NEXT

Fill this out before you go to sleep
while in flight.

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Main Menu / Sleep / In Flight Sleep / Pre In Flight Sleep

* Rate how you feel right now for the next 3 questions.

■ Sleepy

1 3 5
☐ ☐ ☐ ☐ ☐
 Not at all Extremely

■ Relaxed

1 3 5
☐ ☐ ☐ ☐ ☐
 Not at all Extremely

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▪ Sleepy

1 3 5
☐ ☐ ☐ ☐ ☐
 Not at all Extremely

▪ Did you use any strategies to prepare yourself for crew rest during this flight? ☐ Yes ☐ No

If yes, please elaborate

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Sleep Scale

- ☐ 1-Very Alert
- ☐ 2
- ☐ 3-Normal
- ☐ 4
- ☐ 5-Neither alert nor sleepy
- ☐ 6
- ☐ 7-Sleepy
- ☐ 8
- ☐ 9-Very Sleepy, fighting sleep

**Indicate your
Sleepiness for the
last 5 minutes**

This survey is linked to the meal, duty, and sleep surveys. You should not have to actively select this survey. After completing the above survey sections, you will automatically be brought to the sleep scale survey.

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- Sunglasses

Post-In Flight Sleep

- How long have you been out of your bunk? __:__ (hr:min)
- How long did it take you to fall asleep? __:__ (hr:min)
- How long did you sleep? __:__ (hr:min)

NEXT

Fill this out as soon as practical after you wake up while **in flight**.

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 - In Flight Sleep
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 - Ground Sleep
- Sleepiness Scale
- Sunglasses

▪ How many awakenings? ____

▪ Where did you sleep?

If disturbance, please elaborate

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***Rate the quality of your sleep period for the next five questions.**

- **Ability to fall asleep**

1 **5** **9**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

poor great

NEXT

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- **Ability to stay asleep**

1 **5** **9**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

poor great

- **Depth of sleep**

1 5 9
□ □ □ □ □ □ □ □
poor great

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1 **5** **9**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

poor great

1 **5** **9**

☐ ☐ ☐ ☐ ☒ ☐ ☐ ☐ ☐

poor **great**

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■ Where did you sleep?

If other, please elaborate

■ What was your total time spent in your sleeping area?

__:__ (hr:min)

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▪ Was the other bunk occupied? ▾

If yes, how long? __ : __ (hr:min)

*Answer yes or no for the following:
During this sleep period did you...

▪ Use a blanket ▾

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■ Undress to sleep ▾

■ Get called ▾

■ Do other activities ▾

If yes, please elaborate

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Main Menu / Sleep / In Flight Sleep / Post In Flight Sleep

- Wear ear plugs ▾
- Wear eye shades ▾
- Listen to music or watch on-board TV/video ▾
- Use relaxation techniques ▾

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Elaborate if any other technique
was used?

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*Please indicate if the following interfered or promoted the quality of this sleep period.

1 = interferes 5 = promotes

■ Quality of sleep surface

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ Heat

1

☐

3

☐

5

☐

interferes

promotes

■ Cold

1

☐

3

☐

5

☐

interferes

promotes

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Main Menu / Sleep / In Flight Sleep / Post In Flight Sleep

Readiness for sleep

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

Comfort of clothing

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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Thoughts running through your head

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

Pillows

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ **Constant background noise**

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

■ **Background lighting**

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ Low humidity/dry air

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

■ Trips to the bathroom

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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Main Menu / Sleep / In Flight Sleep / Post In Flight Sleep

Someone in the other bunk

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

Seat belt sign

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ Turbulence

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

■ Privacy

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ Bunk size

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

■ Facility size

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ Headspace

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

■ Lighting

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ Ventilation

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

■ Storage space

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ Curtains

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

■ Sheets

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ Blankets

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

■ Pillows

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes promotes

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■ Please elaborate here for other factors that affect sleep.

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* Rate the following on the extent
to which the following items
INTERFERED with your sleep

■ Hunger

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes no effect

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■ Thirst

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes no effect

■ Claustrophobia

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes no effect

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Personal worries

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes no effect

**Respiratory factors (i.e.,
asthma, allergies)**

1 3 5
☐ ☐ ☐ ☐ ☐
 interferes no effect

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▪ Elaborate here for other possible interferences.

▪ Date: _____

DONE

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Main Menu / Sleepiness Scale

Sleep Scale

- ☐ 1-Very Alert
- ☐ 2
- ☐ 3-Normal
- ☐ 4
- ☐ 5-Neither alert nor sleepy
- ☐ 6
- ☐ 7-Sleepy
- ☐ 8
- ☐ 9-Very Sleepy, fighting sleep
- Indicate your Sleepiness for the last 5 minutes**

This survey is linked to the meal, duty, and sleep surveys. You should not have to actively select this survey. After completing the above survey sections, you will automatically be brought to the sleep scale survey.

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Main Menu / Sleep / Ground Sleep

Ground Sleep

☐ Pre-Ground Sleep

☐ Post-Ground Sleep

Selecting "Ground Sleep" you will go to another sub menu where you will choose Pre or Post Ground Sleep.

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Pre-Ground Sleep

▪ Where are you sleeping?

If other please describe below

▪ Lights out time? _____

▪ Date: _____

DONE

Fill this out before you go to sleep
if you are **not in flight**.

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**Indicate your
Sleepiness for the
last 5 minutes**

This survey is linked to the meal, duty, and sleep surveys. You should not have to actively select this survey. After completing the above survey sections, you will automatically be brought to the sleep scale survey.

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Post-Ground Sleep

- How long have you been out of bed? __: __ (hr:min)
- How long did it take you to fall asleep? __: __ (hr:min)
- How many times did you wake up? ____
- Date: _____

NEXT

Fill this out as soon as practical after you wake up if you are not in flight

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- **Ability to fall asleep**

1 **5** **9**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

poor great

- **Ability to stay asleep**

1 **5** **9**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

poor great

NEXT

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■ **Depth of sleep**

1 5 9

□ □ □ □ □ □ □ □ □

poor great

▪ **Quality of sleep**

1 5 9

□ □ □ □ □ □ □ □

poor great

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- 1 5 9
□ □ □ □ □ □ □ □
poor great

- If yes, what did you use to help you sleep?

DONE

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- ☐ 8
- ☐ 9-Very Sleepy, fighting sleep

**Indicate your
Sleepiness for the
last 5 minutes**

This survey is linked to the meal, duty, and sleep surveys. You should not have to actively select this survey. After completing the above survey sections, you will automatically be brought to the sleep scale survey.

Download the Activity Log user manual. [\[pdf\]](#) - [\[word\]](#)

Curator: [Dinah Reduta](#) | Responsible Official: [Dr. Melissa M. Mallis](#)
| [NASA Privacy Statement](#)

Activity Log

Menu

- Actiwatch
- Aircraft Lighting
- Beverage
- Duty
- Exercise
- Meal
- Medications
- Review Log
- Sleep
- Sleepiness Scale
- Sunglasses

[Main Menu / Sunglasses](#)**Sunglasses**

- **ON:** _____
- **OFF:** _____
- **Date:** _____

DONE

Fill this out each time you put on or take off your sunglasses when the glasses have been used, or will be used for a period longer than 15-minutes.

Download the Activity Log user manual. [\[pdf\]](#) - [\[word\]](#)

Curator: [Dinah Reduta](#) | Responsible Official: [Dr. Melissa M. Mallis](#)
| [NASA Privacy Statement](#)

Appendix H

San Jose State University Human Research Institutional Review Board Approval

San José State
UNIVERSITY

**Office of the Academic
Vice President
Associate Vice President
Graduate Studies and Research**

One Washington Square
San Jose, CA 95192-0035
Voice: 408-283-7500
Fax: 408-924-2477
E-mail: gstudies@webos.sjsu.edu
http://www.sjsu.edu

To: Raymond Oyung
NASA Ames Research Center
Aviation Safety Research / Fatigue Countermeasures Group
MS 262-4
Moffett Field, CA 94035-1000

From: Nabil Ibrahim, N. Ibrahim
AVP, Graduate Studies & Research

Date: June 27, 2002

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Activity and Light Exposure Patterns in Flight Crew."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Nabil Ibrahim, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year, and data collection beyond June 27, 2003 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

The California State University:
Chico State Office
Bakersfield, Calicut, Fullerton, Fresno,
Dominguez Hills, Fresno, Fullerton,
Hayward, Humboldt, Long Beach,
Los Angeles, Modesto, Sacramento,
Merced, San Bernardino, San Diego,
San Francisco, San Jose, San Luis Obispo,
San Marcos, Sonoma, Stanislaus

San José State
UNIVERSITY

**Office of the Academic
Vice President**
Academic Vice President
Graduate Studies and Research

One Washington Square
San José, CA 95192-0025
Voice: 408-283-7500
Fax: 408-924-2477
E-mail: gradstudies@sjsu.edu
http://www.sjsu.edu

To: Raymond Oyung
NASA Ames
Mail Stop 262-4
Moffett Field, CA 94035-1000

From: Nabil Ibrahim,
AVP, Graduate Studies & Research

Date: June 27, 2003

This letter acknowledges that the Human Subjects-Institutional Review Board has received the request for extension of the following study:

"Activity and Light Exposure Patterns in Flight Crew."

Since there are no major changes to the protocol, the Human Subjects-Institutional Review Board has granted this project a one-year extension effective from the date of this letter. Data collection beyond June 27, 2004 requires an extension request.

If you have any questions, please do not hesitate to contact me at (408) 924-2480.

The California State University:
Chancellor's Office
Bakersfield, Channel Islands, Chico,
Domínguez Hills, Fresno, Fullerton,
Hayward, Humboldt, Long Beach,
Los Angeles, Maritime Academy,
Monterey Bay, Northridge, Pomona,
Sacramento, San Bernardino, San Diego,
San Francisco, San José, San Luis Obispo,
San Marcos, Sonoma, Stanislaus

Appendix I

Human Research Consent Form

NASA Ames Research Center

National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, CA 94035-1000

Reply to Attn of:

IHS: 262-4

HUMAN RESEARCH CONSENT FORM

Part 1

Title: Activity and Light Exposure Patterns in Flight Crew, H. R. II-02-22.

A. Purpose

The purpose of this study is to collect the activity and light exposure of commercial airline pilots during 40 days of flight activity. A comparison of the differences between the sleep-wake schedules of short haul and long haul pilots in addition to determining the timing of light exposure will be analyzed through the use of an activity monitor and light sensor.

B. Investigators

Principal Investigator: Melissa Mallis, Ph.D., NASA Ames Research Center
Co-Principal Investigator: Ray Oyung, San Jose State University Foundation

C. Nature of Tests and Research

This is an ambulatory study of commercial airline pilot activity and will take place over 40 days during an active flight schedule period. You will wear an activity monitor on your non-dominant wrist and a light sensor around your neck (approximately 4 inches below the chin) to measure sleep/wake activity and light/dark exposure continuously for a period of 40 days. You will be asked to complete a background, sleep, apnea prediction/sleep symptom frequency, and morningness-eveningness questionnaires providing information on demographics, sleep history (at home and during trip layovers), flight experience and general fatigue. You will also be asked to complete an activity log once upon awakening from the main sleep period, once prior to the next main sleep period and several times during the day to provide information on primary and secondary sleep periods, flight duty periods, caffeine consumption, and medication intake. You will also be requested to take a subjective scale of sleepiness several times per day.

D. Manner in Which Tests or Research Will Be Conducted

You will be one of at least 40 participants who volunteer for this study. The study will begin five days prior to your next monthly flight schedule and end five days after your monthly flight schedule. A package will be sent to you with all material required for completing the study. During this period the activity monitor and light sensor will be worn continuously. The activity monitor is the size of a small wristwatch. The light sensor is the size of a face of a small wristwatch. The devices should be removed for showering or during other activities that would get the devices wet. The light sensor should be removed from around the neck each night and placed by the bedside that you sleep with the sensor facing up toward the ceiling. The background, sleep, apnea prediction/sleep symptom frequency, and morningness-eveningness questionnaires can be completed at any time during the study. The activity log should be within easy access during the day for you to log secondary sleep periods, flight duty periods, caffeine consumption, or medication intake. You will be asked to take a scale of subjective sleepiness by selecting a number on a 9-point scale several times per day during the 40-day period. A return shipping air waybill will be enclosed in the package in order for you to return the material back to NASA Ames Research Center after the completion of the study.

E. Duration

The activity monitor and light sensor will be worn for 40 days. The activity log will take approximately 5 min to complete before and after each main sleep period, and may take a total of 15 min throughout the day to record other notes. The background, sleep, apnea prediction/sleep symptom frequency, and morningness-eveningness questionnaire will be completed only once during the study and will take approximately 1 hr in total to complete. The subjective scale of sleepiness takes approximately 5 sec for each trial.

F. Foreseeable Inconvenience, Discomfort, and Risks

The activity monitor is similar to any wristwatch and the light sensor that is worn around the neck is similar to wearing a chain with a pendant or military identification tags. The activity log is roughly the size of a small calculator and will easily fit in a pants or jacket pocket.

G. Right to Withdraw from the Study and the Penalties/Hazards Associated with Withdrawal

Participation is voluntary. You have the right to withdraw from the study at any time for any reason, although we hope you will not volunteer for the study unless you intend to complete it. There are no hazards, penalties, or loss of benefits associated with withdrawal at any time during this study.

H. Answers to Questions

You may receive answers to any questions related to this study by making contact with the Co-Principal Investigator, Ray Oyung by phone at (650) 604-0020, by fax at (650) 604-2177, or by email at royung@mail.arc.nasa.gov.

I. Remedy in the Event of Injury

Not applicable.

I certify that the study for which _____ is to serve as a participant has been explained to him/her in detail.

Signature of Principal Investigator
or Co-Principal Investigator

Date

Part 2

TO THE TEST PARTICIPANT: Read Part 1 carefully. Make sure all your questions have been answered to your satisfaction. Do not sign this form until Part 1 has been read by you and signed by the Principal Investigator. You will receive a copy of this consent form.

1. I, _____ agree to participate in the tests and research described in Part 1 of this form.
2. I am aware of the possible foreseeable harmful consequences that may result from such participation, and that such participation may otherwise cause me inconvenience and discomfort as described in Part 1.
3. My consent has been freely given. I may withdraw my consent, and thereby withdraw from the study, at any time. I understand that the Principal Investigator may request my employee to dismiss me from the study if I am not conforming to the requirements of the study as outlined in Part 1; or (2) that the NASA Medical Monitor may request my employer to dismiss me from the study if, in the Monitor's opinion, my health and well-being are threatened.
4. I hereby agree that all records collected by NASA in the course of this research are available to the Principal Investigator and Co-Investigators. Any other requests for access to information will require a specific request for release.
5. I understand that I have the right to request the Chair of the Ames Human Research Institutional Review Board (HRIRB) to convene a Board if, at any time, I feel that my rights as a human research participant have been abused or violated.
6. I have had an opportunity to ask questions and I have received satisfactory answers to each question I have asked.
7. I understand that every effort will be made to maintain my anonymity and the confidentiality of all data and that only an ID number will identify my data.

Printed Name of the Volunteer Participant

Date

Signature of the Volunteer Participant

Area Code and phone number

Printed Name of the Witness

Date

Signature of the Witness

Area Code and phone number

Appendix J

Pre-Study Questionnaire

Pre-Study Questionnaire

1. Age: _____
2. How much caffeine do you consume per day (e.g., 2 cups coffee, 2 cokes, 3 cups tea, 1 cup decaf espresso, etc.)? _____
3. Which is your dominant hand (left or right)? _____
4. How much sleep do you need to feel well rested? _____ (hr)
5. On average, how much sleep did you obtain over the past week? _____ (hr)
6. What time zone do you live in (e.g., GMT -7)? _____
7. What aircraft type(s) do you fly? _____
8. What is your flight position (e.g., Captain, FO, SO)? _____
9. What is your approximate seniority number in the company (e.g., pilot number 737 of 2,405 pilots in the company)? _____
10. What is your approximate seniority number for the aircraft you fly (e.g., pilot number 4 of 29 747-400 pilots domiciled in KSFO)? _____
11. Name: _____
12. Address: _____
13. City, State, Zip Code: _____
14. Country: _____
15. Phone number(s): _____
16. Fax number: _____
17. Email address: _____

Appendix K

Study Orientation Frequently Asked Questions List

Actiwatch

1. **“Should I take both the Actiwatch and the light sensor around my neck off at night?”**

The Actiwatch (activity monitor) strapped to the wrist should stay on the wrist at all times (except when the device may get wet). Press the event marker when the Actiwatch is taken off and when it's put back on the wrist. Only the light sensor should be taken off during sleep periods without entering the event that it was taken off or put back on in the Actiwatch event category through the main menu of the Palm Pilot-based activity log.

2. **“Why collect the light information?”**

Light is a strong synchronizing element with the human circadian rhythm. We're interested in determining the intensity and duration of light exposure that occurs during flight operations, as well as during off-duty periods. In order to get the most accurate light readings, the sensor must be on the outside of any clothing. This is also the reason why the light sensor must be taken off at night and placed on a bed stand or other location in the same proximity of the eyes while sleeping. If the blankets cover up the light sensor, we would not obtain the most accurate light information such as the amount of light (if any) that may creep through shades, blinds, or curtains. This is also the rationale behind the need to collect information on light use in the cockpit in addition to the timing of when sunrise and sunset occur in-flight.

3. **“What does that button do on the activity monitor and how does the device work?”**

Sleep/wake cycles are obtained from the activity monitor. The device operates on an accelerometer so it measures gross motor activity. The button on the device (event marker) places one bit of information on the records that are downloaded after data are collected. The records are 24 hr time lines of sleep and wake while the event marker places a tick mark on the time line when the button was pressed. Both the activity monitor and light sensor are powered by a 3-volt lithium "watch-type" battery.

4. **“What are the consequences of forgetting to push the event button every now and then (i.e. as I go to bed)?”**

The event marker will assist us in interpreting/analyzing the data after the activity monitors and other equipment/materials are sent back to the lab. I wore an activity monitor, and kept a log for 77 days to determine how compliant I could be with my own protocol. It's quite difficult to remember to press the event marker and/or enter information into the log every day as different events occur, and there are a few missing event marks in my own data set. Try to press that button as many times as you can remember. It won't ruin the analysis but pressing the event marker will make it easier to analyze all the data sets that we receive during the study.

Clock + Application and Time

5. "Can I change the time in the Clock+ application?"

It's important to keep the large center time display (main clock time) in the Clock+ application (in addition to the Palm operating system time) in UTC. Do not change these time zones. All entries are time stamped in UTC. The activity monitor and light sensor are also time synced in UTC. You may however change any of the other four location fields with any time zones you wish in the Clock+ application. Review the Activity Log Manual for more information.

Palm Pilot Activity Log

6. "What does the information in the activity log give you?"

Meal intake, caffeine consumption, medication (some meds contain caffeine or other stimulants that may affect sleep including oral contraceptives), exercise quantity and timing all have an affect which can shift the circadian rhythm in an advanced (earlier) or delayed (later) direction.

7. "Should I enter naps too?"

It's extremely important to log all sleep periods whether main sleep or naps (no matter how short they are). In general, if you're not sure if some information should be added, please add it. If there is no room or space provided in the activity log for additional information you may have, please add it in the Memo Pad application on the Palm Pilot. Ensure any memo entry has a date and time when the event occurred.

8. "How do I delete an entry in the Activity Log that I have added incorrectly?"

There is no way to delete entries but if a mistake has been made and an entry needs to be corrected, you can tap on the review box at the main menu of the activity log which will bring you to a list of the event categories. Press the category for the entry you would like to correct. A list of entries by date and time will be displayed. Select the entry you wish to correct and press "REVIEW". You may now correct that entry. When finished, press "DONE" and press the HOME icon to return to the main menu

9. "With regards to meals, how specific does the description have to be. I am putting Breakfast, Lunch, Dinner & Snack???"

Metabolic studies (like those conducted for space shuttle missions) would require exact descriptions and actual weight of food intake. For the "meal" section, we're interested mainly in type of food that's being consumed such as meat, dairy, vegetable (veg), fruit, grain/starch (pasta, potatoes, breads, cereal, rice), seafood. Thus for the steak and lobster dinner with garlic mashed potatoes, a salad and clam chowder soup and dinner rolls on the side would be: meat, seafood, starch, veg, grain

10. "I want to add more specific info about my schedule. Where should I add it?"

Any information to add for any reason (clarification or rationale of information entered into the activity log, etc) can be added to the memo pad. The reason for this activity log is to collect a profile of events that occur during the study period. The activity monitor and light sensor along with the various questionnaires only provide pieces of the entire picture of what's happening over the study period. Any information in addition to what's requested in the activity log will be very helpful in analyzing the data after your participation is completed.

Miscellaneous

11. "Can the equipment go through airport x-ray machines?"

The activity monitor and light sensor are constructed of the same material that is found in any sports watch. All equipment may go through the x-ray machines at security checkpoints. In addition, each participant will be given (and should keep with them) a document on NASA letterhead stating that they are participating in a NASA study and will have specific equipment for research purposes in their possession. For crews flying international routes, a Certificate of Registration will also be provided.

12. "Who is funding this study and who has been contacted regarding participation?"

To maintain neutrality, we have made contact with representatives at various airlines, ALPA and ATA to request assistance for participation in this NASA funded study.

13. "How safe is the information I'm giving you?"

Participation is voluntary and we adhere to the ethical principles of maintaining each participant's rights to confidentiality and anonymity. We provide no information to anyone concerning the pilots or airlines that are participating in any of our studies. Also, no pilot has been or can be identified to their respective data sets.

Appendix L

Thank You Letter

National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, CA 94035-1000

Reply to Attn of: IHS: 262-4

July 11, 2002

Dear Study Participant:

On behalf of the Fatigue Countermeasures Group, I would like to extend our thanks for your participation in the recent study "Activity and Light Exposure Patterns in Flight Crew." This study was unique in many ways and your contributions to a successful data collection effort are very much appreciated. As we continue our research efforts in this area, we look forward to the possibility of working with you again in future experiments.

Sincerely,

A handwritten signature in cursive script that reads "Melissa M. Mallis". The signature is written in dark ink and is positioned above the typed name and title.

Melissa M. Mallis, Ph.D.
Principal Investigator
Fatigue Countermeasures Group
Human Factors Research and Technology Division

Appendix M

Participant Study Introduction and Instruction Letter

National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, CA 94035-1000

Reply to Attn of:

IHS: 262-4

May 3, 2002

To: Study Participants
From: Fatigue Countermeasures Group

Subject: Activity and Light Exposure Patterns in Flight Crew

Thank you for participating in this study. Enclosed with this letter you should find a:

- Consent Form (unless it has previously been sent to you)
- NASA verification of study participation letter and Certificate of Registration (those flying international routes only)
- Actiwatch (activity monitor) to wear on the non-dominant wrist and manual
- Light sensor to wear around the neck
- Background Questionnaire
- Apnea Prediction/Sleep Symptom Frequency Form
- Pair of morningness-eveningness questionnaires
- Palm Pilot Activity Log with 1 stylus, re-charger, and manual

Consent Form. Please read the consent form and complete Part 2. A witness must be present when you sign this form and please have the witness complete the appropriate spaces at the bottom of the consent form. Once you have read and completed the consent form, keep it in a safe place until the end of the study period. Then send the form to the Fatigue Countermeasures Group in the express mail envelope provided along with the other equipment and materials.

Customs Documents. Please keep the NASA letter with the equipment serial numbers in addition to the Certificate of Registration (international routes only) conveniently located with you during entry and exit through various airports. Security will vary and some officers/agents may require an explanation of the devices that you are carrying through secured airport areas.

Activity monitor and manual. Place the activity monitor on your non-dominant wrist immediately after opening the package, and press the small button on the face of the device. Log the time when the activity monitor was placed on your wrist in the Palm Pilot-based activity log. Wear the activity monitor continuously throughout the study. This device keeps a record of your activity patterns so it is important that you keep it on *all* the time, including sleep periods. **Take it off only when it would otherwise get wet** (e.g. showering or swimming). The only thing to remember when wearing the activity monitor is to press the event marker button:

1. At bed time (lights out)
2. Upon awakening
3. Whenever the activity monitor is taken off (e.g., for a shower)
4. Whenever the activity monitor is placed back on the wrist (e.g., after the shower)

Please read the Actiwatch instruction manual for more detailed information.

Light Sensor. Place the light sensor around your neck approximately 4 inches below the chin and clip it to your clothing (shirt, tie, or jacket) immediately after opening the package. Two types of clips are available for convenience. The face of the light sensor must face forward at all times in order to collect continuous light exposure, and must not be obscured by clothing, lint or dirt. Try to keep the sensor clean for the length of the study. If it does get dirty, use a moist soft cloth to clean.

Background, Apnea Prediction/Sleep Symptom Frequency, and Morningness-eveningness Questionnaires. Complete the questionnaires at your convenience during the study. Some questions relate to duty scheduling and require your logbook or pay sheets.

Activity Log. A Palm Pilot has been included in this package (with a protective case and charger). Use it to log:

1. Sleep information upon awakening
2. Flight information during duty
3. Crew rest information during duty
4. Lighting environment in the cockpit during flight
(shade use, storm or map light use)
5. Caffeine, alcohol, medication use or other daily events
6. Anytime sunglasses are worn more than 15 minutes
7. Bed time (lights out until get up)
8. The subjective scale of sleepiness to be taken before lights out, during each meal, and upon each awakening. **Most importantly, remember that when placing your mark on the scale, it is a reflection of how you are feeling within the last 5 min of when you place the mark.**

After the 5th day past your monthly flight schedule, use the return express service air waybill to return the material back to us at:

NASA Ames Research Center
Fatigue Countermeasures Group
Building 262, Room 196
Moffett Field, CA 94035-1000

If you have any questions at anytime before or during the study, please contact Ray Oyung by phone at (650) 604-0020, fax at (650) 604-2177, or email at royung@mail.arc.nasa.gov. In the event he is not available, please contact Sandy Bowman at (650) 604-6435.

Thank you again for participating in this important research study.

Sincerely,

Melissa Mallis, Ph.D.
Fatigue Countermeasures Group
Human Factors Research and Technology Division

Appendix N

Verification of Study Participation Letter for Airport Security and Customs Officers

National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, CA 94035-1000

Reply to Attn of: IHS: 262-4

July 16, 2002

Dr. Mary Connors
NASA Ames Research Center
MS 262-4
Moffett Field, CA 94035-1000

To Whom It May Concern:

This letter provides information concerning the following equipment:

1. biomedical monitoring device: Actiwatch 64, serial # _____
2. light sensor: Actiwatch-L, serial # _____
3. electronic diary: Palm Pilot Vx, serial # _____

in _____ possession.

The equipment belongs to the United States Government, NASA Ames Research Center, and when traveling internationally, a Certificate of Registration will be in the possession of the crew. The equipment will be returned to Moffett Field, California upon completion of the study.

The crewmember is involved in a NASA Research Study to examine activity and light exposure patterns in flight crew. The Actiwatch 64 the pilot is wearing on the wrist continuously records non-dominant wrist activity and Actiwatch L continuously records environmental light information. They may both be inspected. However, serious loss of data will result if it is removed from the subject for any longer than one or two minutes. The Palm Pilot records specific daily activities of the crewmember and it too can be inspected.

Your cooperation in protecting the integrity of this equipment is greatly appreciated. If you have any questions, please contact Dr. Melissa Mallis at (650) 604-3654, Ray Oyung at (650) 604-0020 or Sandy Bowman at (650) 604-6435.

Sincerely,

A handwritten signature in cursive script, appearing to read "Mary M. Connors".

Mary Connors, Ph.D., Chief
System Safety Research Branch
Human Factors Research and Technology Division

Appendix O

Activity Log Instruction Manual

NASA Ames Research Center
Fatigue Countermeasures Group
Activity and Light Exposure Patterns Study

Activity Log Manual

Introduction

Thank you for participating in the 40-day activity and light exposure patterns in-flight crew study. Using the palm pilot to complete daily entries is designed to be both user friendly and to help you complete them as quickly and as accurately possible. Only a few questions require anything more than a tap or two to complete an entry. Let's get started!

Charge your Palm Organizer

This requires both the Palm Pilot recharging cradle and AC adapter.
Insert the AC adapter cable into the back of the cradle connector.

1.

Plug in the AC adapter into a wall outlet. Use the voltage converter with the AC adapter when using the charger outside the United States (international crews only). Voltage converter information is located on a separate sheet.

Charge the Activity Log by taking it out of the protective aluminum case and placing it in the recharging cradle. Ensure that the cradle light illuminates. The Activity Log should fully charge when left on the recharging cradle over-night. As the device charges, you can continue the set up process.

3.

Controls

Palm controls

Two ways to enter data

1

Using the onscreen keyboards

Tap a blank line on the organizer screen (the cursor should blink to indicate you're in edit mode), or tap the dot under "abc" for the letter keyboard or the dot under "123" for the number keyboard. Tap the characters and then tap "Done".

There are also two other keyboards that you will use. These are the calendar keyboard and the clock keyboard.

Select Date

◀ 2002 ▶

Jan	Feb	Mar	Apr	May	Jun
Jul	Aug	Sep	Oct	Nov	Dec

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Cancel Today

Select a new time

3 : 31 ⬆ ⬇ ⬆ PM

OK Cancel

2

Using Graffiti power writing software

Graffiti® characters are similar to uppercase letters that are formed with a single stroke. Your writing turns into text wherever the blinking cursor appears on the organizer screen. It's worth taking a few minutes to learn. Just remember to write BIG and use normal pressure on the stylus.

Write letters here

Write numbers here

Your Palm Pilot

Your Palm Pilot comes pre-configured, so you will not have to make any changes to the displayed menu; however, it is a good idea to have some knowledge about how to navigate through the various screens.

- **Application Button** – Use this button to toggle between the “All”, “Main”, and “Activity Log” views. Each different view could be considered as, for example, the desktop on your home computer, and can be distinguished by the description in the top right corner of the screen. The next two pictures are examples of the “Activity Log” and “Main” views.

Activity Log

Main

- **Menu/options button** - The menus and menu commands that are available depend on the application that is currently open. Also, the menus and menu commands vary depending on *which part* of the application you're currently using. For example, in Memo Pad, the menus are different for the Memo list screen and the Memo screen. The next two images illustrate how to access the menu/options command.

- **Calculator button** - Calculator enables you to perform addition, subtraction, multiplication, and division. With the calculator, you can do the following operations: Perform basic calculations, store and retrieve values, and display the last series of calculations, which is useful for confirming a series of "chain" calculations.

- **Search/find button** - You can use Find to locate any text that you specify, in any application. As your organizer searches for the text, you can tap Stop at any time. You may want to do this if the entry you want appears before your organizer finishes the search. To continue the search after you tap Stop, tap Find More.

Activity Log

The Activity Log is used to tell a story of the events that will occur over the 40-day period of this protocol. In order to obtain the most accurate information during this period, it is extremely important to enter in as much information as you can as close in time that the event(s) occur.

The Activity Log will display 3 icons in the application field that will be used in the study.

1. **Activity Log:** This is where the majority of information will be entered
2. **Clock+:** This tool will provide you with quick reference to **UTC, which is the time that must be used for all entries.**
3. **Memo Pad:** Use this tool to enter in any information that you would like in addition to information entered into the activity log, but remember to add to each note the UTC date and time before each comment.

Overview

1. Keep the Activity Log with you during the entire study.
2. Information to be entered into the log include:
 - Sleep (while on the ground and in-flight)
 - Duty (flight information, workload ratings, use of aircraft lighting)
 - Activities including meals, beverages, medications, exercise, sunglass usage, and times when Actiwatch or light monitor are taken off and put back on
3. The device will power off automatically if no input has occurred within 2 minutes
 - Power the device on to continue where you left off
4. Place the device onto the cradle to recharge the internal lithium batteries about once per week in order to avoid power loss while away from home
5. **Do not swap the Clock+ home time with a different time zone**

<i>Activity Log</i>	
☐ Sleep	☐ Duty
☐ Meal	☐ Aircraft Lighting
☐ Beverage	☐ Sunglasses
☐ Medication	☐ Actiwatch
☐ Exercise	☐ System

Note – Date and time fields for each question must be filled out to reflect the time an event occurred and not when you are filling out the survey. For example, if you forgot to enter a beverage that you consumed the day before, you would enter the beverage type, beverage amount, the date and time when you consumed the beverage and not the time and date that you're actually entering this event into the Activity Log. This is why it's important to fill in the log of events as they occur to avoid having to remember events, which may cause inaccuracies in the data.

1. Sleep – Selecting “Sleep” will take you to a sub menu where you will choose from “Ground Sleep” and “In-Flight Sleep”.
 - Ground Sleep – After selecting “Ground Sleep” you will go to another sub menu where you will choose Pre or Post Ground Sleep.
 - Pre-Ground Sleep – Fill this out before you go to sleep if you are **not in-flight**.

- Post-Ground Sleep – Fill this out as soon as practically possible after you wake up if you are **not in-flight**.
- In-Flight Sleep – After selecting “In-Flight Sleep” you will go to another sub menu where you will choose Pre or Post Bunk.
 - Pre-Bunk – Fill this out before you go to sleep while **in-flight**.
 - Post-Bunk – Fill this out as soon as practical after you wake up while **in-flight**.
- 2. Meal – Of all events, this entry is the most important to fill out when the meal occurs (for example, after dinner has been ordered at a restaurant) because a 9-point subjective sleepiness scale is administered with each meal.
- 3. Sleep Scale – This survey is linked to the meal, duty, and sleep surveys. You should not have to actively select this survey. After completing the above surveys you will automatically be brought to the sleep scale.
- 4. Beverage – Fill this out after each beverage consumed
- 5. Medication – Fill this out after taking any type(s) of medication.
- 6. Exercise – Fill this out after exercising.
- 7. Duty – Flight safety is paramount. Only enter this information when it is operationally feasible. For those flying multiple legs/segments in a duty day (short haul, domestic, etc. operations).
 - Enter scheduled duty start and end time only for the first leg/segment of the day
 - Enter actual duty end time on the last leg/segment of the day
 Selecting “Duty” will take you to a sub menu where you will start a new entry “New”, continue with the last entry “Last”, or “Exit”. Contents of Duty include the following:
 - Leg Information
 - Flight Phase Ratings
 - Performance
- 8. Aircraft Lighting – Fill this out as best as possible when aircraft lighting is turned on, changes, or is turned off. This information is especially important for night flight operations.
- 9. Sunglasses – Fill this out each time you put on or take off your sunglasses when the glasses have been used, or will be used for a period longer than 15-minutes.
- 10. Actiwatch – Fill this out each time you put on or remove either of the Actiwatch devices. However, the Actiwatch with the light sensor monitor around the neck is taken off each night and placed next to the bed in close proximity (less than 1 meter) from the head with sensor facing the ceiling. This event does not have to be entered. The activity monitor and light sensor should stay on except as noted below.
 - Actiwatch and Light sensor: remove if the device may become wet or submerged in water.

11. Review – Use this to amend any of the prior events or to complete an event that was exited prematurely. Events are ordered by date (not time).

Navigation

1. Tap the Application/home icon at the lower left corner of the display to return to the application field to access the Activity Log, Clock+, or Memo Pad tools
2. During any time while entering information
 - Tap the tab on the upper left corner of the display to return to the main menu.
 - Use the black up/down scroll button at the bottom center of the device buttons to scroll pages forward or backwards within a category
 - If an item was accidentally missed, return to the main menu and tap the review box; select the category to review; select the time/date of entry to edit the information
3. Tap each field to enter information
 - a text keyboard will appear for questions requiring text information
 - a 10-key pad will open for each question requiring a numbered response
4. Tap the down triangle icon on selected questions to activate the drop down list choice menu

Troubleshooting

1. If the Activity Log will not power on or off, the contrast button on the Palm Pilot located on the top left corner of the device may be pinched. Remove the Palm from the case, place it back into the case and try again.

Diagram of the Activity Log Menu Structure

Clock+

1. The Clock+ tool provides a quick reference to UTC, which is the time that **MUST** be used for all entries.
2. Keep the Clock+ display on **WORLD TIME**, which is the second to last icon on the top of the Clock+ display.

3. The main window displays UTC (home time). Up to four other locations may be selected at your convenience by tapping each of the locations below the main time display. The time of each of the four locations will be displayed at the lower right corner of the screen.
4. To customize these locations, double tap one of the time zone boxes you wish to change. This will bring up a list of different time zones. Highlight a selected City or Country and tap "Set".

5. **Do not swap the Clock+ home time with a different location.** If the "Swap" button is accidentally pressed, then press the "Swap" button again to return the main display to UTC home time.

Appendix P

Activity Monitor and Light Sensor Instruction Manual

Actiwatch Manual

NASA AMES RESEARCH CENTER

Fatigue Countermeasures Group

System Safety Research Branch

Actiwatch Operation

Be careful when wearing the Actiwatch-64 (activity monitor) and Actiwatch-L (light sensor). Even those who lead active lives—rollerblading, biking, jogging, can wear an Actiwatch. However, the internal mechanisms are sensitive and non-resistant to large shocks. The components may be damaged if either Actiwatch are knocked against furniture or dropped on a hard floor. The casing is durable and water resistant for normal everyday activity. Although water resistant, **it is not water repellent.**

Please follow the guidelines while using the Actiwatches for this study and if you have any questions or comments do not hesitate to contact Ray Oyung by phone at (650) 604-0020 or by email at royung@mail.arc.nasa.gov.

Why Use an Actiwatch?

The Actiwatches provide a 24-hour estimate of the rest/activity and light/dark cycle. The Actiwatch-64 is an accelerometer and generates a voltage every time the activity monitor is moved. The voltage then passes through circuitry comparing a reference voltage to user specified settings and stores the output to a memory chip. The activity monitor is capable of collecting continuous data for up to 90 days and provides rest/activity data that can be used with previously established algorithms to estimate sleep/wake patterns and circadian phase (internal biological clock timing). The light sensor is capable of collecting continuous data for up to 75 days. Actiwatch sleep and light exposure estimates can provide participant information on time to fall asleep, total sleep time, number and length of awakenings, and average light exposure over the study period.

Guidelines

1. Wear the Actiwatch-64 activity monitor on the non-dominant wrist.
2. Place the Actiwatch-L light sensor lanyard around your neck. Keep the device clipped to your clothing with the light receiving sensor facing forward at all times.
3. Remove the Actiwatch from your neck before each sleep period and place it on a surface close to your head with sensor facing up toward the ceiling.
4. Take both Actiwatches off for showering, swimming, or any other activities in which you may get wet. When operating in a humid or rainy environment, **take care to keep the devices dry.**
5. An event marker button is located on the face of the Actiwatch-64 activity monitor (silver button with blue dot). When you press the button, it marks the time on the data record noting that moment as an "event".

6. It is imperative to adhere to the following procedure to maintain accurate data collection that will later be downloaded for analysis. Press the event marker button when:
 - a. you first put the device on when you receive it and before taking it off to send back at the end of data collection
 - b. beginning a sleep period at lights out when ready to initiate sleep and again at lights on after you get up from the sleep period
 - c. the device is removed and when placed back on the wrist
7. Use the activity log that accompanied the Actiwatch-64 activity monitor assigned to you. Record all "events" when you press the button on the Actiwatch-64 when the device is removed and put back on the non-dominant wrist.

Notes

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