MANAGING SHIFTWORK AND FATIGUE IN LAW ENFORCEMENT AND FORENSIC LABORATORIES

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INTRODUCTION

In the interest of ensuring the accurate collection and processing of forensic data the National Institute of Standards and Technology (NIST) has commissioned Clemson University's Department of Industrial Engineering to review scientific literature which can be of practical use for understanding ways to manage fatigue and shiftwork in law enforcement and to make recommendations for rest and duty restrictions. Similar regulations aimed at controlling for fatigue and shiftwork have become standards in many prominent fields namely healthcare, commercial transportation (e.g. commercial truck driving) and aviation. It is important to understand the effects of fatigue and shiftwork on law enforcement personnel because of the sensitive nature of their work. A slipup in the lab or at the crime scene could leave an innocent person behind bars, or allow a guilty perpetrator to go free. It is well know that errors can happen to the best intentioned investigator and that many of the effects of shiftwork and fatigue can exacerbate the likelihood that an error is committed.

Due to the nature of Crime Scene Investigation, law enforcement officers may be forced to work late at night during known circadian troughs. When and where crime scenes occur often leaves investigators to collect and process data while suffering from the effects of fatigue. The hope of this paper is that allowing Forensic Scientists to understand the effects of fatigue and shiftwork in their field could help them mitigate the negative effects of these challenges.

Unfortunately, there is little direct data available to identify the ideal work/rest schedule for those involved in Forensic Science. For this reason, it was necessary to examine the scientific body of work conducted on the effects of shiftwork in other industrial settings. Specific questions this review will address include:

- Which type of shift rotation is optimal?
- Can individuals adapt to night shifts?
- Are there procedures or processes to improve adaptation?
- Do traditional second and third shifts require different duty and rest periods?
- Can a break in duty during a shift extend the duty period?
- How much duty time can be extended with follow on and/or 'make-up' rest?
- How much 'make-up' rest is necessary for an extended duty period?
- How is duty and rest time tracked among different industries?

SLEEP

The literature is replete with studies demonstrating the impact a lack of sleep, especially quality sleep, has on performance. *These effects are more prominent and have greater repercussions in service areas like law enforcement, which require due diligence owing to the sensitive nature of work.* In general, the consequences of sleep loss and associated fatigue have been shown to negatively affect learning capacity (Curcio, Ferrara et al. 2006), memory consolidation (Karni, Tanne et al. 1994), mood (Dinges, Pack et al. 1997), alertness (Bonnet 1985), cognition (Cheshire, Engleman et al. 1992), coordination (Nakano, Araki et al. 2001), stress levels (Costa 1996), and reaction time (Vgontzas, Pejovic et al. 2007). As a result, getting enough sleep can be seen as a safety issue in law enforcement (Pedersen 2001). Additionally, these effects appear to be independent of the type of work being performed as deficits have been documented in areas as diverse as education (Curcio, Ferrara et al. 2006), healthcare (Montgomery 2007), driving (Lyznicki, Doege et al. 1998), manufacturing (Blachowicz and Letizia 2006), aviation (Bourgeois-Bougrine, Carbon et al. 2003), and more germane to this review - forensic science(Lindsey 2007).

Arguably, all humans have experienced mental fatigue more than once in their lifetime and many have learned to cope with the adverse effects. Even so, fatigue continues to be a common causal factor identified in many accidents including major disasters like the grounding of the Exxon Valdez, the meltdown at the Three Mile Island Nuclear Power Facility, and the explosion at the Bhopal Refinery (Rosekind, Gander et al. 1994). Nevertheless, while coping mechanisms can be incorporated to mitigate the adverse impact of fatigue, the only lasting solution is quality sleep (Caldwell 1997) and the best way to promote quality sleep is through appropriate scheduling and rest requirements (Haus and Smolensky 2006).

Issues associated with how much sleep individuals need, when that sleep should be obtained and what quality sleep entails continues to be debated by scientists, management, and the workforce. However, one thing we can all agree on is that out of necessity, all humans must sleep. However just as eating does not make one a nutritionist neither does sleeping make everyone an expert in sleep and fatigue. Therefore, to fully understand human sleep one must first understand a little about circadian rhythms and sleep architecture.

Circadian Rhythms

The word "circadian" is actually derived from two Latin words *circa* (about) and *dias* (day). Indeed, circadian rhythms are biological processes that in most environments cycle about a normal 24-hour day regulating a variety of physiological processes, including: body temperature, neurotransmitters, hormones like cortisol and melatonin, heart rate, and core body temperature (Blatter and Cajochen 2007) . Indeed, the latter, core body temperature, may be the most sensitive and easily obtained measure of circadian rhythmicity. However, as important as those physiological processes are, even more important to forensic science is that performance is also directly related to one's circadian rhythm and the sleep/wake cycle (Fuller, Gooley et al. 2006).

As can be seen in Figure 1 the circadian rhythm and as a result, performance and sleepiness/alertness, generally reach a minimum between 3 a.m. and 6 a.m., known as the circadian trough (nadir), and a maximum (peak) between 2 and 8 p.m. (Waterhouse, Drust et al. 2005).

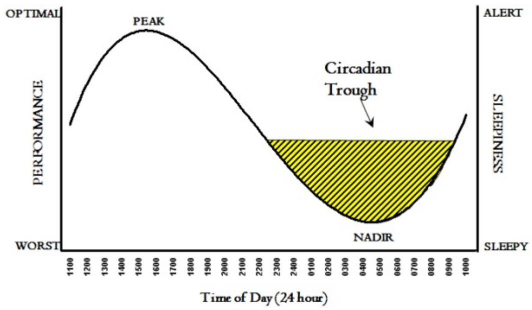

Figure 1. The human circadian rhythm.

Thought to be generated by the suprachiasmatic nucleus within the hypothalamus of the brain, the circadian rhythm is actually about 25 hours, not 24 as observed in most individuals. However, the circadian rhythm is "reset" to 24 hours daily by a series of external references, called zeitgebers (Revell and Eastman 2005). The most powerful of these zeitgebers is natural daylight (Lack and Wright 2007). In simple terms, the presence of sunlight signals the circadian pacemaker that it is day time, while the absence of sunlight indicates night time (Skene and Arendt 2006). With a few notable exceptions like Alaska and other polar regions where the normal light-dark cycle can be markedly different, daytime and nighttime cycles about a 24-hr day.

While sunlight is arguably the most important zeitgeber other references like social cues, meal times, exercise, and levels of naturally occurring hormones produced by the body can influence circadian rhythmicity (Eastman, Hoese et al. 1995; Revell and Eastman 2005; Grandin, Alloy et al. 2006). Regardless of the mechanism however, it is important to note that, the circadian pacemaker remains remarkably stable from day-to-day even in the presence of abrupt external changes such as sleep deprivation and/or time-zone changes (Beersma and Gordijn 2007).

Although consistent within an individual, circadian rhythms do vary slightly from person to person particularly as one gets older (Akerstedt 2007). For instance, there is some evidence that a subset of the population are naturally suited to day work (so-called morning larks) and others to night work (night owls) - yet this may be more subjective than physiological. Likewise, as people age it appears that their circadian rhythms shifts earlier in the day causing earlier rise and bed times (Gander, Nguyen et al. 1993).

Stages of Sleep

Recall that just as performance cycles about the circadian rhythm so do sleepiness and fatigue. Fortunately, sleepiness and fatigue are acute conditions typically relieved by a good night's sleep. Nevertheless, sleep is not just an opportunity to recharge one's batteries and dream. Nor is all sleep the same.

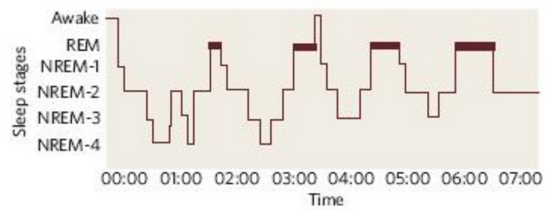

Figure 2. The typical sleep cycle for an adult.

Throughout the course of a sleep period, the body shifts through several stages of sleep characterized by changes in brain activity (Figure 2). The first stage (Figure 2; non-rapid eye movement stage 1 or NREM-1) is brief and consists of very light, transitional sleep. The second stage (Figure 2; NREM-2) is also a fairly light sleep and typically makes up the largest amount of total sleep time over the course of a sleep period. The third (Figure 1; NREM-3) and fourth stages (Figure 1; NREM-4) represent a deeper sleep characterized by slow wave brain activity. It is during these deeper slow wave sleep (SWS) stages where the recuperative work of sleep takes place. The final sleep stage involves rapid eye movement (Figure 2; REM) sleep involving brain activity that resembles being awake and is often associated with dreaming. While it is still unclear what role REM sleep plays, some believe that during REM sleep memories are consolidated and learning is reinforced (Karni, Tanne et al. 1994). Of note, as people age the normal sleep architecture becomes distorted with less time spent in SWS and REM sleep and more time in lighter stages of sleep (Gander, Nguyen et al. 1993; Van Cauter, Leproult et al. 2000).

The Best Time to Sleep

It is well established that the circadian rhythm plays a key role in controlling both the duration and quality of sleep (Beersma and Gordijn 2007). As a person nears the circadian trough several physiological and psychological changes take place including a drop in core body temperature, an increase in melatonin levels, and a natural increase in the pressure to sleep (Murphy and Campbell 1997). During the circadian trough a person's alertness level decreases, their cognitive abilities drop, and performance reaches a minimum (Nakano, Araki et al. 2001). Clearly then, it appears that humans are "designed" to sleep during the night and operate during the day – we are not nocturnal animals. In fact, sleeping outside of the circadian trough often results in reductions in total sleep time, fragmented sleep, less SWS and REM sleep, and performance deficits (Akerstedt, Hume et al. 1997).

The Effect of Sleep Disruptions

In addition to sleeping during the circadian trough, it has been shown that sleep continuity is also a prominent factor influencing sleep quality (Wesensten, Balkin et al. 1999). Evidence suggests that periods of continuous sleep allow the body to reach the deeper, more restorative stages of sleep. In fact, it has been suggested that sleep which is disrupted can actually be more detrimental than no sleep at all because the body is unable to reach the deeper more restorative stages of sleep (Bonnet 1985).

Not only does waking up during the circadian trough result in a decrease in total sleep time and subjective sleep quality but it has also been shown to increase stress levels (Kecklund, Akerstedt et al. 1997). To make matters worse, when sleep disruptions are combined with the stress associated with highly demanding jobs and personal troubles, the effects on the individual can be exacerbated. In effect, a veritable "Catch-22" is created as disruptions in sleep cause stress which in turn can lead to known health effects made worse by job and life stress which in turn produces further sleep disruptions and other sleep-related problems (Akerstedt, Knutsson et al. 2002; Knudsen, Ducharme et al. 2007). One need look no further than the aviation accident record to find numerous examples of how sleep disruptions among aircrew during layovers and while off duty have impacted performance

Sleep Requirements

While there are some individual differences, the scientists seem to agree that the average person needs roughly 8 hours of sleep each night to be properly refreshed (Akerstedt, Hume et al. 1997)**.** A decrease by just a few hours from the recommended amount to as little as five hours of sleep per night can cause serious performance decrements (Dinges, Pack et al. 1997). More important, successive nights of sleep loss can lead to a condition known as *sleep debt*.

As the name implies, this sleep debt must be made up for to have a full recovery (Hardaway and Gregory 2005). Even a loss of 1-hour of core sleep per night can lead to performance deficits over time as seen in Figure 3. However, consecutive nights of 2, 3, and 4 hours of sleep per night can lead to alarming performance deficits. While there is not a one-to-one payback of sleep debt, it is known that after a week of sleeping five hours a night, it can take up to two full nights of sleep to fully recover (Dinges, Pack et al. 1997).

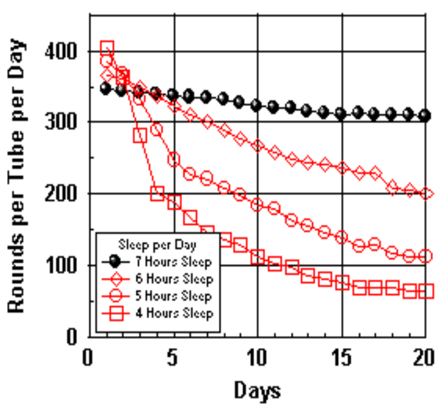

Figure 3. Performance deficits as a result of days of cumulative sleep loss (Source: Department of Behavioral Biology, Walter Reed Army Institute of Research.

Summary

- While all sleep is beneficial, SWS is more recuperative.
- The best time to sleep is during the circadian trough (between 2200-0800).
- Interruptions of nighttime core sleep reduce sleep quality and effectiveness.
- Individuals need roughly 8 hours of sleep to be properly refreshed.
- Sleep loss is cumulative and may take multiple nights of sleep to fully recover.

SHIFTWORK

Shiftwork has become quite common in the modern 24/7 society and is typically defined as effort that occurs outside the hours of 7:00 a.m. to 6:00 p.m. (Blachowicz & Letizia, 2006). Estimates put the number of people in the U.S. engaged in shiftwork somewhere between 20% and 25% of the working population (Akerstedt, 1988; Costa, 1996).

Law enforcement professionals in particular are at risk of mental and physical fatigue due to shiftwork. Forensic experts are subject to voluntary and mandatory overtime assignments as well as long hours waiting to testify in court (Lindsey 2007).

While actual shift schedules vary among industries and locations, a typical shift schedule might take the following form:

First shift:	7 AM - 3 PM
Second shift:	3 PM -11 PM
Third shift:	11 PM -7 AM

What makes schedules like this a concern within all industry, not just forensic science, is that there is clear evidence that shiftwork can have a negative impact on worker performance and health (Haus & Smolensky, 2006). For instance, it is well known that shiftwork is inherently fatiguing (Tvaryanas & Thompson, 2006) and that prolonged shiftwork can lead to sleep disorders, which in turn can cause medical (e.g., gastrointestinal and cardiovascular), social, economic, and quality of life issues (Schwartz & Roth, 2006). Even rotating shiftwork, as is often employed in many industrial settings, can result in a variety of health problems affecting body mass index, waist-hip ratio, and blood pressure (Sookoian, et al., 2007).

Shiftwork and the Circadian Cycle

At the root of many of the problems associated with shiftwork is the impact on normal circadian rhythmicity. Circadian rhythms are biological processes that in most environments cycle about a normal 24-hour day and regulate a variety of physiological processes, including: body temperature, neurotransmitters, hormones (e.g., cortisol and melatonin), heart rate, and core body temperature (Blatter & Cajochen, 2007). However, as important as those physiological processes are, even more important to space transportation is that performance is also directly related to circadian rhythmicity and the sleep/wake cycle (Fuller, Gooley, & Saper, 2006).

As can be seen in Figure 1 the circadian rhythm, and consequently, performance and sleepiness, typically reach a minimum (nadir) between 3:00 a.m. and 6:00 a.m., also known as the circadian trough, and a maximum (peak) between 2:00 p.m. and 8:00 p.m. (Waterhouse, et al., 2005). However, unlike the depiction in Figure 1, when left to its own devices the internal circadian pacemaker is tied to a 25-hour clock, not 24 hours as is observed in most individuals. Nevertheless, the circadian rhythm is "reset" daily to 24 hours by a series of external references, called *zeitgebers* (Revell & Eastman, 2005) - the most powerful of which is natural daylight (Lack & Wright, 2007).

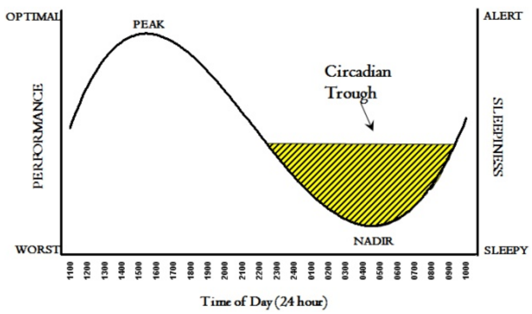

Figure 1. The human circadian rhythm.

In simple terms, the presence of sunlight signals the circadian pacemaker that it is day time, while the absence of sunlight indicates night time (Skene & Arendt, 2006). With a few notable exceptions like Alaska and other polar regions where the normal light-dark cycle can be markedly different, daytime and nighttime cycles revolve around a 24-hr day. While sunlight is arguably the most important zeitgeber, other references like social cues, meal times, exercise, and levels of naturally occurring hormones produced by the body can influence circadian rhythmicity (Eastman, Hoese, Youngstedt, & Liu, 1995; Revell & Eastman, 2005; Grandin, Alloy, & Abramso, 2006).

Although capable of flexibility as one transits multiple time zones or engages in activity outside the normal work/rest cycle, it is important to note that, the circadian pacemaker remains remarkably stable from day-to-day (Beersma & Gordijn, 2007). However, when normal circadian rhythmicity is disrupted by external stimuli like the length and intensity of sunlight, social cues, and work-rest schedules, *circadian desynchronosis* can occur resulting in observable physiological and performance deficits.

In addition to entraining human physiology and performance to local light/dark cycles, zeitgebers also entrain one's sleep/wake patterns (Revell & Eastman, 2005). Indeed, the relationship between circadian rhythmicity and sleep is widely accepted as the circadian rhythm affects both sleep quality and sleep duration (Beersma & Gordijn, 2007). Studies have shown that in order to receive the maximum benefits of sleep, one must sleep continuously during the circadian trough. It is during that time when optimal amounts of deeper, more restorative sleep can be obtained (Akerstedt, Hume, Minors, & Waterhouse, 1997).

If sleep is not obtained during optimal times (i.e., circadian trough) the restorative nature of sleep may be inhibited which when repeated over consecutive days can lead to sleep debt. In turn, sleep debt can manifest as fatigue, sleepiness, and performance deficits (Hardaway & Gregory, 2005).

The inherent problem with most shiftwork is that it requires individuals to function during times that they would normally be sleeping and to sleep during their natural periods of wakefulness. What's more, many organizations require employees to work a given shift for several days or weeks, which can have serious ramifications in high-risk industries if those shifts include all or part of an individual's circadian trough.

Adverse Impact of Shiftwork

The physiological and psychological effects of shiftwork on employees can be significant and long lasting. Sleep disturbances, gastrointestinal problems, cardiovascular troubles, decreased operator performance, chronic stress, and mood disorders are all common maladies experienced by shiftworkers. In fact, at least one study has reported that reduced sleep opportunities associated with working the third shift may reduce life expectancy (Kripke, Simons, Garfinkle, & Hammond, 1979). Knowing that, it should come as no surprise that roughly 20% of all employees engaged in shiftwork leave the job due to problems associated with working shifts (Costa, 1996). It is important therefore, to understand the underlying causes of these problems, the way they develop, and negative effects commonly associated with them.

Sleep disturbances

Most studies agree that shiftwork leads to increased fatigue, sleepiness, and sleep disturbances among workers (e.g., Moore-Ede & Richardson, 1985). Referred to clinically as ShiftWork Sleep Disorder (SWSD), it appears to be more common among those working rotating shifts (e.g., rotating weekly between day, evening, and night shifts), followed by fixed shifts and straight daytime workers (Schwartz & Roth, 2006).

SWSD is characterized by two primary symptoms: 1) excessive sleepiness during the night work period, and 2) insomnia during the daytime sleep period. Both are directly related to the body's inability to properly adapt to the shiftwork schedule and are exacerbated by the lack of exercise, use of alcohol, and emotion-focused behaviors (Samaha, Lal, Samaha, & Wyndham, 2007). Moreover, the effects of shiftwork on sleep quality are seen more strongly in younger workers (Marquie, Foret, & Queinnec, 1999).

Gastrointestinal system

One of the most commonly reported problems associated with shiftwork are gastrointestinal problems (e.g., constipation, heartburn, gas, and appetite disruption). In a recent study conducted by Caruso, Lusk and Gillespie (2004), some 20-75% of shiftworkers reported gastrointestinal problems compared with only 10-25% of daytime workers. In fact, a meta-analysis of 36 studies, including a total of 98,000 workers, showed that night work specifically led to gastrointestinal problems at a rate 2 to 5 times higher than among workers who did not work during the night (Costa, 1996).

Some have suggested that the problems stem from a lack of access to the same nutritional foods available to daytime workers. Supporting this assertion was the finding that those on a rotating shift schedule have a higher body mass index and waist-hip ratio (Sookoian, et al., 2007). However, others suggest that inconsistent eating habits, circadian desynchronization, and sleep deficits cause these problems (Vener Szabo, & Moore, 1989). Regardless of their exact cause, the concern among workers and employers alike is that these problems can develop into chronic disorders like chronic gastritis and peptic ulcers, which can have serious consequences (Smith, et al. 2003).

Cardiovascular system

Shiftworkers have also been shown to be at an increased risk for cardiovascular disorders, especially myocardial infarction. One study in particular showed that shiftworkers have a 40% higher risk of severe cardiovascular disorders (Boggild & Knutsson, 1999). Although the direct cause of this increased risk is not known, lifestyles like smoking, poor dietary habits, and chronic fatigue associated with shiftworking populations are thought to contribute (Moore-Ede & Richardson, 1985). Certainly, chronic stress, which is often associated with shiftwork, has been shown to increase blood pressure, which, in turn, may lead to cardiovascular problems (Costa, 1996).

Mood

Given that sleep loss is commonly associated with decreased reasoning ability and mood changes, it is not surprising that shiftworkers report these problems as well (Blagrove & Akehurst, 2001). A comprehensive study of 23 nurses during their first shiftwork experiences showed a significant relationship between circadian rhythm and mood. Five particular mood aspects were strongly correlated with variations in circadian rhythm: vigor-activity, fatigue-inertia, confusion-bewilderment, friendliness, and total-mood-disturbance. Of note, the effects were found to be equally severe among workers on a 4-on 3-off schedule as on workers on an 8-on 7-off schedule. This suggests that mood was fully affected after only 4 days on the night shift (Florida-James, Wallymahmed, & Reilly, 1996).

It has been suggested that these mood effects are caused by both sleep loss and by the difficultly of maintaining familial and social relationships (Costa, 1996; Lac & Chamoux, 2004). Furthermore, shiftwork has been shown to cause some specific problems among women, in particular (Costa, 1996). Indeed, it has been suggested that the disruption in the body's natural rhythms common in shiftwork adversely affects the reproductive system in many ways including: affecting the regularity of a woman's menstrual cycle, increasing the risk of spontaneous abortions, decreasing the rates of pregnancies, and causing premature delivery and lower birth weights (Hatch, et al., 1999; Nurminen, 1989). Furthermore, women with children are more likely to suffer increased fatigue, from lack of daytime sleep, and increased stress from coping with childcare responsibilities (Dekker & Tepas, 1990).

PERFORMANCE

There are a long list of decrements in performance stemming from fatigue and sleep deprivation. Researchers have found that these impacts include cognitive performance decrements, decreased vigilance and sustained attention, performance variability, slowed physical and mental reaction time, an increase in the number of work related errors, an increased tendency to persistently repeat behaviors, an increase in false responding, an increase in memory errors, and reduced motivation (Rosekind, et al., 1995; Rosekind, et al., 1996; Dinges & Kribbs, 1991). Lamond and Dawson (1999) have equated the result of sleep deprivation to alcohol intoxication. They found that sleep deprivation of 20 to 25 hours, dependent on task type, is equivalent to performance when blood alcohol is .10%, well above the national legal limit of .08%. At this level, alertness, judgment, coordination, concentration, reflexes, reasoning, and depth perception are all negatively impacted. Other performance effects can be determined based on time of day, and length of time the shiftworker has been on shift type.

Performance decrements are affected by time of day and relation to the circadian rhythm, which result in certain tasks being performed better at specific times during the day. Scott (1994) states that performance can be generally predictable if the type of task is known. Tasks that respond to the circadian rhythm are those involving vigilance, manual dexterity, boring repetitive tasks, or those requiring fast reaction time. If these tasks are performed when body temperature is low, performance will be less efficient, and will contain more errors. Other tasks such as those with high-cognitive requirements may be performed best either during the night shift or in the circadian nadir. Tasks primarily involved in immediate memory have been shown to be performed best in the morning (Folkard & Monk, 1980), while working memory tasks are performed better near the middle of the day (Folkard, 1975). An additional consideration is cognitive load. As the memory load imposed by the task increases, the performance was performed better earlier in the day.

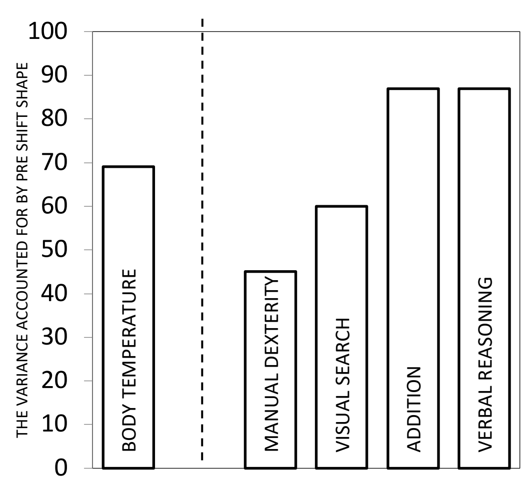

Figure 2. *Adjustment rhythms in different performance measures (figure adapted from Monk & Folkard, 1979)*

The rate at which task performance responds to shiftwork is also dependent on the type of task. For example, certain tasks respond much quicker than others to changes in shiftwork. More complex cognitive tasks were found to have a greater phase adjustment than simple repetitive tasks and body temperature (Scott, 1994). Folkard & Monk (1979) found that mathematical addition and verbal reasoning were the quickest tasks to adjust followed by visual search, and manual dexterity (Figure 2). The memory load of a task may also influence the rate of adaptation (Scott, 1994). The performance adaptation length should be considered when the pace of rotation schedule is determined.

Rest Requirements Associated with Shiftwork

In general, rest can be defined as *the absence of movement of an object in relation to its surroundings.* While this definition sounds plausible when describing cars and baseballs, in the context of human performance, the idea of rest is somewhat ambiguous. There are a number of different kinds of rest, including: physiological rest, sensory rest, emotional rest, and mental rest. The type of rest most pertinent to this review involves bodily recuperation such that human performance is maximized.

The truth is that quality rest has significant effects on operator performance, but few agencies, if any, attempt to quantifiably define rest as it relates to the effects on operator performance. For example the Federal Aviation Administration which is tasked with regulating commercial aviation, loosely defines a rest period for aircrew as:

> "... a period of time required … that is free of all responsibility for work or duty prior to the commencement of, or following completion of, a duty period, and during which the … crewmember … cannot be required to receive contact from the program manager. A rest period does not include any time during which the program manager imposes on a … crewmember … any duty or restraint, including any actual work or present responsibility for work should the occasion arise."
> 14 CFR §91.1057.

While the definition of rest can be defined in many ways for most industries, including law enforcement, there is still a high value placed on its implementation around the work schedule. Table 1 provides a summary of operator rest requirements in different industries.

Unfortunately, many of the current regulations fail to integrate work-rest requirements into the demands of the human circadian rhythm, or the day-night cycle. That is, for truck drivers, the 7:00 AM to 6:00 PM (11 hr.) shift is numerically (time) equivalent to the 11:00 PM to 10 AM (11 hr.) shift, even though the latter directly falls over the circadian trough when performance and alertness are adversely impacted by fatigue and sleepiness. Napping is a common form of rest and has proven highly effective in improving operator performance. The next section discusses this type of rest in more detail.

Table 1. Comparison of Rest Requirements for Different Industries

Trucking[1]	
Maximum consecutive duty time allowed	11 hrs
Minimum rest between duty time	10 hrs
Cumulative duty limit after work span	60 hrs for 7 days or 70 hrs for 8 days
Medical Resident[2]	
Maximum consecutive duty time allowed	24 hrs (+6 hrs for auxiliary activities)
Minimum rest between duty time	10 hrs
Cumulative duty limit (A) after work span (B)	A=320 hrs; B=28 days
Commercial Pilot[3]	
Maximum consecutive duty time allowed	14 hrs[4]
Minimum rest between duty time	10 hrs
Cumulative duty limit (A) after work span (B)	A=500 hrs; B=3 months

[1] Federal Motor Carrier Safety Administration, 2005 (49 CFR §395.5)

[2] Accreditation Council for Graduate Medical Education, 2007

[3] Federal Aviation Administration, 2007 (14 CFR §91.1057)

[4] Maximum flight time for a single pilot is 8 hrs, maximum flight time for 2 pilots is 10 hrs. Also extended duty and flight times apply to heavy crews of 3 and 4 pilots.

Impact of Shiftwork Across Industries

The adverse impacts of shiftwork on those working in law enforcement include risk of officer injury, the possibility of significant civil liability damage awards for avoidable accidents, and compromised public safety among others (Senjo 2011). While it is unclear within the scientific literature what impact shiftwork has on law enforcement, its impact on other industries has been well documented (Akerstedt, 1988; Costa, 1996; Rosekind, et al., 1994) – particularly as it relates to accident causation. In fact, the accident rate associated with rotating shiftworkers has been shown to be twice that of fixed day or night shift employees (Gold, et al., 1992). Perhaps we should not be surprised that several high profile disasters including the Chernobyl and Three Mile Island nuclear reactor incidents, the grounding of the Exxon Valdez, and the Bhopal pesticide disaster, have occurred during the circadian trough (Mitler et al. 1988; Dinges, 1995). The good news is that many organizations have endeavored to reduce the increased risk of accidents associated with shiftwork – some more successfully than others.

Healthcare

In a landmark report by the Institute of Medicine (IOM), it was revealed that as many as 98,000 deaths each year are the result of medical error (IOM, 2000). Exactly how many of these deaths can be attributed to shiftwork, sleep disruptions, and fatigue, is difficult to assess. However, as one might expect in any 24/7 operation, roughly one in three full-time nurses and other healthcare professionals engage in some form of shiftwork or rotating schedule of day and night shifts (Blachowicz & Letizia, 2006). In addition to normal shiftwork, many others (e.g., medical residents, interns, and some practicing physicians) work extraordinarily long hours where 24-, 48-, or even 72-hour duty is not unusual. As such, they are at a higher risk of making serious medical errors (Surani, et al., 2007). The issue became so widespread that the Accreditation Council on Graduate Medical Education and the Association of American Medical Colleges has placed an upper limit on how long medical residents can work (i.e., 80 hours per week averaged over a two-week period).

While a reduction from a traditional 100-hour workweek to an 80-hour workweek is an improvement, one has to wonder if a larger reduction would be even more beneficial; particularly, given a recent study that found a reduction in hours to a more manageable 63-hour week resulted in a sizeable decline in the number of errors made by interns (Landrigan, et al., 2004). What's more, medical residents working a restricted schedule that limits consecutive work hours to 16 hours, have exhibited fewer than half as many attention failures as residents on a schedule of 24-hours on-duty or longer (Lockley, et al., 2004).

Trucking and Highway

Like healthcare professionals, truck drivers also frequently work through the night. However, unlike the frequent decision-making required of nurses and physicians, driving a truck is a skill-based task that requires constant vigilance and alertness. Unfortunately, studies of truck drivers have revealed that they too experience higher levels of sleepiness during the circadian trough. In fact, in at least one study, the degree of driver sleepiness could be predicted based on total number of work (driving) hours and the time of arrival (Kecklund & Akerstedt, 1993).

However, the threat to safety does not end at the doors of the hospital or gates of a factory. Many workers regularly commute to and from work in their vehicles, exposing them to risks associated with shiftwork and fatigue. In fact, the National Highway Traffic Safety Administration (NHTSA) estimates that there are some 56,000 sleep related road crashes annually, resulting in 40,000 injuries and 1,550 fatalities. This data suggest that approximately 4% of fatal accidents can be attributed, at least in part, to fatigue. However, other studies in the U.S. show much higher rates, from 17% of accidents overall to 50% of fatal accidents (Royal Society for the Prevention of Accidents, 2001).

While fatigue-related accidents can occur at any time of day, a meta-analysis of fatal car accidents conducted by Mitler et al. (1988) revealed that considerably more accidents occur between midnight and 6:00 a.m. then any other time of day (Figure 4). Similar trends have been seen within the road transport industry with a peak in accidents from 2:00 – 3:00 a.m. and a second minor peak in the early afternoon (Folkard, 1997).

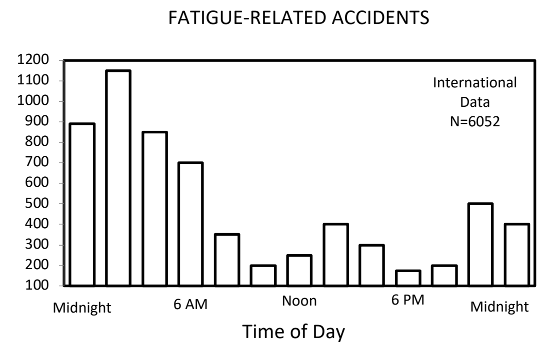

Figure 4. Fatigue related fatal car accidents from Israel, Texas, and New York (figure adapted from Mitler, et al., 1988).

These data are particularly interesting in light of the findings of Garder et al (1994) who surveyed over 200 drivers and found that 31% admitted to falling asleep at the wheel on at least one occasion during the past year. Moreover, employees who worked extended work hours were much more likely to have problems. Specifically, shiftworkers who worked extended hours were more than twice as likely to be involved in a motor crash and nearly 6 times more likely to be involved in a near miss than employees who worked a standard 8 hr shift (Barger et al, 2005). In fact, as the number of extended work shifts increased per month, the risk of a car accident on the way to or from work also increased by over 16%. In months where five or more extended shifts were worked, they were nearly two and one half times more likely to be involved in an accident, and nearly 4 times more likely to fall asleep in traffic.

Aviation

Commercial and military pilots suffer from many of the same complaints as shiftworkers, including the lack of alertness and excessive fatigue. Whether flying multiple-leg short-haul domestic flights, or long duration international flights, aircrews often operate at all points of their circadian clock while transiting multiple time zones (Lowden & Akerstedt, 1998). Such operations can lead to unintended sleep loss particularly when aircrews are forced to sleep during their circadian peak or in unfamiliar accommodations away from home.

Unfortunately, the impact of these disruptions can threaten the efficient and safe operation of flights. In a study of 12 British Airways pilots both subjective and objective sleepiness increased during flights through the night. More alarming, of the 12 pilots studied, ten either involuntarily slept or exhibited symptoms of sleepiness during the flight (Wright & McGown, 2001).

Several scientific surveys have exposed similar problems. For instance, a survey of both long- and short-haul commercial airline pilots revealed that many pilots have experienced fatigue effects directly related to shiftwork including small errors and slow response rates (Bourgeois-Bougrine, et al., 2003). In another study, nearly all the U.S. Army aviation personnel surveyed reported that they had engaged in some form of shiftwork with nearly two-thirds reporting that they did not get enough daytime sleep to properly adjust to the shift change (Caldwell & Gilreath, 2001).

While different than either military pilots or those involved with commercial short-haul domestic flights, pilots involved in international flights are often required to fly multiple legs outside of normal working hours over a period of several days. Given the 19-22 hours that are standard wakefulness hours for commercial pilots on outbound international flights, it should come as no surprise that significant levels of fatigue and performance decrements limits the ability of pilots to visually search their environment – a particularly troubling finding given the visually demanding task of flying an aircraft (Suvanto, Harma, Ilmarinen, & Partinen, 1993). These decrements are often worse during later flights in a multi-leg trip (Petrilli, Roach, Dawson, & Lamond, 2006).

Complicating matters, individuals (both aircrew and passengers) who transit multiple time zones during long, international flights often find their internal circadian rhythms desynchronized from the local light-dark cycle and other zeitgebers. This condition, colloquially referred to as *jetlag*, creates many problems and discomforts for the modern traveler. Unfortunately, the many bodily functions regulated by the circadian cycle adjust to new time zone at different rates, sometimes taking more than a week to fully adjust and resynchronize (Wegmann & Klein, 1985). It is during these times where symptoms of jet lag (e.g., fatigue, increased reaction time, reduced attention, diminished memory, and withdrawn mood) manifest.

As a result, when a passenger or crewmember arrives, Shiftwork presents a similar, but more challenging problem, as the external cues are continually fighting against the internal circadian cycle. While the worker attempts to sleep during the day and work at night, external cues such as the natural light/dark cycle and social cues continually fight adaptation. The strongest zeitgeber, the natural light/dark cycle, in particular is in direct competition with shiftwork adaptation (Lack & Wright, 2007). While this type of exogenous indicator is normally very useful in regulating the circadian rhythm, it can make adaptation to the night shift quite difficult as the body is constantly fighting to return to a typical day/night schedule – particularly on days off when individuals often revert to normal daytime schedules.

Firefighting

Firefighters face a different challenge since they may have the opportunity to sleep during their shift; but, are subjected to sleep disruptions and abrupt waking during emergencies. A study involving waking firefighters up at different times during the night showed higher levels of subjective sleep complaints and irregular sleeping patterns particularly when awakened during the circadian trough (Takeyama, et al., 2005).

COUNTERMEASURES TO FATIGUE AND INSOMNIA

Ideally, law enforcement personnel and forensic experts would always have the opportunity to obtain the quantity and quality of sleep necessary to ensure maximum performance because their work is vital to public safety. Unfortunately, there are many circumstances in which adequate sleep cannot be obtained. In these cases there are some options available to minimize the effects of inadequate sleep. In the case of fatigue, these are only short-term fixes and should not be relied upon as long-term solutions. Some commonly used countermeasures to fatigue and insomnia are presented in **Table 1** and are discussed briefly below.

Table 1. Countermeasures to fatigue and insomnia.

FATIGUE	*INSOMNIA*
Non-Pharmacological	**Non-pharmacological**
Napping	Diet
Light Exposure	Exercise
Physical Activity	
Pharmacological	Routine Sleep Times
Caffeine	**Pharmacological**
Other Stimulants	Melatonin
	Alcohol
	Sedatives

Fatigue

Napping **-** Many people experience some form of fatigue during the following day as a result of sleep loss/disruptions. In these instances, daytime napping has been found to be an effective non-pharmacological countermeasure to fatigue. Napping has also been found to be especially beneficial when taken before the night shift or when an individual is required to remain awake when he/she would otherwise be asleep (Petrie, Powell et al. 2004).

That being said, the larger question is "how long does a nap have to last to be effective?" Not surprising, naps of 1-2 hours have been shown to significantly increase the level of alertness and to a lesser extent the level of performance (Vgontzas, Pejovic et al. 2007) and memory (Tucker, Hirota et al. 2006). However, even naps as short as 10 minutes can be restorative (Brooks and Lack 2006). Still others have demonstrated that naps as brief as 15 to 20 minutes increase the alertness levels of workers and increase the accuracy in vigilance tasks (Purnell, Feyer et al. 2002; Takahashi, Nakata et al. 2004).

Curiously, the point in the circadian cycle when a nap occurs does not seem to influence accompanying improvements in alertness, meaning that the time a nap is taken does not affect the benefits of the nap. This lends itself to the practice of law enforcement departments encouraging officers to take naps whenever their workload is low enough (Pedersen 2001). Furthermore, the effects of sleep inertia, grogginess immediately following waking, do not appear to be a concern when short naps (i.e., less than 1 hour) are taken (Driskell and Mullen 2005).

Light Exposure - Exposure to bright light is another effective means to address fatigue. Recall that the light/dark cycle in humans plays an important role in synchronizing the circadian pacemaker (Duffy, Kronauer et al. 1996). Not surprising then, the exposure to specific types of bright light (i.e., those that simulate the natural wavelengths seen in sunlight) may be used to phase delay the body's circadian rhythm in some operational settings (Boivin and James 2002) and may also help in overcoming the effects of jet-lag due to rapid scheduling changes (Wetterberg 1994; Caldwell 2005; Revell and Eastman 2005; Lack and Wright 2007).

Physical Activity – Some agencies encourage officers to use physical activity as a means to stay awake. When fighting sleep, using a form of transportation, like a bicycle or "walking the beat", as opposed to sitting in a vehicle requires physical activity, which helps prevent the immediate onset of sleep (Pedersen 2001). In parallel, a criminologist could break away from the seated workstation by electing a task that requires a greater level of physical activity when feeling fatigued.

It has been shown that a single 4-hour exposure to light on the first day of the night shift can phase-delay the secretion of melatonin by 2-hours and thus delay the onset of sleepiness and fatigue and improve performance on the night shift (Dawson and Campbell 1991). Dark glasses may also help avoid resynchronization to the natural circadian rhythm and allow workers to adapt more quickly to nighttime shift work (Eastman, Stewart et al. 1994; Yoon, Jeong et al. 2002). There is also some evidence that bright light exposure during the day may help with fatigue by promoting better nocturnal sleep for workers (Wakamura and Tokura 2000).

Caffeine - Because of its abundance, over the counter availability, minimal side effects and low cost, caffeine is perhaps the most commonly used pharmacological countermeasure to fatigue. The use of caffeine improves performance and vigilance during periods of sleep deprivation (Caldwell 2005; Dagan and Doljansky 2006; Phillip, Taillard et al. 2006). Caffeine also improves reaction time. The use of 300-mg of caffeine may sustain performance levels for a period of 24 hours (Caldwell and Caldwell 2005).

In fact, some have suggested that when sleep needs to be delayed for a longer period of time, low doses of slow release caffeine may be a better countermeasure to fatigue than a nap (De Valck, De Groot et al. 2003). Then again, the use of caffeine as a countermeasure to fatigue might not be effective for all people. For instance, frequent users of caffeinated products may build a tolerance that renders the benefits of caffeine useless (Caldwell 2005). After 18 days of chronic use, many if not all individuals experience a complete tolerance to the effects of caffeine (Caldwell and Caldwell 2005).

Stimulants – Although less common in most civilian settings, the use of prescription and over the counter stimulants has also been used as a countermeasure to fatigue. For example, amphetamines have been used in some military operations. Likewise, dextroamphetamine has been shown to improve pilot performance during sustained wakefulness (Caldwell 2005; Caldwell and Caldwell 2005; Wesensten, Killgore et al. 2005; Eliyahu, Berlin et al. 2007) while methamphetamine appears to improve performance in shift workers (Hart, Haney et al. 2005). Regardless, the use of these stimulants is forbidden in law enforcement settings.

Notably, the use of stimulants is accompanied by side effects which include the possibility of addiction and cardiovascular problems (Caldwell 2005). However, more recently, the use of modafinil, a stimulant boasting fewer side effects than traditional stimulants, has been researched as an alternative to other stimulants (Caldwell 2005; Gill, Haerich et al. 2006; Eliyahu, Berlin et al. 2007). Modafinil has also been given in multiple doses over a work shift to sustain wakefulness and improve vigilance (Lagarde and Batejat 1995).

Insomnia

Sleep hygiene refers to a group of behaviors that are typically utilized along with pharmacological aids to reduce insomnia. Like countermeasures addressing fatigue, those effective in reducing insomnia generally fall into two categories: non-pharmacological and pharmacological counter-measures.

Diet - One aspect of good sleep hygiene is diet. While the reasons for insomnia in shift workers vary, in general differences in the timing of meals, the unavailability of well-balanced meals at night, and snacking all contribute to difficulties with sleeping (Atkinson and Davenne 2007). That being said, people who suffer from insomnia should avoid large meals (Morin 2006) and foods with high sugar or caffeine contents before bedtime (Atkinson and Davenne 2007).

Exercise - Another aspect of good sleep hygiene is exercise. Exercise later in the day can increase the depth and length of sleep during the night (Caldwell 1997). It appears that the increase of body temperature from exercise is associated with a faster sleep onset (Stepanski and Wyatt 2003). However, the timing of the exercise is important. Evidence suggests that exercise should be completed 5-6 hours before bedtime and avoided within 3 hours of sleep (Morin, Hauri et al. 1999; Morin 2006).

Routine sleep times - Creating a nighttime routine is also part of good sleep hygiene. Having a consistent bedtime and wake-up time may help in the treatment of insomnia (Caldwell 1997; Morin, Hauri et al. 1999). It has been suggested that having a consistent bedtime will begin to build a connection between the time of day and sleep, and eventually your body will start to automatically fall asleep at the same time every night (Caldwell 1997).

Melatonin - Melatonin is a naturally occurring chemical in the body that is known to induce sleep. As one might expect, the release of melatonin in the body depends on retinal light exposure. Put simply, sunlight inhibits melatonin release while the lack of sunlight permits natural melatonin stores to be released, inducing the onset of sleep (Cardinali, Furio et al. 2006; Skene and Arendt 2006).

If administered properly, exogenous melatonin (melatonin not naturally made by the body) administration has been used to phase shift the sleep cycle to overcome shift work or jetlag (Melatonin 2005; Skene and Arendt 2006). To overcome jetlag and shift work the onset of sleep either needs to be sped up or slowed down. When traveling eastwards or trying to sleep after working the night shift, administration of melatonin will speed up the onset of sleep and allow those affected to get onto the sleep cycle they desire. Melatonin can also be used to speed up the initial onset of sleep for people with insomnia.

Sedatives - Sedatives have been commonly used as a countermeasure to insomnia within the general population. However, within the civil aviation field, the use of sedatives and other hypnotics which induce sleep are generally banned (Caldwell 2005). Nevertheless, sedatives have been shown to be useful for inducing sleep at times when or in places that are not necessarily conducive to sleep (Caldwell and Caldwell 2005).

When considering the use of sedatives, care must be taken to choose the correct one. The available time for sleep must be considered, as sedatives with long half-lives (i.e., the time it takes to decay to half of the initial value), can cause performance decrements if a user is suddenly awoken for duty (Caldwell 2005; Caldwell and Caldwell 2005).

Antihistamines can also cause a sedative effect. However, like sedatives many antihistamines can produce drowsiness and decreased performance (Verster and Volkerts 2004). Notably however, all sedatives have detrimental effects on normal sleep architecture, the overall structure of a night's sleep. Sleep architecture includes succession of sleep cycles, the number of stages, and the length of time spent in each stage (Hirshowitz 2004).

Alcohol - The use of alcohol as a countermeasure to insomnia is generally not recommended. While the consumption of alcohol before bedtime has been shown to speed up the onset of sleep, like other sedatives, alcohol is known to disrupt normal sleep architecture leading to feelings of fatigue and sleepiness upon awakening (Vitiello 1997).

OPERATIONAL QUESTIONS AND RECOMMENDATIONS

The effect of shiftwork on performance and fatigue in the law enforcement community and other industries is a complex topic that continues to attract the attention of scientific and operational communities. While there are literally hundreds of references on the topic, the previous overview has provided a foundation from which to answer the questions regarding shiftwork posed at the beginning of this report. Note that where scientific data exists, answers to each question and specific recommendations will be given. Where limited or no information is available, the reader will be advised and recommendations based on best human factors principles will be provided.

WHAT TYPE OF SHIFT ROTATION IS OPTIMAL?

Although shifts vary widely depending on operational needs, the use of three 8-hour shifts (i.e., morning, afternoon, and night shifts) is common among 24/7 operations including forensic science. Of the three shifts, arguably the third (i.e., night) shift garners the most attention given that it occurs during the circadian trough – a period of time associated with known performance deficits. So, what type of shift rotation could minimize the adverse impact of operating during the circadian trough?

Trying to document how organizations manipulate shift rotations is difficult. However, using the night shift as a benchmark, the way organizations rotate workers among shifts can generally fit into one of four categories (Wilkinson, 1992):

1) A permanent (fixed) night shift, where employees spend all their time working the night shift.
2) A prolonged night shift, where employees work the night shift for a period of weeks to months.
3) A weekly rotating night shift, where employees stay on each shift for one week before rotating to a different shift.
4) A rapidly rotating night shift, where an employee is on the night shift for one to three days before rotating to a different shift or day(s) off.

In effect, the four types of shift rotation can be reduced into two categories: those with permanent or prolonged rotation schedules and those that involve some form of short-term (i.e., weekly/daily) rotation through the shifts. Exactly which type of shift scheduling is optimal (i.e., permanent/prolonged schedules or rotating schedules) continues to be a matter of debate within the scientific literature.

In an extensive review of the scientific literature, Wilkinson (1992) advocated the use of permanent/prolonged shift schedules based on the following findings from a number of studies:

- Employees engaged in permanent/ prolonged night shift schedules appear to sleep more than those working rapidly rotating shifts.
- When uninterrupted by days off, the circadian cycle of those working a permanent night shift can adjust almost completely.
- In some cases, performance on the night shift may be better for those working permanent/prolonged night shifts than rotating shifts.
- Sickness/absenteeism appears to be less prevalent for those working permanent and rapidly rotating shifts than for shifts that rotate weekly.

Although Wilkinson's observations may lead one to conclude that permanent/prolonged schedules are best, other data suggests that rotating schedules may be preferred. For instance, if you ask employees they clearly favor rotating schedules over permanent/prolonged schedules (Wilkinson, 1992). In fact, employees often prefer rapidly rotating schedules like those used by air traffic controllers (i.e., two afternoon shifts followed by two day shifts and a night shift in a five day period) because it maximizes time off between workweeks (Della Rocco & Cruz, 1996). After all, it is very difficult to maintain social relationships while working the evening and night shifts when nearly everyone else is on a normal day/night schedule.

Some have even suggested that in addition to maintaining normal social relationships, rotating shift schedules moderate the disruption to circadian rhythms and reduce sleep loss (e.g., Knauth, 1993; Knauth, 1996; Wedderburn, 1992; Folkard, 1992; Tepas et al., 1985). Even supporters of permanent schedules agree that the circadian cycle never fully adapts to a peak at night and trough during the day since most individuals return to the normal sleep/rest schedules of those around them on their days off. Consequently, any adaptation of the circadian cycle to night shiftwork is frequently disrupted (Wilkinson, 1992). Some evidence suggests, however, that if permanent or prolonged night shifts are utilized it is better to adopt a "many" consecutive night (i.e., 5-7 nights) pattern than a "few" (i.e., 1-4 nights) (Dirkx, 1993).

If an organization chooses to employ a rapidly rotating shift, does it matter which direction the shifts rotate? In other words, a shift schedule can rotate forward (i.e., one or more morning shifts followed by one or more afternoon shifts followed by one or more night shifts), backward (night/afternoon/morning), or be a hybrid of the previous two. Given that the endogenous circadian clock actually runs at 25 hours it would appear that forward rotating schedules would be favored since individuals could extend their day as the shifts are rotated (Knauth, 1993; Knauth, 1996; Barton & Folkard, 1993).

Police agencies are encouraged to use fixed shifts as much as possible and avoid rotating shifts in particular backward rotating shifts (Pedersen 2001). For example, many U.S. air traffic controllers choose rapidly rotating counter-clockwise schedules over other schedules (Note: there is not a single prescribed shift schedule rotation for U.S. air traffic controllers). Referred to as a 2-2-1 schedule, air traffic controllers begin with two evening shifts (e.g., 3:00 p.m. to 11:00 p.m.) on successive days followed by two morning shifts (e.g., 7:00 a.m. to 3:00 p.m.) immediately followed by a night shift (e.g., 11:00 p.m. to 7:00 a.m.). Note that the night shift often begins the same day as the last morning shift leaving little opportunity for sleep. While this may maximize time off duty (i.e., 3 days of a 7 day work week) for the air traffic controller, several studies have shown that rotating schedules often lead to a reduction in core sleep, the rapid accumulation of sleep debt, and most importantly, performance deficits (Della Rocco & Cruz, 1996; Cruz et al., 2003; Signal & Gander, 2007). These rapidly-rotating backward schedules continue to be a concern within the FAA.

Summary and Recommendations

- There does not appear to be any clear consensus regarding the best way for employees to rotate through shifts. However, all agree that organizations should avoid repeatedly disrupting the circadian cycle over the long term.
- For organizations where safety is vital or where the adaptation of the circadian cycle is not interrupted by other factors (e.g., schedule changes on off days), permanent shift schedules should be utilized. However, if either situation is not achieved, a rapidly rotating shift schedule is the "best compromise" (Folkard, 1992).
- If rotating shifts are employed, they should rotate forward (i.e., morning/afternoon/night) rather than backward.
- Individuals on rapidly rotating shift schedules appear to be happier due to improved social relationships - albeit, performance and sleep may be sacrificed. In addition, a rapidly rotating shift schedule keeps the alertness high and only incorporates a few bad "day-sleeps" (Monk, Folkard, & Wedderburn, 1996).
- If a permanent or prolonged shift schedule is utilized, a many-night schedule should be followed (Dirkx, 1993).

CAN INDIVIDUALS ADAPT TO NIGHT SHIFTS?

There is little evidence that individual circadian rhythms ever fully adapt to the night shift when individuals are repeatedly exposed to normal daytime zeitgebers like sunlight, meal cues, and social cues. Even if individuals access meals and social interactions during the night rather than the day, many night shifts end around 7:00 a.m. exposing shiftworkers to ambient sunlight on the drive home, thereby entraining the endogenous circadian rhythm to the local light/dark cycle with a peak during the day and a low during the night. As a result, night shiftworkers sleep less during the day and suffer from performance deficits typical of operating in the circadian trough (Folkard, 1992).

That being said, can shiftworkers adapt to night shift schedules at all? The answer is "it depends." One community that employs permanent/prolonged night shifts is nursing. Dirkx (1993) examined two groups of night shift nurses: 1) those that work the night shift for one to four days before having a night(s) off, and those that work the night shift for five to eight nights in a row before having night(s) off. On the surface, both appeared to adapt to permanent night work. However, it was found that those that work five to eight nights in a row tend to stay in bed longer (presumably sleeping), which, in the long run, may be more adaptive.

It is important to note that while individuals tend to "adapt" to the night shift, that does not necessarily mean that they perform better or that the risk of incident/accidents is any less. Indeed, when the *a priori* risk is constant from shift to shift, the relative safety risk is lowest for the morning shift and is highest for the night shift with the afternoon shift being somewhere in between. Moreover, during the night shift the relative risk is highest during the first hours of the shift and reaches its minimum near the end (Folkard & Tucker, 2003).

Perhaps more important, the relative risk also increases over the first four consecutive night shifts (Figure 3; Folkard & Tucker, 2003) although the possibility of a decline over several consecutive night shifts is possible

(Folkard & Lombardi 2004; Wilkinson, 1992). In other words, while we may do well with one night's sleep loss, risk increases as the workweek continues and sleep debt accrues.

Curiously, when the *a priori* risk of injuries remains constant throughout the day, fewer injuries were reported on the night shift then the morning shift. However, Folkard and Tucker (2003) attributed this to the usual lack of a nurse on the night shift and thereby fewer reported injuries. On the other hand, many morning shifts start at 7:00 a.m., which may require employees to wake at 5:00 a.m. or earlier to report for duty thereby cutting into core sleep.

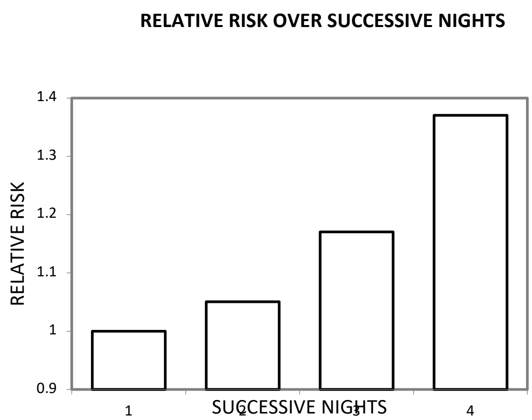

Figure 3. Relative Risk over Successive Nights (figure adapted from Folkard & Tucker, 2003)

So, while risk appears to increase on successive nights working on the night shift, do some people adapt better than others? Indeed, it does appear that some individuals are better suited to adapt to night shiftwork than others. For example, some individuals simply have an ability to overcome drowsiness, easily modify their sleeping habits, and show lower anxiety manifestation; all of which are associated with a higher level of tolerance to shiftwork (Costa et al., 1989). Note however, that while these characteristics helped individuals "cope" with the adverse impact of shiftwork they did not have an effect on the endogenous circadian rhythm. Indeed, their circadian rhythms remained entrained to the local light/dark cycle.

It also appears that shiftwork is tolerated better by younger than older (i.e., late 40's and early 50's) adults. This may be due to the fact that as we age our circadian rhythm flattens out and moves to earlier times of the day (Carrier, Monk, Buysse, & Kupfer, 1997; Brock, 1991). In addition, normal sleep architecture becomes distorted as less time is spent in SWS and REM sleep and more time is spent in less restorative, lighter stages of sleep (Gander, Nguyen, Rosekind, & Connell, 1993; Van Cauter, Leproult, & Plat, 2000; Carrier, et al., 1997).

Personality and chronotype (i.e., the preference to be active early or late in the day) may also influence an individual's ability to adapt to night shiftwork. Specifically, morning-types and introverts both have an earlier phase than night owls or extroverts (Baehr, Revelle, & Eastman, 2000; Duffy, Dijk, Hall, & Czeisler, 1999; Kerkhof, 1985; Kerkhof, & van Dongen, 1996). In fact, extreme morning types wake up about 80 minutes earlier than evening types, which can make the transition to the night shift even more difficult (Kerkhof, 1985).

The second component is sleeping itself. In general, those who rate themselves as more flexible sleepers (i.e., less effected by environmental conditions) and report that they need less sleep often fare better in the shiftwork environment. After all, those working the night shift are forced to sleep when ambient noise and other environmental conditions (e.g., light, temperature, etc.) are less than optimal. This may help to explain why shiftworkers usually report getting about 7 hours less sleep per week than their non-shiftworking counterparts (Monk, 1997).

The third component involves social and domestic factors. A high domestic load or family pressure to revert to a more normal work/rest schedule during days off can make it impossible for some shiftworkers to maintain a nocturnal lifestyle. When facing social or domestic pressures, shiftworkers often go back to a more normal 9:00 a.m. to 5:00 p.m. shift schedule, which makes it much harder when their night shifts resume.

Other factors that can be aggravated during shiftwork are sleep disorders and health problems, including insomnia, gastrointestinal problems, epilepsy, and heart disease. Some shiftworkers even resort to chronic alcohol and drug use to cope with family problems or to help them sleep. The problem is that alcohol and drugs often lead to a decrease in sleep quality and quantity, which in turn exacerbates any problems associated with shiftwork. In the end, a vicious cycle is set in motion, which leads to more issues. As a result, many companies require that shiftworkers do not have any of these problems prior to starting shiftwork.

Summary and Recommendations

- Adaptation to the night shift is more difficult than either the morning or afternoon shifts, respectively.
- In general, while people adapt mentally to shiftwork that includes night shifts, performance deficits and the relative risk associated with normal circadian variation remain.
- Side effects for shiftwork (particularly those employing night shifts) include sleep disorders, gastrointestinal problems, social problems, cardiovascular problems, chronic stress, and performance deficits.
- Employees should be counseled against the use of alcohol and other sleep aids (either prescription or non-prescription) since they may delay adaptation and exacerbate fatigue associated with shiftwork.
- Where possible organizations should screen employees for health problems that can be aggravated by shiftwork.

ARE THERE PROCEDURES OR PROCESSES TO IMPROVE ADAPTATION?

By its very nature the circadian cycle is relatively inflexible; however, the body does retain the ability to slowly adapt to changes within 1.5 hours in either direction from its natural period of 25 hours (Moore-Ede & Richardson, 1985). Unfortunately, when the circadian rhythm is forced to shift in excess of 1.5 hours, as would be the case with shiftworking populations, serious problems can occur. While many shiftworkers simply learn to cope and/or adapt to the effects, others never fully do (Thorne et al., 2006).

Ideally, shiftworkers would always have the opportunity to obtain the quantity and quality of sleep necessary to ensure maximum performance. Of course, this assumes that shiftwork does not impede normal sleep times. Clearly, that is not the case for individuals working the third shift.

Depending upon when the morning shift starts, the same can be said for those working the morning shift as well. While optimal starting and ending times for each shift do not exist, management should avoid early start times in the morning shift mainly because it requires that employees wake up during the lowest part of the circadian trough and may impact sleep quality, performance, and safety. On the other hand, while a late start (e.g., 9:00 a.m.) may be preferred by those working the morning shift, a late start in the morning equates to a late end for the afternoon shift and a late start for the nightshift, all but ensuring that night shift workers will not adapt to a nighttime schedule.

Regardless of when a shift starts and ends, there will always be shiftworkers that simply cannot obtain adequate sleep. As with anyone who fails to get adequate sleep, there are some options available to improve sleep quality during the day and enhance the opportunity to adapt to the shiftwork quickly. Note however that in most cases these are only short-term fixes and should not be relied upon as long-term solutions.

Melatonin

Melatonin is a naturally occurring chemical in the body that is known to induce sleep. As one might expect, the release of melatonin in the body depends on retinal light exposure. Put simply, sunlight inhibits melatonin release while the lack of sunlight permits natural melatonin stores to be released, inducing the onset of sleep (Cardinali, Furio, Reyes, & Brusco, 2006; Skene & Arendt, 2006).

If administered properly, exogenous melatonin (melatonin not naturally made by the body) administration has been used to phase shift the sleep cycle to overcome shiftwork or jetlag (Melatonin, 2005; Skene & Arendt, 2006). To overcome jetlag and shiftwork the onset of sleep either needs to be sped up or slowed down. When traveling eastwards or trying to sleep after working the night shift, administration of melatonin will speed up the onset of sleep and allow those affected to get onto the sleep cycle they desire. Melatonin can also be used to speed up the initial onset of sleep for people with insomnia.

Sedatives

Sedatives have been commonly used as a countermeasure to insomnia within the general population. In fact, sedatives have been shown to be useful for inducing sleep at times when or in places that are not necessarily conducive to sleep (Caldwell & Caldwell, 2005). When considering the use of sedatives, care must be taken to choose the correct one. The available time for sleep must be considered, as sedatives with long half-lives (i.e., the time it takes to decay to half of the initial value), can cause performance decrements if a user is suddenly awoken for duty (Caldwell, 2005; Caldwell & Caldwell, 2005).

Antihistamines can also cause a sedative effect. However, like sedatives many antihistamines can produce drowsiness and decreased performance (Verster & Volkerts, 2004). Notably, all sedatives have detrimental effects on normal sleep architecture.

Alcohol

The use of alcohol as a countermeasure to insomnia is generally not recommended. While the consumption of alcohol before bedtime has been shown to speed up the onset of sleep, like other sedatives, alcohol is known to disrupt normal sleep architecture leading to feelings of fatigue and sleepiness upon awakening (Vitiello, 1997).

Light Exposure

Exposure to bright light, a natural zeitgeber, has proven effective at reducing fatigue and improving circadian resynchronization. Recall that the light/dark cycle in humans plays an important role in synchronizing the circadian pacemaker (Duffy, Kronauer, & Czeisler, 1996). Not surprising then, the exposure to specific types of bright light (i.e., those that simulate the natural wavelengths seen in sunlight) may be used to phase delay the body's circadian rhythm in some operational settings (Boivin & James, 2002) and may also help in overcoming the effects of jet-lag due to rapid scheduling changes (Wetterberg, 1994; Caldwell, 2005; Revell & Eastman, 2005; Lack & Wright, 2007). In addition, there do not appear to be any age or gender differences in response to 3000 lux (Kripke, Elliott, Youngstedt, & Rex, 2007).

It has been shown that a single 4-hour exposure to light on the first day of the night shift can phase-delay the secretion of melatonin by 2-hours and thus delay the onset of sleepiness and fatigue and improve performance on the night shift (Dawson & Campbell, 1991). Dark glasses may also help avoid resynchronization to the natural circadian rhythm and allow workers to adapt more quickly to nighttime shiftwork (Eastman, et al., 1994; Yoon, Jeong, Kang, & Song, 2002). There is also some evidence that bright light exposure during the day may help with fatigue by promoting better nocturnal sleep for workers (Wakamura & Tokura, 2000).

Unfortunately, while attempts to limit natural zeitgebers, such as exposure to the sun, can improve an individual's ability to sleep, it is not without potential negative consequences (Lack & Wright, 2007). For example, while bright light therapy and the use of sunglasses during the day can help workers adjust, the body never fully adapts to shiftwork cycle (Lac & Chamoux, 2004). As a result, this can lead to chronic stress and fatigue, among other side effects. Still, the usefulness of strategically placed bright light has proven useful.

Diet and Exercise

One aspect of good sleep hygiene is diet. While the reasons for insomnia in shiftworkers vary, in general differences in the timing of meals, the unavailability of well-balanced meals at night, and snacking all contribute to difficulties with sleeping (Atkinson & Davenne, 2007). That being said, people who suffer from insomnia should avoid large meals (Morin, et al., 2006) and foods with high sugar or caffeine contents before bedtime (Atkinson & Davenne, 2007).

Another aspect of good sleep hygiene is exercise. Exercise later in the day can increase the depth and length of sleep during the night (Caldwell, 1997) and when performed at night can further help to adapt to night shiftwork (Atkinson & Davenne, 2007).

It appears that the increase of body temperature from exercise is associated with a faster sleep onset (Stepanski & Wyatt, 2003). However, the timing of the exercise is important. Evidence suggests that exercise should be completed 5-6 hours before bedtime and avoided within 3 hours of sleep (Morin, Hauri, et al., 1999; Morin, et al., 2006).

Enhancing the Sleep Environment

Effort should be made by the shiftworker to ensure that the sleeping environment is conducive to falling asleep. For example, blackout shades and comfortable earplugs or sound attenuating headphones will improve day-sleep. In addition, creating bedtime routine is also part of good sleep hygiene. Having a consistent bedtime and wake-up time may help in the treatment of insomnia (Caldwell, 1997; Morin, Hauri, et al., 1999) as the circadian rhythm eventually adapts to yield sleep at these times (Caldwell, 1997).

Education

While many of the above countermeasures can provide some relief from the adverse impact of shiftwork and improve adaptation, educating and increasing the awareness of the workforce can enhance their efficacy. In doing so, it is important to incorporate both the shiftworker and management in the education process, as each can make improvements to the shiftwork schedule that the other cannot. For example, the shiftworker can use their time off-duty to help them prepare for their tasks (i.e., limiting the use of drugs, alcohol and caffeine, imposing regular bedtime rituals, and keeping to a consistent sleep-wake cycle), while management can make improvements to the work environment that will help employees cope with the demands of shiftwork.

Summary and Recommendations

- Early morning starts should be avoided and flexible work times should be encouraged
- Controlled exposure to known zeitgebers such as, sunlight, meal cues, and social cues can ensure that people are working during the circadian peak and are resting during the circadian trough.
- Bright light treatments pre-launch, during the mission and post-launch can facilitate adaptation.
- Current findings indicate that melatonin has shown little effect with facilitating adaptation in spaceflight.
- Bright light should be used when necessary and can be used during the night shift to aid in circadian adaptation (Revell & Eastman, 2005).
- A structured and regimented daily schedule adhered to 7 days a week has also shown to help individuals maintain adaptation.
- Dietary needs of shiftworkers should be satisfied with a cafeteria.
- The sleep environment should be stimulating, pleasant, and inviting (Monk et al., 1996).
- Shiftworkers should be educated on techniques to aid adaptation and coping strategies.

DO TRADITIONAL SECOND AND THIRD SHIFTS REQUIRE DIFFERENT DUTY AND REST PERIODS?

The scientific literature does not address this question directly; however, there are clear differences between the shifts with the night shift being of greatest concern due to accumulating sleep loss. While there are some individual differences, scientists seem to agree that the average person needs roughly 8 hours of sleep each night to be properly refreshed (Akerstedt, Hume, Minors, & Waterhouse, 1997). Although individuals do well with one night sleep loss, a decrease by just a few hours from the recommended amount to as little as five hours of sleep per night can cause serious performance decrements (Dinges, et al., 1997). Specifically, sleep restriction has been shown to impair vigilance and working memory (Belenky, et al., 2003; Van Dongen, Maislin, Mullington, & Dinges, 2003), increase the propensity to fall asleep (Guilleminault, et al., 2003; Carskadon & Dement, 1981; Banks, & Dinges, 2005), and generally lead to a general decrease in vigor and alertness (Dinges & Kribbs, 1991; Kleitman, 1963).

More important, successive nights of sleep loss can lead to a condition known as *sleep debt*. As the name implies, sleep debt can be reduced through replenishing sleep, which must be accrued in order to obtain full recovery (Hardaway & Gregory, 2005). Even a loss of 1-hour of core sleep per night can lead to performance deficits over time as seen in Figure 5. However, consecutive nights of 2, 3, and 4 hours of sleep per night can lead to alarming performance deficits.

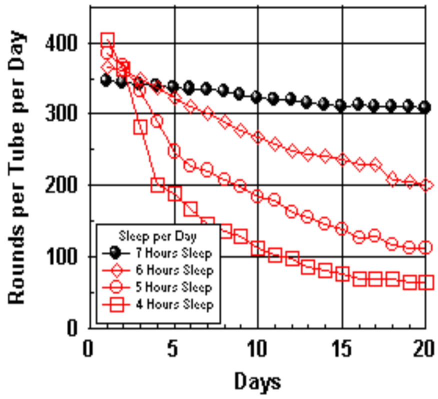

Figure 5. Performance deficits as a result of days of cumulative sleep loss (Source: Department of Behavioral Biology, Walter Reed Army Institute of Research).

> ***Summary and Recommendations***
>
> - Performance and sleepiness is worst for the night shift, followed by the day and evening shifts.
> - It is recommended that sleep debt be tracked regardless of the shift worked, although the night shift is of greatest concern.

CAN A BREAK IN DUTY DURING A SHIFT EXTEND THE DUTY PERIOD?

Extending the workday beyond 8 hours to 12 hours or more is not unique. Many occupations require long duty days including those involved in healthcare, emergency personnel like paramedics, firefighters and police officers, and many others. It is important to note that many of those involved in work beyond a normal duty day are involved in tasks that are either highly specialized or doing things that cannot be easily shared through shiftwork (Stampi, 1989). In other words, there may be few options available for shiftworkers in those situations.

There are other situations where management may have the flexibility to employ a variety of shift schedules. Unfortunately, the decision to move from a traditional 8-hour shift to one of 12-hours or more is not an easy one since some have suggested that worker error rates may increase between 80% and 180% for some tasks when going from 8 hour to 12-hour shifts (Kelly & Schneider, 1982). Moreover, even moving to a 12-hour shift involves more than just time spent working. Commuting time must also be taken into account whenever shift schedules are extended (Tepas & Monk, 1987). Assuming 1-hour commuting both directions and a 12-hour workday, 14 hours of a normal 16-hour awake time (i.e., assuming 8 hours of sleep) would be spent working leaving only a few hours for family and personal needs.

Nevertheless, the question is whether an organization can safely extend the duty day by incorporating a break in duty (i.e., napping)? The answer is yes; but proceed with caution.

While scientists agree that the average person needs roughly 8 hours of sleep each night to be properly refreshed (Akerstedt, et al., 1997), many workers simply do not get that much sleep daily. One supplement to normal core sleep is a nap (Dinges, Orne, Whitehouse, & Orne, 1987). Note that the operative term used was a “supplement,” not a “replacement” or “alternative” to core sleep, as naps do not eliminate the decline in cognitive performance and vigilance that occurs during normal circadian variation or sleep loss. Rather, naps merely moderate the adverse effects fatigue (Della Rocco, et al., 2000). That being said, the experts all agree that naps can be quite beneficial, particularly for individuals engaged in shiftwork (Dinges, Whitehouse, Orne, & Orne, 1988; Akerstedt, 1988).

While, in general, napping is viewed as a positive addition to any shiftworkers routine, a word of caution is required. Napping may have a negative effect on the quality and quantity of the subsequent main sleep period (Akerstedt & Torsvall, 1989). In other words, many individuals have experienced difficulty getting to sleep at night following a longer nap during the day.

That being said, the literature has consistently reported that naps are particularly effective at improving performance during short- and long-term sleep deprivation. While long-term sleep deprivation is rarely seen in shiftworking populations, short-term sleep deprivation is observed, particularly where night shifts are included. In those populations, even a little sleep in the form of a nap can be effective at improving a variety of performance and behavioral measures (Dinges, et al., 1975).

So, how long does a nap need to be in order to be effective? There appears to be no clear consensus as to what constitutes a short, medium, or long nap and therefore most have avoided such classifications. Rather, the duration of a nap is only meaningful when considered relative to an individual’s sleep cycle. For example, napping up to, but not more than 45 minutes in bed typically allows an individual to wake up refreshed with some short-term gains (Rosekind, et al., 1996). This is because in most cases the sleep period has not exceeded lighter sleep stages (Stage I and II), so awakening is quick with few residual effects.

In contrast, individuals engaged in longer naps run the risk of waking up during one of the deeper stages of sleep (Stages III or IV), which often results in a temporary state of lowered arousal and performance decrements immediately upon awakening. This phenomenon, referred to as *sleep inertia,* can persist for several minutes (Tassi & Muzet, 2000) and may produce a short-term (roughly 10-15 minutes) decrement in performance, vigilance, and cognition (Della Rocco, Comperatore, Caldwell, & Cruz, 2000).

Although the impact of sleep inertia can be quite debilitating, the effects can be reduced or even eliminated by keeping the nap length short, reducing prior sleep debt, waking during non-slow wave sleep, and avoiding waking during a circadian trough (Della Rocco, et al., 2000; Driskell & Mullen, 2005; Tassi & Muzet, 2000). Additional measures to counteract against sleep inertia include engaging the worker (e.g. by initiating a conversation) or exposing the worker to pink noise (intermediate between white noise and red noise) immediately upon awakening (Tassi, et al., 1992).

Given the adverse impact sleep inertia poses, it is typically recommended that a long nap should be at least two hours in length. This would allow enough sleep time to complete an entire sleep cycle which lasts roughly 90-120 minutes in adults plus a reasonable amount of time to overcome any effects of sleep inertia (Martin, 2004; Rosekind, et al., 1996).

While shorter naps of less than 45 minutes and naps of at least 2 hours are recommended, a nap of approximately 45 minutes to two hours in duration should be avoided. A nap of this duration may force an individual to wake up while in slow wave sleep; thereby, exacerbating any effects of sleep inertia.

For practical purposes, most organizations are more interested in how long a nap must be in order to be effective rather than the short-term effects of sleep inertia. Not surprisingly, naps of 1-2 hours have been shown to significantly increase the level of alertness and to a lesser extent, the level of performance (Dinges, et al., 1988; Vgontzas, 2007) and memory (Tucker, et al., 2006). However, even naps as short as 10 minutes can be restorative (Brooks & Lack, 2006). Still others have demonstrated that brief naps of 15 to 20 minutes increase the alertness levels of workers and increase the accuracy in vigilance tasks (Purnell, Feyer, & Herbison, 2002; Takahashi, Nakata, Ogawa, & Arito, 2004).

Although short naps can be effective, there does appear to be a loose relationship between nap length and improvements in performance, vigilance, and cognitive tasks. In general, the longer the nap duration, the greater the benefits achieved by the nap. Typical of the few studies that have directly compared nap length, Della Rocco et al., 2000 found that a one or two hour nap is more effective than a 30 minute nap which is more effective than a 15 minute nap in improving alertness, with the one and two hour naps being statistically equivalent. These data suggest that the largest recuperation or relative payoff occurs in the early part of the nap (Buxton, 2003).

In perhaps one of the most ambitious studies of its kind, Mollicone and his colleagues (2007 & 2008) examined the effect of daily naps of 0.4 to 2.4 hours time in bed (TIB) following 10 days of sleep restriction of 4.2, 5.2, 6.2, and 8.2 hours TIB in 93 healthy adults. Remarkably, there did not appear to be any differences in sleep efficiency between sleep obtained in one episode at night or split-sleep episodes divided among nighttime sleep and a daytime nap (Mollicone, Van Dongen, and Dinges, 2007). Perhaps more important, splitting sleep up did not negatively affect daytime psychomotor vigilance, speed, and accuracy of cognitive throughput, or subjective sleepiness. Instead, performance appeared to be related to total TIB. This suggests that split sleep schedules that include naps during the day are reasonable when operational tasking requires nighttime shiftwork (Mollicone, Van Dongen, Rogers, and Dinges, 2008).

Summary and Recommendations

- Extending the shift from 8 hours to 12 hours or more will reduce the ability of workers to interact socially outside of the work environment and can interfere with the ability to get necessary core sleep.
- Although strategically placed naps are not a replacement for core sleep they can moderate performance deficits associated with the circadian trough.
- Naps have the potential to be more effective during the night shift where deficits are typically more pronounced.
- A nap as short as 10 minutes can be restorative; however there is a positive relationship between nap length and performance.
- Longer naps of 1-2 hours should be avoided when there is a potential need to respond immediately upon awakening due to the effects of sleep inertia.

How much duty time can be extended with follow on and/or 'make-up' rest?

Again, the literature does not address this question directly. Perhaps the better question is can duty time be extended by strategically placing naps and if so, how long do those naps have to be. Most studies have focused on two types of nap placements: prophylactic and supplemental. Prophylactic naps are those naps that occur before a sleep debt is incurred, whereas supplemental naps include those that take place once sleep loss has been accrued.

When thought of in these terms, prophylactic naps are generally preferred over supplemental naps since they occur "after a period of sufficient main sleep … [and] before serious sleepiness/fatigue has set in" (Buxton, 2003). In addition, prophylactic naps tend to be short in nature and produce more vigilance and performance improvements with less sleep inertia than supplemental naps (Buxton, 2003).

The timing of prophylactic naps in relation to anticipated sleep loss is very important as well, with earlier naps being more advantageous (Della Rocco, et al., 2000). In fact, the earlier the nap is taken in relation to the anticipate sleep debt, the "more robust and longer lasting" the performance benefits (Dinges, et al., 1987). Consider, for example, a crewmember scheduled to work the night shift; a short nap just before reporting for duty would slow the onset of fatigue/sleepiness, thereby allowing the crewmember to exhibit greater alertness and safer performance than those who did not nap prior to working the night shift (Buxton, 2003; Petrie, Powell, & Broadbent, 2004).

So, are there optimal times to nap? Indeed, for prophylactic naps, there are more optimal times to take naps than others and not surprising the preferred napping times are directly related to an individual's circadian cycle. Recall that the circadian rhythm typically reaches a minimum between 3 a.m. and 6 a.m. and peaks somewhere between 2 p.m. and 8 p.m. (Waterhouse, et al., 2005). Just as performance cycles about the circadian rhythm so does sleepiness and fatigue.

During the circadian trough a person's natural inclination to sleep increases, their alertness level decreases, their cognitive abilities drop, and performance reaches a minimum (Nakano, et al., 2001). Sleeping outside of the circadian trough often results in reductions in total sleep time, less SWS and REM sleep, performance deficits, and frequent awakenings (Akerstedt, et al., 1997). Indeed, studies have shown that taking a nap during the circadian trough restores and improves performance and vigilance more than one taken during a non-trough time (Della Rocco, et al., 2000) and has the least impact on a person's circadian rhythm (Takeyama, Kubo, & Itani, 2005).

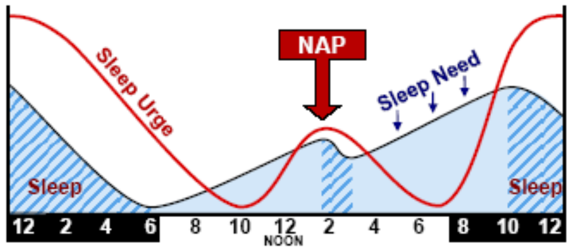

Figure 6. Temporal placement of nap: in relation to the circadian rhythm (Figure taken from Arthur, 2008)

Nevertheless, there is also tremendous pressure to sleep in the afternoon between 1 p.m. and 4 p.m. (Figure 6). Often referred to as the post-prandial dip, napping during the mid-afternoon has been shown to be more efficient and has more impact compared to naps taken at other times of the day. Consequently, it is often recommended that workers nap during the afternoon prior to working a night shift (Buxton, 2003).

However, there are issues (i.e., sleep inertia) associated with awakening from a nap during the circadian trough that are not as evident during other times of the day. It appears that sleep inertia is significantly worse during the circadian trough than during the day (Scheer, Shea, Hilton, & Shea, 2008), particularly when awakening from non-REM sleep (Silva, E. and Duffy, J., 2008). What's more, the effects may be worse for older adults (Silva & Duffy, 2008). The circadian nature of sleep inertia has important ramifications for those in mission critical tasks that may require optimal performance immediately upon awakening.

In one particularly interesting meta-analysis, Driskell and Mullen (2005) examined 12 studies that investigated the use of naps as a countermeasure to fatigue and performance. Using a multiple regression, they were able to show that naps as short as 15 and 30 minutes could reverse the effects of sleep deprivation (i.e., return performance to, or exceed baseline measures) up to 6 hours while naps in excess of 4 hours sustained performance up to 10 hours. Naps of 1 and 2 hours sustained performance 7 and 8 hours, respectively.

While Dirskell and Mullen's meta-analysis is intriguing, others have seen substantially less improvement. For example, Brooks and Lack (2006) showed improvements of up to 125 minutes following a 20-minute nap and 155 minutes following a 30-minute nap. Furthermore, Driskell and Mullen did not compare differences that may exist among shifts and/or time of day. It is possible that performance effects would be less during the circadian trough.

When working the night shift, it is recommended that employees take a prophylactic nap before work or early on into the shift. Surprisingly, recommendations regarding naps may vary according to the type of shift rotation. On a fast shift rotation of less than five days between shift changes, workers may benefit from a short nap during the early part of the night shift (Buxton, 2003; Dinges, 1995). However, if on a slow shift rotation (five or more days between shift changes) or on permanent nightshift, workers should avoid napping and keep any necessary naps brief so that their circadian cycles corresponds with nocturnal activity (Buxton, 2003).

Summary and Recommendations

- Exactly how much duty time can be extended with follow on and/or "make-up" rest is unknown.
- Naps in anticipation of sleep loss have been shown to improve vigilance and performance.
- Naps just before reporting for the night shift are recommended to improve performance.
- Caution must be exercised when napping during the circadian trough, particularly if performance needs to be optimal immediately upon awakening, as sleep inertia is known to last longer during those times.
- Short naps can sustain performance up to 6 hours while longer naps may sustain performance as long as 10 hours. Others have shown significantly less sustained improvement with shorter naps.
- It is quite likely that the efficacy of the naps would be reduced during the circadian trough.

How much 'make-up' rest is necessary for an extended duty period?

While there is no evidence that individuals can store or "bank" sleep in anticipation of potential sleep loss associated with shiftworking (Stampi, 1989), the question is how long it takes to fully recover and if duty time can be extended. Here again, the scientific literature is unclear. For example, in a study performed by Akerstedt and Torsvall (1981), the sleep after the night shift was found to be shorter. Individuals also ranked the sleep after the night shift worse than other shifts. However, the night shift is not the only shift with problems. The length of the sleep after the morning shift was found to be similar in length to that of the sleep after the night shift. As age increases, more problems arose in connection with sleep length and sleep quality. Individuals who are considered morning active have difficulty adjusting to the day time sleep after that occurs after the night shift (Akerstedt & Torsvall, 1981).

On the other hand, others have found that sleepiness, fatigue, and most performance deficits associated with sleep loss can be overcome with one or more nights of 8-10 hours of quality sleep during the circadian trough (Tilley et. al., 1982; Dinges et al., 1997; Caldwell, & Caldwell, 1997; Sallinen, et al., 2008). Precisely how long recovery sleep needs to be in order to restore performance to baseline levels is dependent largely on the extent of the sleep debt with moderate to large debts requiring more than one recovery night (Sallinen, et al., 2008).

One thing that is known is that "payment of sleep debt" is not a one-for-one proposition. In other words, a shiftworker who works five consecutive nights averaging 7 hours of sleep per night would accrue 5 hours of sleep debt (1 hour x 5 days). Rather than requiring 13 consecutive hours (8 hours + 5 hours to compensate for the sleep debt) of recovery sleep, 8-10 hours of sleep should be sufficient. In fact, extending the sleep period beyond 8-10 hours can actually produce a phenomenon referred to as "sleep drunkenness" – a condition of prolonged sleepiness similar to a hangover (Herschovitch, Stuss, & Broughton, 1980; Taub & Berger, 1973).

While from a physiological/performance point of view recovery from sleep debt associated with shiftwork may be accomplished in one night, social concerns and morale may require more time. After all, off-duty time involves more than simply recovering from the stress of work. Days off allow social goals to be achieved as well. Therefore, the number of consecutive working days should be kept to only five to seven. Where possible, the shift schedule should also permit time off during the weekend when most family members are also enjoying time away from work and school. To do otherwise risks marital problems including divorce (Tepas, et al., 1985).

Summary and Recommendations

- Recovery from sleep loss and fatigue associated with shiftwork can typically be completed with 8-10 hours of quality sleep during the circadian trough.
- The number of days required to recover from sleep debt is tied to the degree of debt accrued. Moderate to large debts require more than one recovery night to return to baseline levels.
- Efforts to extend recovery after the night shift to 2 or more days off including weekends is encouraged to ensure full recovery and facilitate social health.

HOW IS DUTY AND REST TIME TRACKED AMONG DIFFERENT INDUSTRIES?

Generally speaking, all shiftworkers seem to get a reasonable amount of time to attend to personal maintenance, which includes sleeping, exercise and social interactions. However, that is an ideal world. Do they really get 8 hours of sleep as required? Moreover, are the pre- and post-sleep activities really to attend to "personal maintenance" or is it spent on other duty related or administrative tasks? What's more, can one equate the operations in different industries? Unfortunately, the answers to these questions are beyond the scope of this review.

Creating a shiftwork schedule manually can be beneficial particularly when trying to adapt to changing task demands or to personalize schedules that accommodate annual leave and sick days. Unfortunately, larger and more complex schedules are very difficult to complete by hand and the use of algorithms becomes a necessity.

Recently, the scientific community has seen a proliferation of scheduling tools, many of which are based on many of the techniques found in operations research (Ernst, Jiang, Krishnamoorthy, Owens, & Sier, 2004). While the tools vary from one to another, most of the models track performance and alertness across days, nights, weeks, and even months. Central to all models is the integration of work and days off with sleep duration, some measure of recovery during sleep, time awake, circadian phase, and performance.

To address fatigue related concerns associated with shift work, several shift work-scheduling tools have been developed. While all offer some degree of assistance to those tasked with managing shift workers, differences do exist. To give the reader a sense of the variety of tools being used, a brief description of several will be presented below.

- ***TURNI***[1] - TURNI (Abbink, Fischetti et al. 2005) was established for use by NS Reizigers, the Netherlands' Railway system, which operates 5,000 time-tabled trains per day with over 3,000 drivers and 3,500 conductors in 29 crew depots. The purpose of TURNI is to assign drivers and conductors to shifts and trains while following federally mandated laws and allocating the 'good' and 'bad' shifts fairly. This system adds in penalties for over-scheduling workers, multiple transfers, night shifts, and positioning shifts. The drawback of this system is that reassignment of duties due to disruptions is more difficult than with the manual distribution of duties.
- ***FAST*** **-** The Fatigue Avoidance Scheduling Tool (Eddy and Hursh 2001; Eddy and Hursh 2006). FAST was developed for use by the U.S. Air Force (USAF) as the computer user interface for their Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model. The FAST interface allows the military scheduler to predict the performance levels of pilots based on past history such as sleep prior to assignment. FAST also allows for the construction of an optimal schedule based on the pilot's physiological condition and indicates when and if pharmacological aids will be needed to address fatigue.
- What makes the FAST model particularly appealing is that it incorporates performance and alertness, sleep propensity and sleep intensity, equilibrium state, progressive sleep debt under extreme measures, and sleep timing. Recently the USAF has introduced the FAST interface to markets outside the military for potential use.
- ***ALTITUDE*** **-** ALTITUDE was developed for use by Air Transit in Canada, which operates 18 aircraft and 1,200 flight legs per month with over

[1] Unfortunately, several of the names of the shift work scheduling tools used acronyms that were undefined in any of the literature reviewed.

1,000 personnel. This model determines the best flight itinerary for each fleet, any repositioning of aircrafts needed, the release of aircraft, and maintenance schedules. The model incorporates maximum and minimum workload, the minimum rest time between scheduled flights for pilots, the maximum number of overseas trips without any time off, and other government and labor union contract rules while avoiding deadheads and minimizing the number of flight legs per duty period. The crew schedule for each month is completed in about three days and has helped lower the company's turnover rate (Desrosiers, Lasry et al. 2000).

- ***CrewResource Solver*** - The CrewResource Solver (Yu, Pachon et al. 2004) was developed by Continental Airlines which operates over 345 aircraft, 4,500 pilots and 1,100 flights daily. This model is composed of four modules: staffing, vacation, planning, and training. The staffing module incorporates pilot work hours based on contractual and government rules, identifies shortages and surpluses based on planned flight schedules and current staffing levels, and transfers or relocations of pilots based on their future flight schedule. The other modules incorporate vacation bids, training, available resources, new hires, and pilot availability.
- ***DISSY*** - DISSY (Emden-Weinert, Kotas et al. 2001) was developed for the European Union's bus and tram system. This model incorporates federal laws, union contracts and company agreements on weekly rests, nightly rests and maximum driving times. There is also a social aspect incorporated into the model that allows drivers to express their preference for shift types, duty types and days of the week. This model evenly distributes working times, hard shifts (shifts with multiple transfers) and length of shifts.
- ***ERG*** - ERG (Hare 1997) was developed for use by healthcare facilities and works with the ILOG's Solver library. This model generates shift rotations that satisfy staffing requirements, allows for part-time or full-time shifts and is flexible enough to be used to staff a variety of departments. The constraints of the model include baseline staff levels, minimum and maximum consecutive days worked, minimum and maximum number of hours per shift and week, shift change restrictions and allowable shifts.

Of these tools, the most appealing to commercial space transportation is likely to be the FAST. What makes FAST particularly appealing is that it was built and validated using actual data from the field and laboratory and is based on scientific models of sleep and cognitive performance. In that way, it incorporates performance and alertness, sleep propensity and sleep intensity, equilibrium state, progressive sleep debt under extreme measures, sleep timing, and the transmeridian phase shift. In addition, FAST is dynamic and allows the scheduler to view the manner in which performance changes over time. The scheduler also has the ability to view the variability of performance based on user percentile.

Summary and Recommendations

- Most industries that have established requirements use log books to track duty and rest time.
- Key measurements that are tracked include: consecutive duty time, rest between duty time, and cumulative duty time in a given work span.

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