Spring 2014

# Workplace sleepiness: causes, consequences and countermeasures

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# WORKPLACE SLEEPINESS:

# CAUSES, CONSEQUENCES AND COUNTERMEASURES

by

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A THESIS

Presented to the Faculty of the Graduate School of the

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

In Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

in

ENGINEERING MANAGEMENT

2014

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## PUBLICATION THESIS OPTION

This thesis consists of the following articles that have been submitted for publication as follows:

Pages 13-34 a paper at Mary Kay O'Connor Process Safety Center Symposium in College Station, Texas.

Pages 35-64 a paper at the American Society for Engineering Management Conference.

Pages 65-95 a paper submitted for publication in the American Society of Safety Engineers journal, *Professional Safety*.

## ABSTRACT

Sleep deprivation is an epidemic problem in our society that adversely affects the quality and safety of our daily lives. At home and on the job, inadequate sleep is associated with considerable social, financial, and health-related costs, due to instability of waking functions. Research has shown that, sleep deprivation among workers, whether from sleep disorders, lifestyle or shift work, can hinder the proper performance, and in extreme cases may pose hazard to the workers themselves and their environment. Deficits in daytime performance can have profound effects in the processing industry where workers are often required to perform monotonous tasks that provide low levels of stimulation but also involve critical decision making and problem solving skills.

This study provides a comprehensive literature review of the current scientific research efforts in order to promote a better understanding of the relationship between sleep deprivation, productivity, performance, health and safety of the organizations. It highlights the consequences of insufficient sleep for workplace functioning and the ways in which workplace characteristics and lifestyle choices may affect sleep quality and quantity. Moreover, the adverse impact of poor sleep on organizations has been addressed through deficits in attention, concentration, memory, cognitive functioning and reaction time as well as increased incidence of anxiety, lower motivation and poor social relationship. Findings indicate that such destabilized behavioral outcomes can lead to increased rates of performance losses, absenteeism, physical or psychological injuries in addition to human errors and accidents.

Finally a variety of countermeasure strategies including caffeine, bright light, exercise, task design, sleep education and scheduling policies are discussed as potential measures to maintain workers' alertness and performance. A preliminary survey is also presented in order to explore the performance of individuals in industrial settings and the potential impact of inadequate sleep. The results indicate the need for further research on workplace sleepiness and the potential issues to consider. It is important for managers to take such human limitations into consideration in order to decrease errors, reduce job dissatisfaction and improve organizational productivity and safety.

# ACKNOWLEDGMENTS

I would like to gratefully thank my advisor Dr. Susan Murray for her guidance, patience, and most importantly, her constant support during my graduate studies. She has been helping me to develop my background in Engineering Management with all her enthusiasm, and immense knowledge. Her guidance helped me all time in this research and made an unforgettable experience for me.

I extend my sincere gratitude to my other committee members, Dr. Matthew S. Thimgan and Dr. Steven Corns for all their valuable guidance, assistance and time through this project.

I also would like to thank my husband, Pouria, for his love, support and understanding. These past few years have not been an easy ride, both academically and personally. I truly thank him for being by my side.

I specially want to mention my gratitude and love to my parents and my brother who have always been supporting me spiritually and encouraging me with their best wishes.

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# 1. INTRODUCTION

## 1.1. PROBLEMS MOTIVATING THIS STUDY

Why is sleep so important and how does it affect the human body? How much sleep is enough to function? Why and how can a lack of sleep cause impaired performance? What are the common causes of sleep deprivation? Why is sleep deprivation dangerous and how does it affect our safety?

Most people know, more or less, the answers to these questions and how lack of sleep can affect their daily lives. Yet, they often knowingly or unknowingly deprive themselves of adequate amounts of sleep. Unfortunately, sleep deprivation is an everyday occurrence in modern society where success is often associated with long hours of work. Many contemporary workplaces insist on around-the-clock operations to meet the demands of the 24/7 marketplace. Thus people working such long hours on top of their personal daily activities, tend to give up their night time sleep and sacrifice it for money and lifestyle. Eventually, they become so accustomed to low levels of alertness that they forget how it's like to feel wide awake [1].

Nowadays, sleep is often regarded as a luxury, whereas it is a necessary life process which is essential for productivity and should be at the top of everyone’s list to ensure maximum daytime performance. Recent research analysis show that average sleep duration has generally declined among workers over the last two decades [2]. Results of the National Sleep Foundation’s annual poll reveal that about two-thirds (63%) of Americans have reported dissatisfaction with their sleep during the week. In addition 43% of a sample Americans between the ages of 13 and 64 say they rarely or never get a good night's sleep on weeknights [3].

Generally, in today's fast paced world, where people are in rush to get things done and speed things up, there are more and more demands being put on working individuals that could impact their quality and quantity of sleep. Although people often cope with relatively little sleep, but this may be far less than what they need to function at their best. Recent studies indicate that decreased sleep time can destabilize the wake state by negatively affecting behavioral [4-6], emotional [7-10], and cognitive aspects [7, 11-14] of human functioning and compromise mental and physical wellbeing [15,16]. However, such impairments to alertness are often unrecognized by the affected individuals. People are unaware of sleep loss-induced errors which can adversely affect the quality of their lives and hinder proper performance of many essential tasks at home or on the job [1, 17]. Yet, the degree to which sleepiness may influence an individual can range from slight injuries to catastrophic accidents. In extreme situations such as machine operation or vehicle driving, sleep related errors can be hazardous to the individual and his/her environment [14, 18, 19]. It is worth mentioning that accumulated sleep loss is particularly dangerous in long, routine, highly over-learned tasks as well as vigilance-based duties and safety-sensitive operations [2, 20-23].

Furthermore, sleep loss is a big public safety hazard every day on the road. Studies of drowsy drivers identify sleepiness as a probable cause of major accidents and car crash injuries in different modes of transportation [5, 24-27]. Results of the National Sleep Foundation's 2012 poll indicate that, about one-fourth of train operators (26%) and pilots (23%) experience impaired job performance due to sleepiness at least once and a significant number report that sleepiness has caused near miss and safety problems on the job [29]. In addition, a number of the most devastating human and environmental

disasters have been partially attributed to sleep loss and consequent performance failures, including the catastrophic chemical leak in Bhopal, India; the nuclear reactor meltdowns at Three Mile Island and Chernobyl; as well as the explosion of the space shuttle Challenger and grounding of the Exxon Valdez oil tanker [30-32]. Human inattention and sleep-related errors occurring in all of these accidents not only cost millions of dollars to clean up, but also had adverse consequences on the environment and public health.

In addition to sleep-related accidents which can occur in an instant, sleep loss can also harm people over time by degrading their physical and mental wellbeing [15, 16]. Chronic lack of sleep can increase the risk of various health problems such as decreased immune function [33], obesity, diabetes and cardiovascular disease [7, 34] and may even cause the beginning of fatal processes preceding death [35-37]. Sleep deficiency can also negatively affect emotions and contribute to poor morale and mood changes as well as impaired social relationships [38, 39]. Indeed, such issues have a significant economic impact on individuals and businesses in particular. Poor sleep costs businesses directly through errors, accidents, medical care, absenteeism, and turn over and indirectly through lost productivity due to poor social relationships, lowered motivation and reduced cognitive performance [19, 40, 41]. Many employees do not physically miss work due to sleepiness; however they often show up too tired to perform their job. Albeit the impact of sleep loss is often unrecognized, it still has a major impact on how well a business functions. It is, therefore, in the best interest of businesses to pay attention to their employees' sleep and implement strategies in order to experience lower absenteeism, improved safety, and increased productivity levels, whereas ignoring these factors can

lead to decrements in human capability and to the potential for catastrophes that can result in tremendous societal and individual costs.

## 1.2. PURPOSE OF THE STUDY

The main objective of this research is to describe the importance of sleep deprivation on workplace performance and safety. Given that workplace sleepiness does not receive frequent attention and employed people tend to have a higher prevalence of short sleep duration than unemployed people [2], this research will primarily focus on the consequences of insufficient sleep for workplace functioning and raises sleep issues that are related to occupational safety.

There is a large body of research on sleep quality, circadian rhythms, sleep disorders, general sleep patterns in various developmental stages, the effects of work schedule on sleep, and the relationship between sleep and particular types of occupations. Although these scientific literatures have focused extensively on the effects of sleep loss on individuals' waking alertness and performance, there is fairly little research that has specifically examined workplace sleepiness and its critical role in predicting occupational safety. Therefore this study reviews existing literature on sleep deprivation and related topics to address the variables that underlie sleep deprivation and their effects on performance in order to improve safety and productivity of organizations.

## 1.3. BRIEF OVERVIEW

The following is a brief overview of some major information regarding sleep deprivation which have emerged repeatedly throughout this study. To better understand

the relationship between sleep and performance, this review will focus on three major topics including non-work related causes of sleep deprivation, work-related causes of sleep deprivation, and consequences of sleep deprivation on performance.

The growth of research on disturbed and inappropriately timed sleep has led to significant discoveries about physiological processes which can influence human performance. Circadian rhythms, homeostatic process, and sleep cycles, are the main sleep factors which are fundamental to the determination of alertness and sleepiness [42, 43].Circadian rhythm, a biological clock that regulates our sleep/wake pattern on 24 hour basis is a major determinant of daily variations in alertness and cognitive performance. Homeostatic process which builds up pressure for sleep according to the time spent awake or asleep, interacts with circadian process in order to regulate sleep need and intensity [44]. Extended periods without sleep, interrupted sleep, and working against the body's natural sleep/wake cycle disrupts the interaction of these regulatory processes and impairs an individual's ability to remain alert and attentive [45].

In addition to those factors that affect one's biological clock and cause physiological sleepiness, there are also environmental factors that cause subjective sleepiness. Therefore, all the factors either subjective or physiological that affect regulatory processes have the potential to cause sleep loss and contribute to daytime alertness and functioning on the job. The current study will focus on the most common causes of sleep deprivation that are related to contemporary lifestyle and workplace factors. One's job performance can suffer from inadequate sleep caused by a variety of non-work related factors including medical disorders, poor sleep hygiene, or family responsibilities [19, 46, 47]. These factors whether applied voluntarily such as sacrificing

sleep for other activities or involuntarily such as insomnia, cause variety of sleep problems which can be carried over into the workplace. Figure 1.1 provides a diagram for the most common non-work related issues affecting sleep quality and quantity.

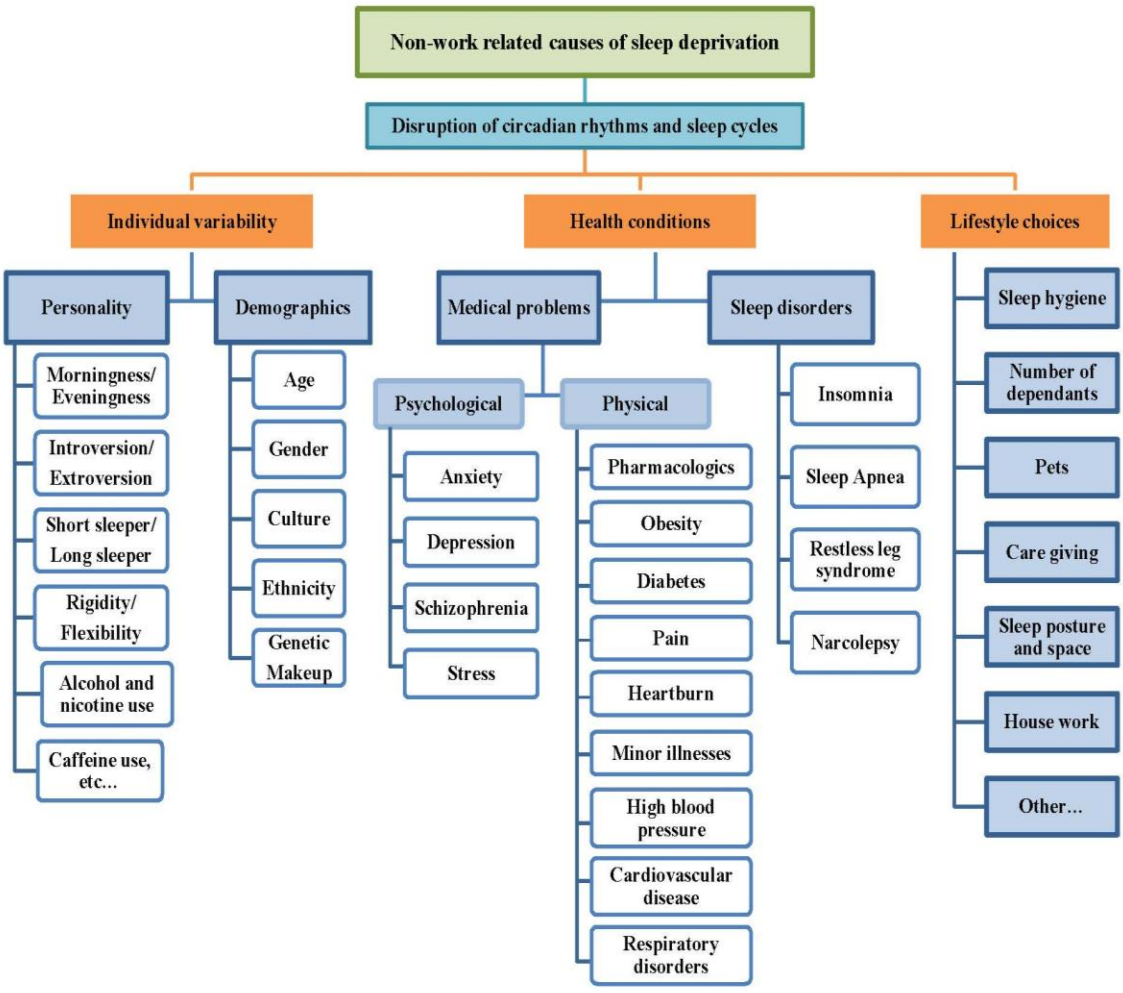


Figure1.1. Non-work related causes of sleep deprivation

Additionally, a great deal of scientific literature has focused on the effects of workplace characteristics on sleep loss [23, 48]. Without a doubt, elevated levels of sleepiness are a common feature of a 24/7 society which often requires people to work

outside of regular office hours. As shown in Figure 1.2, shift work, long work hours, changing work schedules, and traveling across time zones can all disrupt circadian rhythms and usual sleep patterns and degrade waking function [14, 21, 31, 49-51]. The adverse effects of sleep loss can get more compelling in those occupations that involve strong vigilance, isolation, and repetitive, monotonous tasks as well as poor environmental conditions with limited stimulation [45, 52].

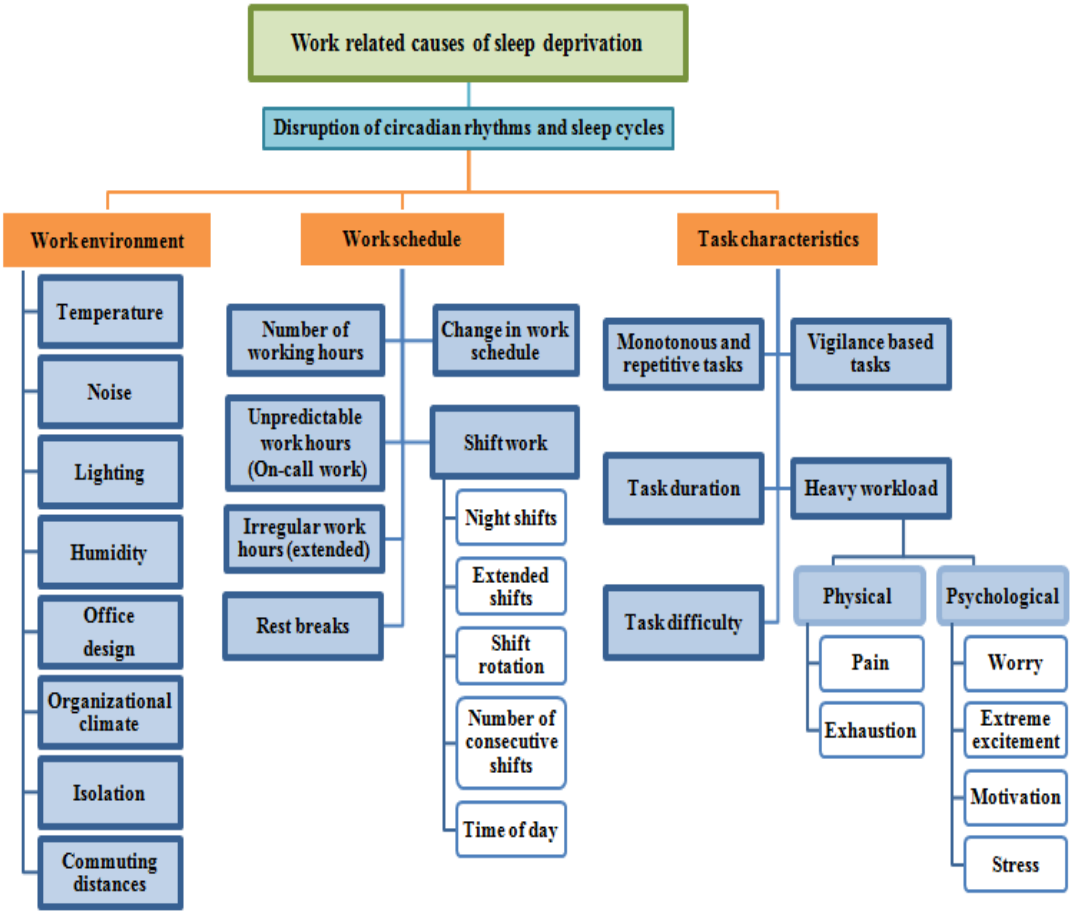


Figure1.2. Work related causes of sleep deprivation

Regardless of the causes, inadequate sleep can influence performance on the job, both in terms of the number of mistakes and the efficiency speed. The effects of sleep loss are broad, and consequences may affect social and financial well-being of individuals and organizations and even nations as a whole. Sleep deprivation studies repeatedly show the decreased quality and quantity of work is associated with many physiological and psychological decrements as well as impaired cognitive performance and instability of waking neurobehavioral functions [10]. Generally, the clinical symptoms of sleep deprivation include disruptions in cognitive functioning, such as impaired memory [12, 14, 23], weakened concentration and attention [14, 21, 23], schematic thinking [7], and impaired judgment [53], as well as behavioral decrements in terms of slower reactions [19], delayed responses [14, 18, 19], errors [14, 55, 56], micro sleep attacks [ 6, 54] and variety of other factors which lead to lower capabilities and efficiency of task performance [57].

In addition, during periods of intense sleepiness people experience emotional disturbances including stress, anxiety, irritability, depression, aggression, lowered motivation and deteriorated interpersonal responses [7, 9]. Such psychological changes can decrease one's control over performance and may result in serious problems specifically in occupations where people are required to work effectively together for long periods of time. Other than psychological affects, excessive sleeplessness can have significant outcomes for physiological performance by causing vision disturbances [5], intensified muscle tonus [7], decreased immune function [15] and sleep disorders including apnea, insomnia, narcolepsy, restless leg syndrome and heart diseases [23, 48]. Interestingly, there is bidirectional relationship between sleep and physical/psychological

wellbeing. Just as poor health and negative emotions disrupt sleep quality, poor sleep can impair individuals' psychology and compromise health by causing illnesses [33]. Figure 1.3 summarizes the data from different studies on the effects of sleep deprivation on performance in four categories.

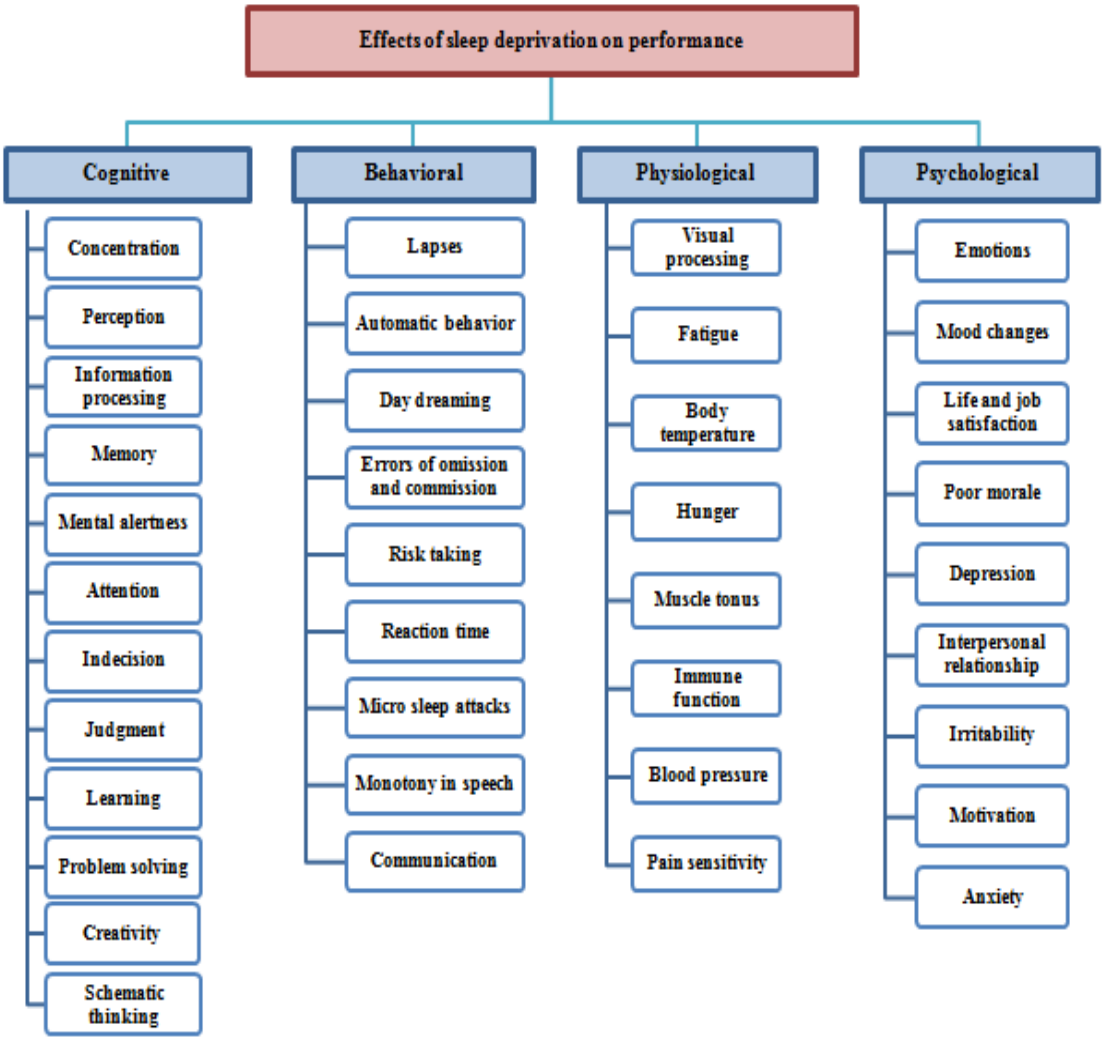


Figure1.3. Consequences of sleep deprivation on performance

It is notable that impaired performance certainly reflects the combined influence of a large number of factors which interact with each other. These interactions can have significant effects on safety and productivity of the organizations and impact their social and financial well-being, such as depicted in Figure 1.4. More importantly, each of these performance variables can interact with a variety of work related or non-work related factors, which more directly influence vigilance performance. Therefore interactions between these factors should be considered in order to take account of potential interrelationships and examine their contributions in daytime functioning and possible safety risks.

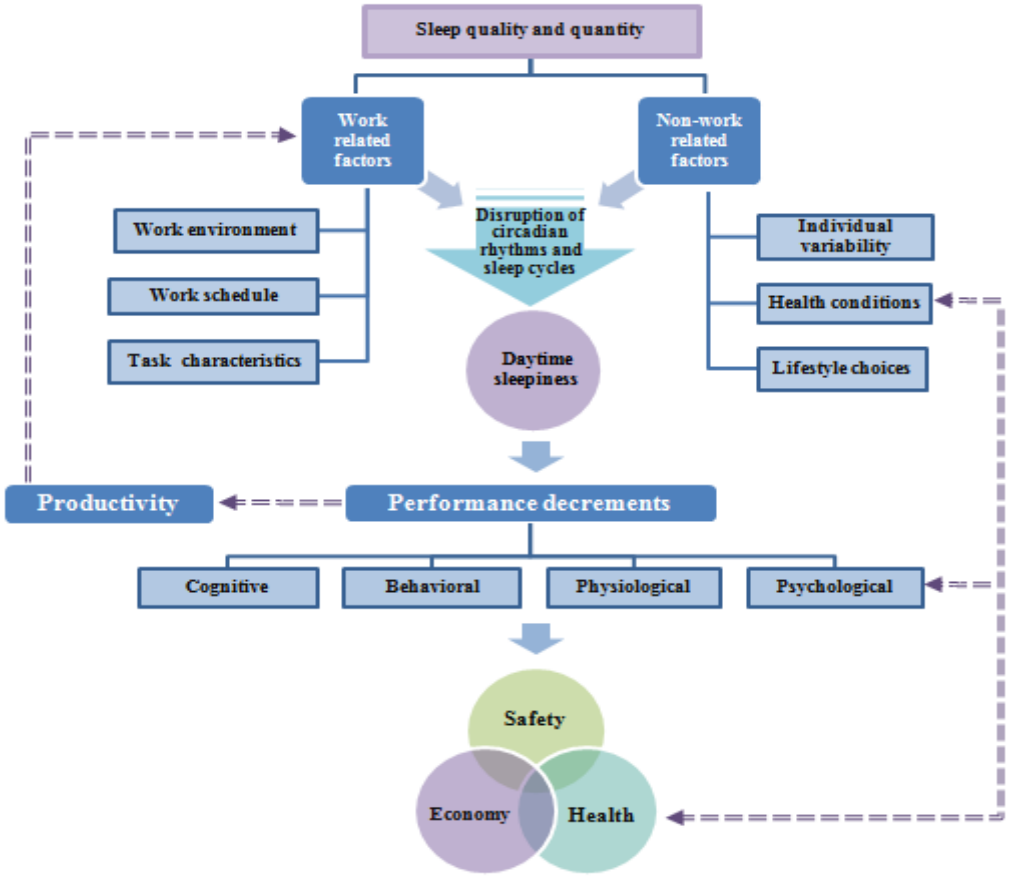


Figure1.4. Interactions between causes and consequences of sleep deprivation

## 1.4. CHAPTER ORGANIZATION

This thesis consists of five sections. It begins with an introduction which gives general information about the effects of sleepiness on workplace performance and the motivation for this research. In the second and third part of the study two published conference papers are presented. In both papers a preliminary survey is conducted in order to explore the performance of individuals in industrial settings and the potential impact of inadequate sleep. The results support the relationship between sleepiness and decreased daytime performance.

The first paper is from the Mary Kay O'Connor Process Safety Center (*MKOPSC*) Symposium. It begins with a discussion of sleep physiology, circadian rhythms, individual sleep requirements, and sleep debt in humans. Following this basic information, common objective and subjective measures of sleepiness are examined to assess the potential causes of sleep deprivation on workplace safety. The second conference paper was published by American Society for Engineering Management (ASEM); the focus of this article is on behavioral and pharmacological countermeasures and managerial recommendations such as scheduling policies, task design, work hours and conditions based on findings from sleep studies. These recommendations can be used for individuals and organizations to minimize risk of injuries and accidents in workplace.

The next part of the thesis includes a journal paper that was submitted to American Society of Safety Engineers (ASSE) journal, *Professional Safety*, as a part of this research. It provides a basic review of information regarding sleepiness in general with particular emphasis on related performance decrements and how they can put health and safety at risk. The final section is the conclusion and recommendations of this

research. It outlines the future research direction and discusses how to promote better sleep habits and increase health and safety of organizations.

# PAPER

## 1. The Impact of Inadequate Sleep on Worker Performance


### Abstract

Workers in the chemical process industry are often required to work long hours performing monotonous tasks, all hours of the night and day. Their work performance can suffer from inadequate sleep caused by a variety of factors including sleep disorders such as sleep apnea that affects the quality of sleep, sleep deprivation resulting from limited hours of sleep, or other sleep related issues such as shift work which can influence the ability to sleep. Research has shown that inadequate sleep can affect vigilance, information integration, and reasoning abilities. Such performance effects can have significant and dangerous results in the processing industry were workers are often involved in monitoring tasks that provide low levels of stimulation but also can require critical decision making and problem solving skills.

This research presents an industrial survey that explores the performance of individuals and the potential impact of inadequate sleep. Questions were taking from the Pittsburgh Sleep Quality Instrument (PSQI) to measure the workers' sleep quality. Other questions explore the workers' perceptions on this issue and evaluate the perceived benefit.

The expected results will likely indicate the need for further research in this area and indentify potential incidents and issues to consider when designing operation procedures and facilities. It is important to take such human limitations into consideration in order to decrease errors and improve system safety.

**Overview of Sleep**

Understanding sleep is important to better understand the impact of lack of sleep on wakefulness, attention lapses, and decreased cognitive abilities. Sleep, one of the most mysterious commodities, can be characterized as a naturally induced alteration in consciousness. Although the sleeper may appear to be unconscious, many complex cognitive, physiological and behavioral processes occur during sleep [1]. Sleep has been defined from a scientific standpoint on the basis of both the behavior of a person while asleep and also related physiological changes that occur to the waking brain's electrical rhythms in sleep. The behavioral criteria consist of a lack of mobility or slight mobility, slow eye movements, specific sleeping posture, reduced response to external stimulation, increased reaction time, elevated arousal threshold, and impaired cognitive function. The physiological criteria are based on the findings of EEG, electro-oculography (EOG) and electromyography (EMG) [2].

Sleep is a behavioral state that is considered as a natural part of every individual's life and therefore quality of sleep has a great impact on the quality of life. Basically, a healthy individual requires a specific amount of sleep necessary to achieve full alertness and an effortless level of functioning during waking hours. Individual sleep needs vary; although most adults require approximately eight hours of sleep per night, some people need six hours and some require more than eight hours of sleep to feel wide awake and function at their peak level during wakefulness.

Morningness-eveningness preference is the individual differences that most clearly explains the variations in the rhythmic expression of biological or behavioral patterns and

particularly sleep/wake schedules. Researches have shown that morningness-eveningness can vary with age and has a marked influence on habitual sleep patterns and sleep parameters in the middle years of life [3]. “Larks” are morning people who spontaneously awaken in the early morning and retire to bed early, while on the other hand “owls” are evening people who tend to stay up until midnight or later. Since owls and larks vary on levels of consciousness or alertness throughout the day and night, it is important to take advantage of this natural tendency to maintain alertness at work especially in *24/7* operations. It has also been shown that sleep requirements are known to change in a fairly predictable manner over the course of a lifetime [4].

Modern scientific research has proved that sleep is a vital physiological human need like food, water, and air. The exact physiological function of sleep is unknown. It has been suggested by several theories that growth, homeostasis of body systems, and maintenance of cognitive functions occur during the sleep period. Two physiological processes are known to occur during sleep periods which are circadian rhythms and sleep cycles [5]. Circadian rhythms and sleep cycles are essential to the determination of alertness and fatigue, hence, all the factors related to sleep and circadian rhythms are likely to contribute to sleep debt and fatigue.

**Circadian Rhythm**

Circadian rhythm, a biological clock with a rhythmic cycle of about 24 hours, regulates the timing of our sleep/wake patterns based on our physiological response to daylight and the onset of darkness. This 24-hour circadian clock is regulated by cues such as exposure

to light, meals, exercise and social cues. Its role is to program us on a 24-hour schedule to sleep at night and to be awake during the day. All humans, like other mammals, have a circadian pacemaker in the brain that regulates physiological and behavioral functions on a 24-hour basis. Many physiological functions of the body, including sleep/wake, digestion, body temperature, performance capabilities, mood, immune functions, and hormone secretion are found to be governed by this circadian rhythm.

It is found that on a regular 24-hour schedule with sleep at night, there are two peaks of sleepiness and alertness. Core body temperature is lowest at 3–5 A.M. and 3–5 P.M. which is also the time when physiological sleepiness is greatest and performance capabilities are lowest, and as a result fatigue may reach the highest level. The two alertness peaks come about at 9–11 A.M. and 9–11 P.M. During this period, one may have difficulty falling sleep even if his/her sleep was poor in the previous night. The circadian clock normally keeps in step with local time because it is sensitive to specific time cues from the environment, notably sunlight and patterns of social activity. This circadian pattern is consistent in humans and is highly resistant to change. When a person suddenly changes the pattern of time cues such as shift work and jet lag, the circadian clock cannot adjust immediately. Many cases such as shift work, prolonged wakefulness and travel across time zones, contribute to insufficient sleep. Unfortunately, all of these conditions are common in today’s work environments in which continuous or sustained operations are required. In the worst of cases, a condition known as circadian desynchrony may occur in which this natural pattern of sleep and wakefulness is completely disrupted [6].

Generally, the circadian system is very difficult to adjust to the need of work/rest schedule in a short time. For example, working at night creates a reversed pattern of nighttime activity and daytime sleep thus the individual tries to override the basic circadian pattern of sleeping at night and being awake during the day. This sets up a situation in which the clock is receiving conflicting time cues from the environment. In addition, most shift workers revert to the usual pattern of daytime activity on their days off. This frequent switching from one pattern to another can lead to the circadian clock's becoming chronically out of step with local time. Shift workers are at a delicate risk due to their night schedules that maintain constant internal/external disagreement, while travelers may experience one cycle of de-synchronization and inconsistent shift scheduling.

**Sleep Cycles**

Historically, sleep has been viewed as a state during which the human organism is turned off however scientific findings have clearly established that sleep is a complex process during which our brain is very active. Throughout sleep process human brain experiences two different sequential states, rapid eye movement (REM) and non-rapid eye movement (NREM). Each of these states is considered by distinctive behaviors and purposes. NREM comprises four deeper stages of sleep. Stage 0 refers to the awake state. Stages 1 and 2 are lighter stages of sleep. Stage 1 sleep is very brief, and is a transitional stage between wakefulness and deep sleep. Over half of our sleep time is spent in Stage 2 of sleep. In stage 2 the sleeper is unaware of the surroundings but can be easily aroused. The deeper stages of sleep are stages 3 and 4 when waking the sleeper is difficult. Stage 4

is important because it is a time of energy conservation, repair of the immune system and renewal. Complex changes occur in the brain while we are asleep. These can be monitored with an electroencephalogram (EEG), which measures the brain's electrical activity and associated brainwaves. An adequate amount of both REM and NREM sleep are required for optimal functioning in humans.

Disruption of specific sleep stages can result in differential effects on waking performance and alertness. There is a period of time (5-15 minutes) immediately after being awakened from deep sleep where there is some remaining sleepiness. This transient period from sleep to fully awake has been termed “sleep inertia” which has negative effects on individual’s cognitive performance. The intensity of sleep inertia depends on the sleep stage preceding the awakening. When aroused from deep stages of sleep, individuals report more severe sleep inertia which may last even longer. A daytime nap, longer than 15 minutes, induces stronger sleep inertia compared with a shorter nap [7]. Sleep inertia should be taken into consideration in operational environments where humans are sleep deprived and napping at the work place is common. Despite the fact that very short naps could have positive long-term effects on biological functions, sleep inertia can be considered as one of the main limiting factors in napping strategy. Since napping is considered as a possible strategy to increase the vigilance level of night workers and many nightshift workers are awakened in this fashion, this is a point that should be taken seriously.

**Sleep Deprivation**

In this day and age, it is known that, sleep is a complex and active physiological state that is vital to human survival. When someone is deprived of sleep the main physiological response is sleepiness. Sleepiness is a warning from brain to prompt an individual to gain sleep. Insufficient sleep makes human brain shift spontaneously from wakefulness to sleep in order to meet its physiological need for sleep. The sleepier the person, the more rapid and frequent are the intrusions of sleep into wakefulness. Sleepiness is such a powerful biological signal that the individual will fall asleep in an uncontrolled and spontaneous way regardless of the time and situation to recover his/her sleep deprivation.

In human studies, experimental sleep deprivation mostly falls into two categories of total sleep deprivation and partial sleep deprivation. Total sleep deprivation (TSD) involves the complete lack of sleep, typically for at least 24 hours, although recent studies have extended this period to as long as 88 hours. While technically one has not lost any sleep until after one's usual bedtime, the TSD period begins at the last awakening. Thus, if someone skips one night of sleep at their usual wake time the next morning they will have undergone 24 hours TSD. Partial sleep deprivation (PSD) is a more common phenomenon in the real words and involves getting some sleep, but an inadequate amount over night. Acute PSD involves only one or few nights of inadequate sleep, while chronic PSD involves at least a week of restricted sleep. Effects of PSD have been reported with as much as 7 hours in bed over several nights or as few as two nights PSD with four hours time in bed [8]. Sleep debt results from a combination of both acute and chronic sleep deprivation conditions. The term "sleep debt" is widely used to describe constantly

accumulated sleep loss. Moreover, it should be noted that sleepiness is different from fatigue. Fatigue, however, can be a secondary consequence of sleepiness. Loss of sleep and disruption of the circadian cycle can result in fatigue which consequently can have a profound effect on an individual's physiological process, wellbeing, work performance, and safety. Regardless of how one enters into a fatigued state, adequate sleep is the only naturally occurring cure.

In summary, one of the major causes for human fatigue in workplace environment is insufficient sleep. Sleep loss can be caused by lifestyle choices and disrupted sleep cycles as well as medical, psychiatric, and primary sleep disorders. Unfortunately, in todays' lifestyle, operational environments are prone to both continuous and sustained conditions that lead to insufficient sleep. Most people get less amount of sleep than that required by an individual for full restoration which results in sleep deficit. Therefore, insufficient sleep and uncontrolled sleep episodes can have catastrophic consequences at many different industrial workplaces. Disasters may occur while a person is operating machinery or even in situations, such as driving a car, in which inattention would put an individual at risk. Many laboratory-based studies have demonstrated that sleepiness resulting from acute or cumulative sleep deprivation is associated with impairments across a wide variety of cognitive functions. [7]

**Sleep Disorders**

The two most common sleep disorders are insomnia and sleep apnea. Sleep apnea is characterized by a cessation of breathing during sleep that causes the sleeper to awaken

repeatedly to resume breathing. The breathing pauses can last from 10 seconds to several minutes and can occur hundreds of times each night. The sleeper is usually unaware of the repeated apnea episodes and associated brief awakenings that occur throughout the night.

Generally, insomnia refers to too little sleep, hypersomnia refers to too much sleep and parasomnia states a deviation from normal sleep patterns. Insomnia comprises experiencing problems falling asleep, staying asleep, waking too early, and/or not feeling rested even after ample time in bed. Insomnia is believed to be present in about 5%–6% of the population and is mostly caused by high levels of anxiety associated with worries, traumatic event, or prolonged stress from work, depression, or other sources. The consequences of insomnia affect several dimensions of an individual's health including both physical and psychiatric disorders, especially depression. The adverse effects associated with insomnia extend to fatigue, memory problems, decreased ability to concentrate and make decisions. One of the greatest health risks associated with insomnia is the increased occurrence of industrial accidents. Studies among varying worker populations have shown an association between insomnia and decreased work productivity, increased absenteeism, and poorer job performance [9].

**Workplace Safety**

Along with disrupted sleep cycles and primary sleep disorders, environmental stimulants may trigger alertness and vigilance. Unfortunately, in todays' lifestyle, many operational environments are prone to both continuous and sustained conditions that lead to

insufficient sleep. Some of the common characteristics of today's occupational world that can cause sleep loss include extended or unusual working hours, long night shifts, isolation, insufficient break time, strong vigilance and long monitoring hours. Many important occupations (i.e. police, emergency medical services, and military command teams) require people to work effectively together for long periods of time throughout day and night. The main concern with extended working hours is disruption of sleep cycles and thus increased fatigue-related errors which can increase risk of accidents. Monotonous and repetitive tasks worsen the performance process and increase the likelihood of errors associated with sleep deprivation. Laboratory studies have shown that tasks which require consistent, sustained alertness are most susceptible to sleep loss [10]. This is a cause for concern in the process industry where so many operational tasks can be monotonous but critical for safety.

In addition, several environmental factors directly contribute to human fatigue and alertness. Noise, light, weather, temperature, an uncomfortable sleeping space, and even sociocultural influences can delay or interrupt the sleep period. Pain, stress, worry, and excitement are some of the internal factors that affect sleep quality. Besides these, other factors such as, type of work, physical/mental workload, physical posture, staff relationships, and job satisfaction are other stimulants in workplace environment can also decrease alertness and human performance.

Regardless of the causes, inadequate sleep can influence a host of other factors including mood, attention, and other cognitive functions and can reduce workers' performance and

put them and others at higher risk of accidents. Laboratory data indicate that, for most people, one night with two hours less sleep than what is usually required is sufficient to degrade subsequent waking performance and alertness significantly [11]. *S*leep deprivation causes serious problems in both personal life and the workplace. It also is one of the main reasons for unscheduled absenteeism. Sleep deprivation negatively affects work performance and productivity by causing excessive daytime sleepiness and fatigue. Sleepiness can be associated with degradation of all aspects of functioning including perceptual and cognitive processes, negative mood states, information processing, memory, judgment, reaction time, physical and psychomotor coordination, and numerous other parameters [12].

Without adequate sleep, employees have decreased vigilance and more difficulty concentrating, learning, and communicating. Memory lapses increase. Problem-solving, judgment and decision making abilities decline. Sleep-deprived employees experience adverse mood changes and negative emotions. As a result individuals demonstrate poorer performance which not only puts workplace safety and economy at risk but also affects individuals' physical and mental wellbeing and their social relationship. These factors can contribute to inefficiency and job dissatisfaction and consequently have an impact on the entire organization's productivity and also increase industrial accidents. Sleep deprivation has been shown to negatively affect a wide range of cognitive, behavioral, physiological, and emotional measures [13]. As sleep deficiency accumulates, it impacts neurobehavioral performance comprising micro sleeps, performance lapses and day dreaming.

Excessive day time sleepiness is the most common consequence of sleep deprivation. While sleep deprived, human brain shifts spontaneously from wakefulness to sleep in order to meet its physiological need for sleep. The sleepier the person, the more rapid and frequent are the intrusions of sleep into wakefulness. Such spontaneous micro sleep episodes and sleep attacks (i.e. involuntary naps) can result in day time sleepiness, behavioral lapses or error of omission (i.e. failure to respond in a timely manner during cognitive performance demands). Also intrusion of sleep into wakefulness causes longer and more sleep inertia and as it was stated before, sleep inertia is characterized by confusion, disorientation, and increased response latencies which can all lead to degraded waking performance and alertness. A sleepy person's performance can begin to degrade even before actual sleep intrudes into waking. A micro sleep can be associated with a significant performance lapse during which an individual does not receive or respond to external information. These uncontrolled sleep episodes can occur while people engage in potentially dangerous activities such as standing or operating machinery or driving a car where inattention would put an individual at risk. For monitoring task these episodes can cause operators to miss warning signs and alarms and/or make errors in their responses during time critical events.

Research shows that resistance to disease is degraded when deprived of sleep [14]. Although sleep loss contributes to illnesses, but more importantly it threatens health by increasing the risk for injuries resulting from accidents. In addition sleep deprivation can be very serious and dangerous not only to the individual but also to others who may be impacted by the actions of the sleep deprived. While sleep deprived, an individual may

experience spontaneous micro sleep episode and be unable to respond and perform properly. In such situations, the level of sleepiness can degrade human performance significantly and cause an operational incident. Consequently, SD poses a potentially severe risk to performance and safety of all individuals involved in the task. As sleep deprivation increases the risk of human-error related accidents, especially with vigilance-based tasks and safety-sensitive occupations grows. Studies of shift-workers, truck drivers, medical residents and airline pilots during sleep debt show an increased risk of crashes and near misses [8].

**Research Methodology**

This research presents an industrial pilot survey that investigates the degree of inadequate sleep and fatigue on individuals and its potential impact on various indicators of productivity and work performance. Moreover the results can be used to better understand the causes of performance degradation in the workplace, to evaluate work/rest schedules, to plan work and sleep in operational missions, and to determine the timing of fatigue countermeasures to anticipated performance decrements.

The survey contained about 33 questions related to work and sleep quality. Most questions were categorical multiple-choice of 3–5 responses, some open-ended, and some were measured by a Likert scale. Several questions were taken from the Pittsburgh Sleep Quality Instrument (PSQI) to measure the workers' sleep quality [15]. The PSQI Questionnaire is primarily used to measure many of the characteristics of sleep and assess mood and sleep disorders. Other questions in the survey explore the workers'

perceptions on this issue and evaluate the impacts of SD on incidents and accidents in workplace. The survey comprised 33 questions that can be categorized in 4 main parts: (1) background information, (2) sleep quality, (3) work performance and (4) risks and accidents.

1) The first 10 questions include background information about each employee including personal demographics (e.g. age, gender, height and weight) and some information about their job and work schedule. The inclusion of these individual characteristics is important to this study because it helps in analyzing the influence of these characteristics on daytime functioning. A number of these factors that are assumed to play a role in affecting mood state and performance can be further analyzed as control variables. Furthermore, interactions between these background factors should be included in order to take account of potential interrelationships and examine their contributions in daytime functioning. Moreover, questions related to physical health complaints and caffeine intake can be considered as a part of this group.

2) Along with demographics, some questions about sleep quality and duration of wakefulness were used to further assess the potential contribution of fatigue and sleepiness in workers. To maintain effective performance, sleep quality is as important as sleep quantity; therefore subjects have been asked about their sleep patterns such as sleep interruptions, estimated sleep latency, total sleep time, and frequency of awakenings during sleep to indicate quality of their sleep while off-duty. Questions on sleep disorder symptoms such as not comfortably breathing, having pain, having bad dreams, restless

legs syndrome, and parasomnia helps exclude subjects with any kind of sleep disorders. These questions assess the workers' overall level of sleep deprivation and quality of sleep.

3) We have also asked some questions regarding employees' social activities, work engagement and performance. This group of questions captured a subjective evaluation of the quality of job accomplishment due to the severity of sleep deprivation. Questions about subjective perception on daytime dysfunction such as concentration problems, alertness deficiency, difficulty in performance, and absenteeism due to sleep problems are beneficial in evaluation of performance factors which can be influenced by sleep deprivation.

4) Five final questions asked about the likelihood of accidents and errors at workplace while individuals are sleep deprived. The last question is an open-ended one which asks subjects about any significant mistake during their job activities due to inadequate sleep. This can be an important issue since it has potentially serious consequences not only for the worker but also for all other employees.

**Results**

Participants consisted of five people with ages ranging from 50 to 70 years old. This sample was made up of 80% males and 20% females. Questionnaire was filled out anonymously to assure confidentiality. In the total five participants, average work duration was 6-9 hours and there were no significant differences between demographic

characteristics of each subject. Moreover there was no report or complaints indicating a significant health problem. This small sample served as a pilot study and the survey will be disseminated much more widely in the future.

Overall 20% of subjects had suffered from sleep disruptions and had taken medicines to go to sleep. Even though this subject reported that the mean sleep duration at night was 7-9 hours, the overall sleep quality was rated fairly poor and rarely had a good night sleep in both on and off- duty days. It can be assumed that subjects experienced poor sleep due to sleep fragmentation caused by children and frequent arousals. Interruptions of sleep not only reduces the total amount of sleep, but may result in ‘‘sleep inertia,’’ which can impair performance for up to 30 min after waking [16]. Additionally, respondents were asked to report their work schedules to be able to address their sleep patterns. 40% of participants had variable work schedule (multiple, changing work schedule, etc.). 20% had flexible work schedules and the remaining 40% had fixed work schedules with typically 8 hours of work per day. Those with variable work schedules had more complaints about staying alert at work but generally, no significant correlation was found between work schedules and overall performance.

All subjects in this study stated that they did not have enthusiasm to get things done and continue their work semi-automatically while fatigued or sleepy. Those who had impaired night sleep complained more about having difficulty in alertness and napping at work. Missing a day of work in order to get more sleep was common among those who had a low quality of sleep. Research has shown that sleep deficit can impair performance

such as decision-making, reasoning, judgment, and communication. Statistical demonstration of the common performance factors which can be impaired by sleep loss is shown in the figure below.

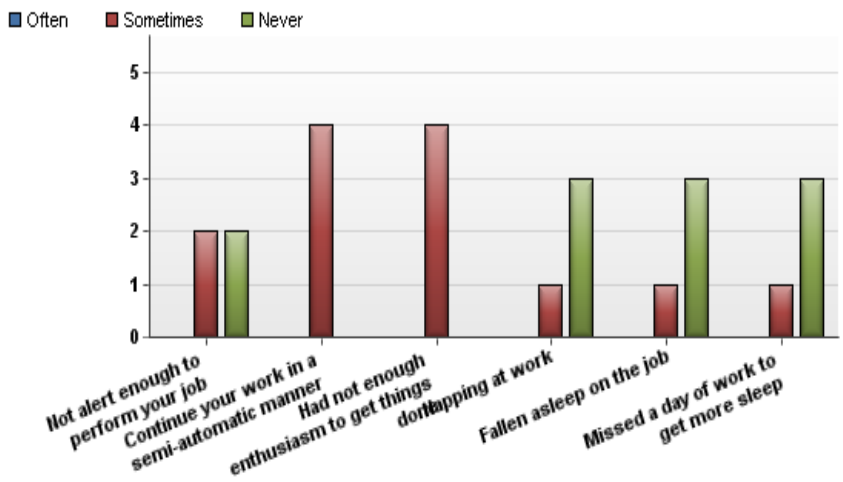


**Figure 1.** Performance Factors Reported to be Impaired by Sleep Loss

As expected, there were some differences among groups who had fairly good sleep quality and those who did not sleep well at night. All performance indicators were deteriorated during on-duty for people with poor sleep habits. The subjects, who felt various degrees of sleepiness and fatigue at work, have performed some environmental changes to obtain alertness. These changes in environmental stimulations include, changing temperature, stretching and changing position, walking and talking to co-workers and drinking caffeine.

To address any possible incidents at work, respondents were asked to report their performance quality as well as their colleagues. From the list of factors which are

demonstrated in Figure 2, it can be observed that none of the factors were experienced very likely or severely. 67% reported anxiousness and forgetfulness were somewhat likely to happen because of fatigue or sleepiness. It was somewhat likely to experience decreased reaction time, low concentration and decreased attention by 33% of the participants.

| Question | Not Likely | Somewhat Likely | Very Likely | Severely |
|---|---|---|---|---|
| Misinterpretation | 100.00% | 0.00% | 0.00% | 0.00% |
| Decreased memory | 100.00% | 0.00% | 0.00% | 0.00% |
| Decreased reaction times | 66.67% | 33.33% | 0.00% | 0.00% |
| Anxiousness | 33.33% | 66.67% | 0.00% | 0.00% |
| Low concentration | 66.67% | 33.33% | 0.00% | 0.00% |
| Forgetfulness | 33.33% | 66.67% | 0.00% | 0.00% |
| Failure in required act performance | 100.00% | 0.00% | 0.00% | 0.00% |
| Performing task at the wrong time | 100.00% | 0.00% | 0.00% | 0.00% |
| Performing task in the wrong order | 100.00% | 0.00% | 0.00% | 0.00% |
| Decreased attention | 66.67% | 33.33% | 0.00% | 0.00% |
| Taking unnecessary acts | 100.00% | 0.00% | 0.00% | 0.00% |
| Increased false alarms | 100.00% | 0.00% | 0.00% | 0.00% |

**Figure 2.** Reported Likeliness of Errors Due to Sleep Deprivation

The last set of questions focuses on mistakes and accidents while sleep deprived. The results have indicated that participants rarely noticed making errors while sleep deprived. No accidents or major mistakes with a potential of life loss were specified. An open-

ended question asked about the most significant error participants or any of their co-workers have made affecting their job performance. Reduced output, inattention to details and not being fast enough in critical situations were the common answers for this question. Variable shifts and job stress was specified as a major contributor in reduced output.

To sum up, the mentioned results partially support our hypotheses. Analyzed results indicate that quantity of sleep did not have a significant relationship with performance. However, quality of sleep was negatively related to alertness and consequently performance. Therefore, how good a worker sleeps at night does seem to be tied to the worker's productivity. Additionally, the majority of participants confirmed that not getting adequate sleep has some impact on their work, mood and their social life. The 20% who had sleep problems clearly stated that the major impact was on mood. These results associated with sleep deprivation are in agreement with majority of past researches and supports the fact that sleep deprivation in many cases can affect performance by decreasing alertness.

In the end, the main goal is to come to an understanding of how sleep affects human physical and cognitive performance. This can be beneficial for making predictions about possible risks in applied settings and thereby assist in presenting more solutions to overcome this problem. Although there is no simple, universal solution to fatigue in the workplace, a variety of countermeasure strategies (e.g. education, exercise, nap, formal policies, healthy diet and reduced environmental stimulants) have been proposed in

previous researches to maintain alertness and on-the-job performance. Similarly, carefully designed human-machine systems may help reduce fatigue and improve both sleep patterns and overall quality of life. Therefore, further research in this area is neeed to indentify potential incidents and issues particularly in operational settings and facilities. It is also imperative that we acknowledge these human limitations and design work environments to improve system safety and allow workers to function and perform their best within these limitations.

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## 2. Managing Sleep Deprived Workers


### Abstract

Sleep deprivation is pervasive in modern society. Many occupations require people to work effectively for long hours, often performing monotonous tasks. As a result individuals demonstrate poorer performance which not only affects individuals' physical and mental wellbeing but also puts productivity and safety at risk which can result in significant costs. Sleep deprivation among workers, whether chronic or acute, whether from disorders, lifestyle or shift works, poses severe issues for engineering managers. Micro sleeps, sleep attacks, and lapses in cognition can be common for individuals suffering from sleep loss. These human behaviors can lead to increased risk of human error, accidents, and performance losses. Research has shown that sleep related fatigue influences a wide range of human abilities such as vigilance, communication, information integration, and reasoning abilities that can impair safety in operational settings where workers are often involved with critical decision making and problem solving skills. This paper summarizes biological factors associated with sleep and sleep loss (i.e. common performance decrements, sleep cycles, circadian rhythms, and sleep apnea). It describes how managerial decision such as scheduling policies, task design, and working conditions can be used to minimize fatigue and sleepiness in workplace. In addition a variety of countermeasure strategies including caffeine, healthy diet, bright light, exercise, and good sleep habits are discussed as potential measures to maintain workers' alertness and performance. A preliminary survey of individual's perception of these countermeasures is also presented. This information can help engineering managers

improve worker performance and reduce job dissatisfaction caused by sleep deprivation and improve organizational productivity, performance, and safety.

**Keywords**

Sleep Deprivation, Work Performance, Fatigue Countermeasures, Sleepiness, Work Schedules, Alertness,

## Introduction

In an age of increased emphasis on health and safety, it seems the importance of sleep has been largely ignored with today's hectic lifestyle where success is often linked to long hours of work. Contemporary workplaces often conflate sleeplessness with productivity and accomplishment by admiring those who work extra hours and considering them as ambitious and hard working. At the same time, we cannot avoid 24 hour operation jobs, shift work, repetitive and monotonous duties which may contribute to sleepiness and fatigue.

Generally, interrupted sleep, extended periods of sleeplessness, inadequate quality of sleep and working against the body's sleep-wake cycle, negatively impacts daytime functioning and performance. Lack of sleep contributes to serious health problems, and may even shorten lifespan. It also greatly impairs a wide range of cognitive, behavioral, and emotional measures. Tasks involving cognitive processing are particularly sensitive to sleep deprivation due to decreased alertness, impaired memory and declined speed of psychomotor responses. Compared to well-rested people, those who are sleep-deprived tend to disengage perceptually from the external environment, think more slowly, make

more mistakes, and have memory difficulties. These negative effects may lead to errors and performance lapses as well as putting workers and others at higher risk of accidents. Also workers tend to take more risks while sleep deprived which can be a serious problem particularly in critical jobs where they are expected to make fast decisions. Sleep loss not only affects employee's wellbeing and social life but also compromises the safety of the entire workplace. Consequently it can have a major impact on how well a business functions.

**Biology of Sleep**

Sleep is perhaps one of the most important and yet least understood behavioral state that reenergizes the body and allows the brain to store and reorganize information. Many complex cognitive, physiological, psychological and behavioral processes constantly occur during sleep. Basically, a healthy individual requires a specific amount of sleep to achieve full alertness during waking hours. Like many other physiological parameters, there are individual variations in sleep needs. Although most adults require approximately eight hours of sleep per night, some people may need six hours or more than eight hours of sleep to feel refreshed and function at their best during wakefulness (Van Dongen, H., Rogers, N. L., & Dinges, D. F. , 2003). What is interesting is that prolonging the sleep time by 2–3 hours over what is an individual daily standard, does not significantly enhance one's general efficiency (Ferrara, M., & De Gennaro, L. , 2001).

Human alertness regularly oscillates in a highly predictable manner in the course of a day. This naturally occurring pattern is controlled by two physiological regulatory

processes. One is a homeostatic sleep process and the other is circadian sleep process. Homeostatic process represents an increased drive for sleep as wakefulness is extended and a declined propensity during sleep. It increases as a function of previous wakefulness and decrease over the course of a sleep period. Circadian rhythms, an internal biological clock with a rhythmic cycle of about 24 hours, regulates our sleep-wake patterns based on some internal and external cues such as exposure to light, meals, exercise and social life. Its role is to program us on a 24 hour schedule to sleep at night and to be awake during the day. All humans, like other mammals, have a central circadian pacemaker in the brain that not only regulates sleep-wake cycles but also controls a variety of body functions on a 24-hour basis. Many physiological functions of the body, including digestion, body temperature, performance capabilities, mood, immune functions, and hormone secretion are governed by circadian rhythm.

One of the major findings is that on a regular 24 hour schedule with sleep at night, there are two peaks of decreased alertness and increased sleepiness. Generally speaking, sleep tendency increases during certain early morning hours 2–7 a.m. and, to a lesser degree, during a period in the midafternoon 2–5 p.m., whether or not one has slept. During this period, core body temperature drops and physical function may reach the lowest level. On the other hand, the two alertness peaks come about at 9–11 a.m. and 9–11 p.m. During this period, one may have difficulty falling asleep even if his/her sleep was poor in the previous night (Rosekind, M. R., Gander, P. H., Gregory, K. B., Smith, R. M., Miller, D. L., Oyung, R., ... & Johnson, J. M.,1997). The circadian system is highly resistant to change and very difficult to adjust to the need of work/rest schedule in a short time. Many cases such as shift work, prolonged wakefulness and travel across

time zones create a reversed pattern of nighttime activity and daytime sleep by receiving conflicting time cues from the environment. For most shift workers, frequent switching from one pattern to another can cause their circadian clock becoming chronically out of step with local time. For this reason, shift workers are at a delicate risk that maintains constant internal/external disagreement, while travelers may experience one cycle of de-synchronization and inconsistent shift scheduling (Rosekind, M. R., Gander, P. H., Gregory, K. B., Smith, R. M., Miller, D. L., Oyung, R., ... & Johnson, J. M., 1997). Nevertheless, circadian rhythms differ slightly from person to person. Larks are morning people who spontaneously awaken in the early morning and retire to bed early, while on the other hand owls are evening people who tend to stay up until midnight or later. Since owls and larks vary on levels of consciousness or alertness throughout the day and night, it is important to take advantage of this natural tendency to maintain alertness at work especially in 24/7 operations (Carskadon, M. A., Wolfson, A. R., Tzischinsky, O., & Acebo, C. ,1995).

Today, it is fully understandable that sleep is a complex physiological process during which our brain is very active. Electrical activities of brain which occur during sleep can be monitored and measured with an electroencephalogram (EEG). Throughout sleep process, human brain experiences two different sequential states, rapid eye movement (REM) and non-rapid eye movement (NREM). NREM comprises four distinct stages of sleep. Stage 1 is very brief, semiconscious and transitional stage between wakefulness and deep sleep. Over half of our sleep time is spent in stage 2 of sleep which is the actual beginning of sleep. In stage 2 the sleeper is unaware of the surroundings but can be easily aroused. Stage 3 of sleep, is called slow wave sleep, during which body

temperature drops; metabolic activity slows and waking the sleeper gets difficult (Humphries, J. D., 2009). Stage 4, deepest phase of sleep, is important to the determination of alertness and fatigue because it is a time of energy conservation, and repair of the immune system (Ganz, F. D., 2012). Sleep then moves into the REM phase when one becomes temporarily paralyzed with the exception of the eyes. The eyes move rapidly, heart rates and breathing become irregular and dreaming occurs. REM plays a major role in memory storage, retention, and mental performance. Moreover REM sleep is more prevalent in the latter half of an eight hour sleep period of the night (Czeisler, C. A., 2006). At the end of REM, sleep progresses back to the lighter stages of sleep, and the sequence begins all over again. The entire sleep cycles last approximately 90 to 100 minutes and may repeat four to five times a night.

Disruption of specific sleep stages can result in differential effects on waking performance and alertness. In stage 1 or 2, the person is more likely to wake up feeling alert. But if awakened from Stage 3 or 4, confusion and dizziness may be experienced and lead to “sleep inertia”. Sleep inertia is a transient period from sleep to fully awake. This state usually lasts 5 to 15 minutes and starts immediately after being awakened from deep sleep. The intensity of sleep inertia depends on the sleep stage preceding the awakening. When aroused from deep stages of sleep, individuals report more severe sleep inertia which may last even longer (Czeisler, C. A., 2006). Sleep inertia can have negative effects on alertness and individual cognitive performance therefore it should be taken into consideration in operational environments where humans are sleep deprived and napping at the work place is common or when people are awakened at home to make critical decisions during crisis situations.

**Sleep Deprivation and Its Consequences in Workplace**

Sleep deprivation is a state caused by inadequate quantity or quality of sleep, including voluntary or involuntary sleeplessness and circadian rhythm sleep disorders. Sleep loss is cumulative and when constantly accumulated is described as a term sleep debt. Larger sleep debts require greater amounts of restorative sleep to recover normal levels of performance and mood. Cumulative buildup of sleep pressure appears to be a key feature of sleep debt. Sleep debt can result from a combination of both total and partial sleep deprivation. Total sleep deprivation (TSD) involves the complete lack of sleep, typically for at least 24 hours. Technically, the TSD period begins at the last awakening. Thus, if someone skips one night of sleep at their usual wake time the next morning they will have undergone 24 hours TSD. Partial sleep deprivation (PSD) is a more common phenomenon in the real word and involves getting some sleep, but an inadequate amount over night (Van Dongen, H., Rogers, N. L., & Dinges, D. F. , 2003). Moreover, it should be noted that sleepiness differs from fatigue. Fatigue, however, can be a secondary consequence of sleepiness.

Lifestyle choices, family life and sleep environment may cause people to sleep fewer hours than what their body needs to maintain wakefulness. For instance, parents with young children almost always experience sleep deprivation because of frequent wakes in the night for feeding or comfort. Furthermore, sleep loss can be caused by disrupted sleep cycles and other work demands. Unfortunately, nowadays operational environments are prone to both continuous and sustained conditions that lead to sleep deficit. Some of the common characteristics of such occupational environments include extended or unusual working hours, long night shifts, isolation, insufficient break time,

strong vigilance and a monitoring component. The main concern with extended working hours is disruption of sleep cycles and thus increased fatigue-related errors leading to accident risks. Many shift workers and night workers sleep contrary to the body's natural wake-sleep cycle; as a result they get less sleep than that required for full restoration. Thus, sleep quality and quantity is often lower for those working at night, or starting early in the morning. Task characteristics are further mediators in the effect of sleep on task performance. Monotonous and repetitive tasks worsen the performance process and increase the likelihood of errors associated with sleep deprivation. Studies have shown that tasks which require consistent, sustained alertness are most susceptible to sleep loss (Sluiter, J. K., 1999). In addition, work effectiveness decreases particularly when the subjects perform long, compulsory, difficult, sitting activities in an unchanging environment with limited lighting, little supply of sound, and low motivation (Bonnet, M. H., & Arand, D. L., 2003). This is a cause for concern particularly in the process industries where so many operational tasks can be monotonous but critical for safety.

Along with physical characteristics of work, physiological and mental conditions can also disturb a person’s sleep. Stress, worry, excitement in addition to mental workload, job satisfaction and even sociocultural influences are some endogenous factors that can trigger vigilance (Humphries, J. D., 2009). A range of physiological sleep disorders such as sleep apnea, insomnia, narcolepsy, restless leg syndrome, depression, heart diseases, and even poor general health can contribute to the problem of sleep deprivation. It is remarkable that, the relationship between sleep and health is bidirectional; just as poor health disrupts sleep, poor sleep can compromise health and contribute to illnesses. Research shows that resistance to disease is degraded and immune

function is decreased when deprived of sleep (Ganz, F. D., 2012). Sleeplessness correlates with a probability of developing diabetes, high blood pressure and a range of other poor health problems, such as stomach problems, impaired sexual function, hypertension, and weight gain (Drake, C. L., Roehrs, T., Richardson, G., Walsh, J. K., & Roth, T. , 2004).

Health problems are not the only casualties of sleep deprivation. Several days of continuous sleep deprivation may impair memory and induce a wide range of effects on cognitive functions. Challenging tasks involving cognitive processing are delicately sensitive to sleep deprivation for the reason that inadequate sleep reduces performance impairing working memory and attention (Durmer, J. S., & Dinges, D. F. , 2005). Impaired attention slows responses and reaction times and causes lapses in attention which yields to making mistakes and errors of omission. Studies indicate that, for most people, one night with two hours less sleep than what is usually required is sufficient to degrade subsequent waking performance and alertness significantly (Monk, T. H., 1991). Sleeplessness can be linked to impairment of numerous aspects of cognitive functions including judgment, information processing, problem-solving, decision making, as well as learning, communicating and experiencing difficulties in keeping concentration. Without adequate sleep, memory lapses increase and reasoning process becomes schematic, which can deteriorate the outcomes in the tasks that required flexible thinking and creativity (Harrison, Y., & Horne, J. A., 2000). In addition sleep deprivation has been shown to indirectly affect a wide range of behavioral and emotional measures. Insufficient sleep can negatively affect performance by contributing to such factors as impaired social relationship, poor morale, less satisfaction in personal life, and

depression. During periods of intense sleepiness people experience negative emotions and are more likely to report feeling stressed, aggressive, sad, and angry and have a worse attitude in general (Orzeł-Gryglewska, J. , 2010).

As sleep deficiency accumulates, human brain shifts spontaneously from wakefulness to sleep in order to meet its physiological need for sleep. The sleepier the person, the more rapid and frequent are the intrusions of sleep into wakefulness. Such spontaneous micro sleep attacks can result in day time sleepiness, inattention, forgetfulness, and performance lapses (Dinges, D. F., 1989). Micro-sleeps, brief episodes of unintended sleep, may cause sleep inertia and lead to significant performance lapses during which an individual does not receive or respond to external information. These uncontrolled sleep episodes can occur while people engage in potentially dangerous activities such as operating machinery where inattention would put an individual at risk. For monitoring tasks these episodes can cause operators to miss warning signs and alarms or make errors in their responses during critical times. Sleepiness can also impair physical and psychomotor coordination (Durmer, J. S., & Dinges, D. F., 2005). Due to automatic behavior a person continues to perform routine duties but is incapable of active cognition. Automatic behavior plus difficulties in keeping concentration and slower reactions lead to lower capabilities of task performance and increased number of errors. This can become particularly hazardous when individuals perform routine, highly over-learned tasks or long, compulsory, sitting activities.

The connection between sleep and occupational accidents has been reported in variety of studies. Researchers have studied the impact of sleep deprivation on shift-workers, truck drivers, medical residents and airline pilots to show an increased risk of

crashes and near misses. Studies show that most injuries in shift workers occur between 10 p.m. and 2 a.m. It has been estimated that about 65% of human-error-caused catastrophes such as nuclear accidents at Three-Mile Island, Chernobyl, and Exxon Valdez oil spill occurred between midnight and 6 a.m., and human error is the cause of 60% to 90% of all industrial and transport accidents (Krauss, A. D., Chen, P. Y., DeArmond, S., & Moorcroft, B., 2003). The changes in sleep time across the circadian pattern can also be hazardous to workers and their environment. Archived data of accidental deaths recorded by the National Center for Health Statistics revealed that accidental deaths increased dramatically immediately following the spring shift of Daylight Savings Time (Coren, S., 1996). Without a doubt, sleep deprivation may threaten health by increasing the risk of human-error related injuries and accidents. Sleep deprivation can be very dangerous not only to the individual involved in the task but also to others who may be impacted by the actions of the sleep deprived. Therefore, insufficient sleep and uncontrolled sleep episodes can have catastrophic consequences at many different industrial workplaces, especially those with vigilance-based tasks and safety-sensitive occupations.

**Managing Sleep Deprivation (Coping Strategies)**

In general, people tend to underestimate the importance of sleep. Those who suffer from sleep deprivation can be totally unaware of their impaired capabilities and unable to judge when it is no longer safe to work. The dangers of sleepiness can be intensified by the fact that people can get so accustomed to sleepiness and low levels of alertness that may not recognize their sleepy condition (Rosekind, M. R., 2005). There is a need to

develop awareness about complex nature of sleep in order to promote their wellbeing and prevent catastrophic events. Organizations and industries have an ethical responsibility to evaluate operations and work schedules to minimize detrimental impact of sleepiness on on-the-job performance and public safety.

A variety of well-tested countermeasure strategies can help individuals maintain alertness and get the job done as safely as possible. However, all the following recommendations provide temporary relief from the symptoms of sleep deprivation and they are not a long term solution and cannot be substitute for sufficient sleep. Regardless of how one enters into a sleepiness state, adequate sleep is the only naturally occurring cure to overcome sleep deprivation. Since work-related causes of sleepiness are largely under the control of the organization, employers need to be aware of the risks and take strategies to identify, assess, and monitor individuals with sleep-related issues. Work schedules developed through employee-driven processes have shown a reduction in sleepiness, absenteeism and low morale in extended hour operations (Kerin, A., & Aguirre, A., 2005). However, many professions such as commercial trucking and airline industries are governed by regulatory policies that dictate the amount of rest required. In such operations, drowsy employees should be encouraged to report if they do not feel rested. They need to monitor not only their own level of alertness but also watch out for symptoms of sleepiness in their coworkers. To prevent any possible chance of hazard, individuals, specifically those who engage in dangerous tasks should not report for duty. Organizations can design the workplace and adopt technological innovations to assess risks and monitor any sleep related error, especially for jobs that are sensitive to decreased attention due to sleepiness. They can benefit from technology by instituting a

system of screening for chronic daytime sleepiness or untreated sleep disorders in order to identify causes of decreased productivity at work (Mulgrew, A. T., Ryan, C. F., Fleetham, J. A., Cheema, R., Fox, N., Koehoorn, M., ... & Ayas, N. T. , 2007).

A successful management of sleepiness requires an organizational culture where everyone is aware of the risk from sleep deprivation. Sleep education which can be considered as part of organizations' health awareness program can provide basic information about individual sleep needs. Organizations can educate employees about the misconceptions regarding sleep and sleepiness, and interrelationships of changes in the body's circadian rhythms, sleep problems, and health symptoms. Undoubtedly educating and training employees about the risks associated with sleepiness and how to cope with them via available approaches will contribute to better performance. A study on night shift workers reached the conclusion that an educational program improves health, fatigue, and increased daytime sleep (Kerin, A., & Aguirre, A., 2005). In addition, involving families of shift workers in educational sessions can be a very effective tool, as it provides them with an understanding of the employee's need for sleep and proper nutrition. Daytime sleep is an essential part of night-shift worker's life, therefore their families should support them by making desired condition for sleep such as blocking eliminating daytime noise and light interruptions (Kerin, A., & Aguirre, A., 2005).

Many forms of flexible working arrangement (FWA) such as part time work, compressed work weeks, flextime, job sharing, career breaks, family related leaves, annualized hours have traditionally been introduced to meet employees' needs and demands (Krauss, A. D., Chen, P. Y., DeArmond, S., & Moorcroft, B. , 2003). Creating a culture which would allow employees to participate in the decisions about their work

hours and redesigning their schedules can cause a great deal of performance benefits. A study of facility managers has also confirmed that employee involvement in scheduling working hour, compared to schedules changed mandatorily by management can lead to lower levels of absenteeism and turnover (Kerin, A., & Aguirre, A., 2005). In this regard, there is a classical approach, called hours-of-service (HOS) policies that limits active duty hours for all personnel to assure that adequate time for sleep is obtained between consecutive periods of work. An HOS approach is intended to provide rest opportunities by regulating specific requirements when individuals are not in charge (Beilock, R., 1995). Yet the ability to cope with shift work varies from person to person. For example those who biologically require less sleep tend to cope better with shift work than those who need more. Conversely morning people suffer more from shift work than "night owls" (Humphries, J. D., 2009). If people have a non-fluctuating shift work schedule, their bodies may adapt to it. This schedule is when the workers stay with the same timetable every day; even though it is during untraditional work hours. In summary, organizations should be concerned about the potential losses of productivity as a result of decreased performance during vulnerability zones of human body. It would be better to try to match shift rotations with individual's natural sleep patterns to help them get at least as many hours of sleep as possible.

Other than work hours, shift-work schedules can be improved in a number of other ways. More specifically, to better accommodate shift workers with increasing alarm loads, managers need to consider the number of successive shifts, the length of the shifts and the condition of breaks within and between shifts. According to the circadian report, those workers who start their typical workday before 7 a.m. or end their typical workday

after 7 p.m., are considered as shift workers. Number of shifts in a row should not be more than 4 to 5 consecutive days. Workers should have at least one, and ideally, two consecutive days off each week (Czeisler, C. A., & Fryer, B., 2006). Successive nights of work increase health and safety risks. Consecutive night shifts whether they are fixed or rotating should be kept at minimum. The human body gradually adjusts to new shifts and struggles to go to sleep and wake up at the same times every day. Therefore quick shift changes should be avoided in order to maintain the body's natural rhythms. Moreover, the length of the shift work should be scheduled in a way that allow for adequate recovery periods during the shift and between shifts. Likewise, the nature of the task should be taken into consideration. Tasks with heavy physical or mental workload, or monotonous tasks, can lead to poor performance and should be shortened. Besides this, brief rest breaks can allow workers to recover from sleepiness and muscle fatigue. In general, regular rest breaks can be an effective means of maintaining performance and preventing the accumulation of accident risks specifically over prolonged tasks. While two hour lunch time breaks are common in some industrial settings, under at least some circumstances the scheduling of additional micro-breaks can be beneficial. A work-rest schedule should include the frequency, duration, and timing of rest breaks and should be regularly re-evaluated. Organizations can also provide employees a rest opportunity to take a nap during their break times. Napping as a coping strategy, can be used to reduce sleep debt and moderate the effects of fatigue and sleep loss. There is a strong evidence that napping during prolonged periods of sleep deprivation has beneficial and recovery effects when compared with no napping. The recovery value of the nap can be particularly useful for nightshift workers (Takeyama, H., Kubo, T., & Itani, T., 2005).

For most shift workers napping on the job, during shifts could compensate for daytime sleep deprivation or could decrease the nocturnal sleepiness. Recently, some businesses have provided facilities and opportunities for on-the-job napping (Anthony, W. A., & Anthony, C. W., 2005). Despite the fact that the benefits of a nap do not last as long as a good, long sleep, yet it can help individuals to recover from fatigue and increase the vigilance level. A short afternoon nap can be effective in combating sleepiness. Research has proved that a 20-minute nap in the mid-afternoon improved subjective sleepiness and performance levels (Hayashi, M., Watanabe, M., & Hori, T., 1999). However longer daytime naps can induce a chance of entering sleep inertia. Sleep inertia can be considered as one of the main limiting factors in napping strategies for the reason that it involves a period of transitory confusion and impaired cognitive performance that immediately follows awakening.

Since well-rested workers are more likely to be healthy and productive, it should be in businesses' best interest to pay attention to employees' sleep needs. These days, many organizations implement company sponsored health promotion programs that are designed to reduce health risks. These programs are designed to assist employees to reduce stress and excess body weight as well as increase physical activity, improve nutrition, and reduce tobacco and alcohol use (Talvi, A. I., Järvisalo, J. O., & Knuts, L. R., 1999). Moreover employers might consider providing relaxation therapies. Such physical and mental relaxation techniques are frequently used for the treatment of sleep disorders and include hypnosis, meditation, massage, and yoga. These practices promote relaxation at the workplace and improve sleep quality. Typically, an employee may be sleepy either voluntary or involuntary due to job constraints, or because of the effects of

an untreated sleep disorders which has been aggravated by job conditions. Hence, employees need access to health-care advice and counseling to their physicians to rule out underlying health problems and effectively manage their sleep problems. Physicians may be able to resolve causes of daytime sleepiness by either behavioral or medical treatments. Some medical stimulants such as Modafinil, Melatonin and Caffeine can maintain alertness levels, particularly during the day. However, these pharmacological agents may cause the body to develop a resistance and dependence. Over time, individuals may have difficulty falling asleep without them or their body adapts to the drug and it becomes less effective (Rosekind, M. R., Gander, P. H., Gregory, K. B., Smith, R. M., Miller, D. L., Oyung, R., ... & Johnson, J. M. ,1997). Caffeine is one of the most widely used substances in our society to combat sleepiness. Caffeine helps restore better levels of wakefulness and can be effective in reducing the adverse impact of misalignment of circadian phase. Studies show that caffeine consumption reduced driving incidents related to sleep loss. Also a glucose-based energy drink significantly improved sleepy drivers' lane drifting and reaction time (Horne, J. A., & Reyner, L. A., 2001). It is notable that the combination of drinking coffee followed immediately by a 20-minute nap has been shown to provide positive effects that lasts for several hours, which significantly reduces the likelihood of having a sleep-related accident (Moorcroft, W. M., 2003). Besides caffeinated drinks, employees should have easy access to healthy food, which can counter sleepiness. What they eat or drink can play an integral role in maintaining alertness on the job. Foods rich in carbohydrates may induce sleep, whereas high protein foods are recommended to promote wakefulness (Rosekind, M. R., Gander, P. H., Gregory, K. B., Smith, R. M., Miller, D. L., Oyung, R., ... & Johnson, J. M., 1997). More

to the point, employees' performance can be influenced by their work environment and their engaged type of tasks. Managers should pay a particular attention to certain characteristics of the physical environment such as noise, lighting, heat, and humidity which may have an effect on sleepiness. A typical workplace should have bright lighting and cool but comfortable temperatures with plenty of air changes per hour (Krauss, A. D., Chen, P. Y., DeArmond, S., & Moorcroft, B., 2003). Lighting improvements can increase alertness and improve performance. Light administration has also been used successfully in laboratory studies to adjust circadian phase (Horowitz, T. S., Cade, B. E., Wolfe, J. M., & Czeisler, C. A., 2001). In order to develop workplace performance, managers and ergonomists should team up to improve working conditions by appropriate worker selection, posture, ergonomics training, and exercise instruction (Balci, R., & Aghazadeh, F., 2003). Experiments show that physical activity is one of the most effective ways of combating sleepiness. Some stretching and light exercise not only promotes organization's wellbeing but also helps drowsy individuals stay awake. Other than these, motivation, social interaction and conversation can be a useful operational strategy. The individual must be actively involved in the conversation to maintain alertness. Studies indicate that the lack of conversation is a predictor of declining physiological alertness (Rosekind, M. R., Gander, P. H., Gregory, K. B., Smith, R. M., Miller, D. L., Oyung, R., ... & Johnson, J. M., 1997). Some works suggest that up to a point, motivation can temporarily overcome deficits of sleep loss. There is some evidence that sleepiness decreases due to motivation in working as part of a team rather than working individually (Baranski, J. V., Thompson, M. M., Lichacz, F. M., McCann, C., Gil, V., Pastò, L., & Pigeau, R. A., 2007).

Along with work-related aspects which are largely under the control of the organization, employees also have responsibilities to arrive at work in a fit state and be aware of their fatigue level. Individuals environment, tasks and diet can be different at home than work. They need to give particular attention to their home situation, lifestyle and many other non-work related aspects that can affect their sleep quality. The best preventive strategy which should be taken into consideration by employees, is improving their sleep quality. All the behaviors, environmental conditions, and other sleep-related factors that can affect sleep quality are considered under the heading of sleep hygiene. Good sleep hygiene can help improve some causes of daytime sleepiness. A common recommended practice is to maintain a consistent sleep schedule for bedtimes, and wake up times. Also a regular pre-sleep bedtime routine can condition relaxation in preparation for falling asleep and improved sleep onset latency. These predictable set of pre-sleep activities include such things like reading a book or brushing teeth (Mindell, J. A., Meltzer, L. J., Carskadon, M. A., & Chervin, R. D., 2009). Physical aspects of the environment can also affect sleep. Exposure to noise as well as exposure to heat or cold leads to difficulties in falling asleep and staying asleep. A comfortable sleep surface is also important to promote sleep. Other main sleep hygiene recommendations include exercising in the late afternoon or early evening, eating a light bedtime snack and avoiding coffee, alcohol, and nicotine. A regular light exercise can enhance deep sleep; however strenuous exercise results in physiological activation, which may interfere with sleep. Therefore, it is advisable to avoid strenuous exercise within six hours of going to bed (Rosekind, M. R., Gander, P. H., Gregory, K. B., Smith, R. M., Miller, D. L., Oyung, R., ... & Johnson, J. M., 1997). In addition individuals should be cautious about what they

eat or drink before bedtime. Human body is programmed to digest food during the day, so it's better not to eat a big meal just before bedtime. However, hunger may disturb sleep, so light bedtime snack such as warm milk seems to help individuals sleep (Stepanski, E. J., & Wyatt, J. K., 2003). Drinking anything with caffeine such as coffee or energy drinks may produce detrimental effects on subsequent sleep. The effects of caffeine usually lasts for three to five hours, although in sensitive individuals the effects may remain active for up to 10 hours (Rosekind, M. R., Gander, P. H., Gregory, K. B., Smith, R. M., Miller, D. L., Oyung, R., ... & Johnson, J. M., 1997).Yet, these effects depend on the amount of caffeine ingested over the whole day and also vary from person to person. Alcohol can promote relaxation and thereby help a person fall asleep, but it also produces significant disruption in subsequent nocturnal sleep and will not let individuals wake up feeling refreshed. It suppresses REM sleep in the first half of the night and may cause awakenings from intense dreaming activity and headaches. Therefore, it's better to avoid alcohol ingestion as far as six hours prior to bedtime due to fragmentations in sleep (Landolt, H. P., Roth, C., Dijk, D. J., & Borbely, A. A., 1996).

**Research Methodology and Results**

This research presents an industrial pilot survey that investigates the degree of inadequate sleep and fatigue on individuals and its potential impact on various indicators of work performance. Moreover the results can be used to better understand the causes of performance degradation in the workplace, to evaluate work-rest schedules, to plan work and sleep in operational missions, and to determine the timing of fatigue countermeasures to anticipated performance decrements.

The survey contained 33 questions that can be categorized into four parts. Multiple-choice, open-ended, and Likert scales were used. Several questions were taken from the Pittsburgh Sleep Quality Instrument (PSQI) to measure the workers' sleep quality (Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J., 1989). The PSQI Questionnaire is primarily used to measure many of the characteristics of sleep and assess mood and sleep disorders. Other questions in the survey explore the workers' perceptions on this issue and evaluate the impacts of SD on incidents and accidents in workplace.

1) The first 10 questions include background information about each employee including personal demographics (e.g. age, gender, height and weight) and some information about their job and work schedule. The inclusion of these individual characteristics is important to this study because it helps in analyzing the influence of these characteristics on daytime functioning. A number of these factors that are assumed to play a role in affecting mood state and performance can be further analyzed as control variables.

2) Along with demographics, some questions about sleep quality and duration of wakefulness were used to further assess the potential contribution of sleepiness in workers. To maintain effective performance, sleep quality is as important as sleep quantity; therefore subjects have been asked about their sleep patterns such as sleep interruptions, estimated sleep latency, total sleep time, and frequency of awakenings during sleep to indicate quality of their sleep while off-duty. Questions on sleep disorder symptoms such as not comfortably breathing, having pain, having bad dreams and restless legs syndrome helps exclude subjects with any kind of sleep disorders.

3) We have also asked some questions regarding employees' social activities, work engagement and performance. This group of questions captured a subjective evaluation of the quality of job accomplishment due to the severity of sleep deprivation. Questions about subjective perception on daytime dysfunction such as concentration problems, alertness deficiency, difficulty in performance, and absenteeism due to sleep problems are beneficial in evaluation of performance factors which can be influenced by sleep deprivation.

4) Five final questions asked about the likelihood of accidents and errors at workplace while individuals are sleep deprived. The last question is an open-ended one which asks subjects about any significant mistake during their job activities due to inadequate sleep.

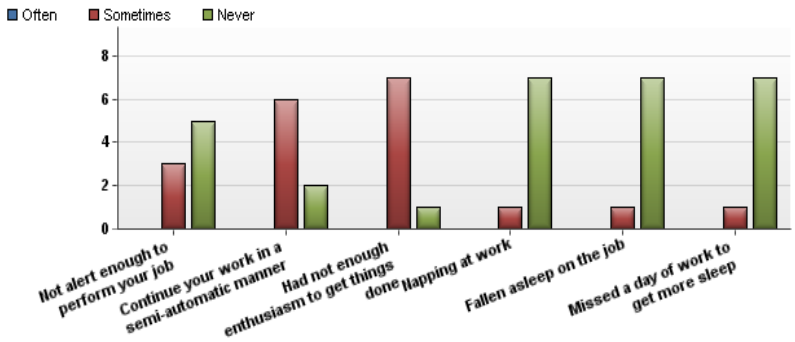
Participants consisted of thirteen people with ages ranging from 40 to 70 years old. This sample was made up of 80% males and 20% females. Questionnaire was filled out anonymously to assure confidentiality. In the total thirteen participants, average work duration was 6-9 hours and 20% were working more than 12 hours including any overtime or extra hours. Moreover there was no report indicating a significant health problem. This small sample served as a pilot study and the survey will be disseminated much more widely in the future.

Overall 20% of subjects had suffered from sleep disruptions and had taken medicines to go to sleep. Even though the mean sleep duration at night was 5-7 hours, the overall sleep quality was fairly good. 22% reported a fairly poor sleep which can be assumed that sleep fragmentation caused by children, frequent arousals, and episodes of confusion can play a role in this regard. Additionally, respondents were asked to report

their work schedules to be able to address their sleep patterns. 20% of participants had variable work schedule (multiple, changing work schedule, etc.). 50% had flexible work schedules, 10% rotating shifts and the remaining 20% had fixed work schedules with typically 8 hours of work per day. Those with variable work schedules had more complaints about staying alert at work and they believed their sleep quality had some impact on their mood and social life. However generally, no significant correlation was found between other work schedules and overall performance.

As expected, there were some differences among groups who had fairly good sleep quality and those who did not sleep well at night. More than 70% of participants stated that they did not have enthusiasm to get things done and continued their work semi-automatically while fatigued or sleepy. This group on average had a good night sleep 3 to 4 nights a week on work days. Missing a day of work in order to get more sleep was common among those who usually work more than 12 hours a day and had low quality of sleep due to interruptions. Statistical demonstration of the common performance factors which can be impaired by sleep loss is shown in the exhibit below.

**Exhibit 1.** Performance Factors Reported to be Impaired by Sleep Loss



All subjects in this study, who felt various degrees of sleepiness and fatigue, stated that they drink caffeine during work hours based on a mean ration of 4-7 times a week. Moreover changing position, walking and talking to coworkers were other frequent strategies to maintain alertness.

To address any possible incidents at work, respondents were asked to report their performance quality as well as their colleagues. From the list of factors which are demonstrated in Exhibit 2, it can be observed that none of the incidents were experienced severely. Decreased attention, low concentration, and forgetfulness were the factors that have been experienced very likely or somewhat likely. It is interesting that 85% reported anxiousness were somewhat likely to happen because of fatigue or sleepiness.

**Exhibit 2.** Reported Likeliness of Errors Due to Sleep Deprivation

| Question | Not likely | Somewhat Likely | Very Likely | Severely | Mean |
|---|---|---|---|---|---|
| Misinterpretation | 62.5% | 25.0% | 12.5% | 0.0% | 1.5 |
| Decreased memory | 50.0% | 37.5% | 12.5% | 0.0% | 1.6 |
| Decreased reaction times | 42.9% | 57.1% | 0.0% | 0.0% | 1.6 |
| Anxiousness | 14.3% | 85.7% | 0.0% | 0.0% | 1.9 |
| Low concentration | 37.5% | 50.0% | 12.5% | 0.0% | 1.8 |
| Forgetfulness | 37.5% | 50.0% | 12.5% | 0.0% | 1.8 |
| Failure in required act performance | 50.0% | 50.0% | 0.0% | 0.0% | 1.5 |
| Performing task at the wrong time | 75.0% | 25.0% | 0.0% | 0.0% | 1.3 |
| Performing task in the wrong order | 62.5% | 37.5% | 0.0% | 0.0% | 1.4 |
| Decreased attention | 37.5% | 50.0% | 12.5% | 0.0% | 1.8 |
| Taking unnecessary acts | 57.1% | 42.9% | 0.0% | 0.0% | 1.4 |
| Increased false alarms | 87.5% | 12.5% | 0.0% | 0.0% | 1.1 |

The last set of questions focuses on mistakes and accidents while sleep deprived. The results have indicated that minor mistakes such as near misses were the only experienced factor by 25% of participants. Half of participants noticed making errors rarely while sleep deprived. No accidents or major mistakes with a potential of life loss were specified. An open-ended question asked about the most significant error participants or any of their co-workers have made affecting their job performance. Reduced output, inattention to details, monotony and time pressure were the common answers for this question. In summary, analyzed results indicate that quantity of sleep did not have a significant relationship with performance. However, quality of sleep was negatively related to alertness and consequently performance. Therefore, how good a worker sleeps at night does seem to be tied to the worker's productivity. Additionally, the majority of participants confirmed that not getting adequate sleep has a major impact on their mood and some impact on their work and their social life. These results associated with sleep deprivation are in agreement with majority of past research and supports the fact that sleep deprivation in many cases can affect performance by decreasing alertness.

## Conclusion

To most organizations, employees are those who should be responsible for identifying and managing their sleep problems. However, according to the current review, the impact of sleepiness on occupational health and performance is evident and requires attention from businesses and industries. In brief, Workplace-related sleep loss not only puts workplace productivity and safety at risk but also affects individuals' physical and emotional wellbeing as well as their social relationships and overall quality of life.

Understanding how sleep affects human physical and cognitive performance can be beneficial in finding better solutions to cope with sleepiness and minimizing risk of accidents and errors in applied settings.

Education, nap, exercise, flexible schedules, policies, healthy diet and reduced environmental stimulants are a variety of countermeasure strategies which have been suggested in previous studies to enhance alertness and on-the-job performance. The goal of all operational countermeasures is to assist both employees and employers by reducing health costs associated with sleep loss and improving workplace safety and efficiency. It is also imperative that by implementing effective strategies and considering employee preferences, businesses will experience lower absenteeism, improved morale, and increased productivity levels. Still, further research particularly in operational settings and facilities is needed to identify potential risks associated with sleepiness.

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## 3. Working While Sleep Drunk? Effects of Fatigue on Safety

Sleepiness is a pervasive problem in our daily lives and can adversely affect our physical and mental wellbeing as well as degrade our performance and safety either at home or on the job. Insufficient sleep impairs performance in terms of errors, slowed reaction time, reduced memory, attentional lapses and many other cognitive and behavioral deficits which can compromise safety causing injuries and catastrophic accidents. A lack of sleep among workers can create unsafe workplace endangering individuals, organizations, and the public. Although the impact of poor sleep on performance is clear, its potential safety risks are often not widely recognized. One of the reasons for this is that sleepiness cannot be directly measured. It can be inferred from a range of cognitive, behavioral, physiological and psychological performance variables which can be affected by sleep loss, but these effects can varying among people. Researchers have investigated the relationships between sleep deprivation and performance decrements.

### Sleep is an Active Process

Sleep is a natural state of rest which is necessary to reenergize the body physically and mentally in order to achieve full alertness throughout waking hours. During sleep our body becomes moderately inactive, however, brain is very active, storing and reorganizing information as well as orchestrating a wide range of biochemical, physiological, behavioral and psychological processes (Piotrowski, 2010). Throughout the sleep process the human brain experiences sequential stages. These stages can be divided into two entirely different behavioral states of, *rapid eye movement* (REM) and

*non-rapid eye movement* (NREM). NREM comprises four distinct stages of sleep. Stage 1 is brief, transitional stage between wakefulness and deep sleep. Stage 2 of sleep is the actual beginning of sleep when the sleeper is unaware of the surroundings but can be easily aroused (Humphries, 2009). The deeper stages of sleep are stages 3 and 4 during which body temperature drops, metabolic activity slows and waking the sleeper gets difficult. Stage 4, the deepest phase of sleep, is important to the determination of alertness because it is a time of energy conservation and repairing immune system (Ganz, 2012). Sleep then moves into the REM phase where the most dreaming occurs. During this final phase of sleep one becomes temporarily paralyzed with the exception of the eyes. This stage is also called paradoxical sleep because despite of the externally paralysis, the body is in a state of arousal and brain wave patterns are similar to that observed during wakefulness. Thus, REM plays a major role in memory storage, retention, and mental performance. Furthermore REM sleep is more prevalent in the latter half of an eight hour sleep period of the night (Czeisler, 2006). At the end of REM, sleep progresses back to the lighter stages of sleep, and the sequence begins all over again. The entire sleep cycles last approximately 90 to 100 minutes and may repeat four to five times a night. Hence, adequate amounts of both REM and NREM sleep are necessary to ensure full functioning. Moreover, the continuity, timing, and patterning of different stages of sleep are necessary for optimal performance (Dahl, 1999).

There is no substitution for sleep; the quality and quantity of out sleep has a great impact on our quality of life and work efficiency. Moreover, disruption of specific sleep stages can result in differential effects on waking performance and alertness. In first stages of

sleep, the person is more likely to wake up feeling alert. However, if awakened from deeper stages confusion and dizziness may be experienced due to *sleep inertia*. Sleep inertia is a transient period experienced immediately after awakening from deep sleep where there is some remaining sleepiness. Although sleep inertia typically includes a brief period of 5 to 15 minutes upon awakening from a normal night's sleep, it may last even longer when awakened from deep stages of sleep. The effects may dissipate rapidly within the first hour after awakening and in some rare cases can still be measured after two hours (Van Dongen, Belenky, & Krueger, 2011). The negative effects of sleep inertia on alertness and individual cognitive performance should be taken into consideration particularly in operational environments where humans are sleep deprived and napping at work place is common. Sleep inertia can be problematic when emergency personnel or on-call individuals are awakened and expect to perform immediately. Despite the fact that napping might result in sleep inertia, however short naps (approximately 20 minutes) have positive long-term effects on biological functions and have been considered as a possible strategy to increase the vigilance level.

Many other factors besides sleep inertia affect individuals daytime functioning. Two noteworthy biological processes that regularly oscillate in a highly predictable manner in the course of a day are the *homeostatic process* and *circadian processes*. These two processes interact with each other in naturally occurring pattern to regulate sleep propensity and daytime alertness as well as cognitive performance (Czeisler, 2006). The homeostatic process represents an increased pressure for sleep over time spent awake and a declining propensity during sleep period (Van Dongen, & Dinges, 2003). Beyond

driving the body to fall asleep and to wake up, circadian process adjusts waking behavior by regulating our sleep/wake patterns based on an internal biological clock with a rhythmic cycle of about 24 hours. This biological clock is regulated by several time cues such as exposure to light, meals, exercise and social activities in order to program the body on a 24 hour schedule. Since circadian rhythms are generated internally, rhythmicity continues in the absence of periodic external time cues. In addition, a variety of physiological functions including heart rate, digestion, core body temperature, cognitive functions, mood, immune functions, and endocrine patterns are also found to be governed by circadian rhythms (Czeisler, & Fryer, 2006) (Czeisler, 2006). Therefore circadian pacemaker which keeps track of time of day modulates our waking behavior, as reflected in our performance, generating circadian rhythmicity in almost all neurobehavioral variables (Van Dongen, & Dinges, 2003). Throughout the waking day as the homeostatic pressure for sleep increases, the circadian pacemaker sends out a stronger pressure for wakefulness. The interplay between the two processes modulates sleep propensity and daytime alertness leading to relative improvement during the day and relative impairment during the night (Van Dongen et al., 2011). This explains why under ordinary circumstances productivity and safety decreases over a course of a night. Furthermore, the circadian system is highly resistant to change and very difficult to adjust to the need of work/rest schedule in a short time. Many cases such as shift work, prolonged wakefulness and travel across time zones create a reversed pattern of nighttime activity and daytime sleep. In such cases, the individual fights the biological clock and tries to override the basic circadian pattern of sleeping at night. This sets up a situation in which the clock is receiving conflicting time cues from the environment. In addition,

most shift workers revert to the usual pattern of daytime activity on their days off. This frequent switching from one pattern to another can lead to the circadian clock's becoming chronically out of step with local time.

One of the key findings concerning circadian process is that on a regular 24-hour schedule with sleep at night, there are two *peaks of vulnerability* when alertness is decreased and sleepiness is increased. Generally speaking, sleep tendency may reach its highest level during certain early morning hours (2–7 a.m.) and, to a lesser extent, during a period in the midafternoon (2–5 p.m.), whether or not one has slept (Mitler et al., 1988). During this timeframe when physiological sleepiness is greatest, core body temperature is lowest thus the capability to function diminishes. Not surprisingly, frequency of naps occurring around these circadian peaks also reveal a pattern for greater sleep pressure during these two time spans. On the other hand the two alertness peaks come about at 9–11 a.m. and 9–11 p.m. during which one may have difficulty falling sleep even if his or her sleep was poor in the previous night (Miller, Shattuck, Matsangas, & Dyche, 2008).

**How Much Sleep is Enough?**

Like many other physiological parameters, people have individual needs for the amount of sleep. Although most adults require at least 8 hours of sleep per night, some people may need 6 hours of sleep to maintain work effectiveness (Van Dongen, Rogers, & Dinges, 2003). It is generally, recommended that healthy adults sleep 7-9 h/day (Luckhaupt, Tak, & Calvert , 2010). Epidemiological studies define short sleep duration as average sleep duration of 6 hours or less per day. In addition, several other studies

indicate that, for most people, limiting sleep to 7 hours or less over successive nights result in significant cumulative performance deficit (Belenky et al., 2003) (Whitmire, et al. 2009). Interestingly, prolonging the sleep time by 2–3 hours over what is an individual daily norm does not significantly enhance one's general efficiency (Ferrara, & De Gennaro, 2001). *Morningness-eveningness* preference is a further individual difference that most clearly explains the variations in the sleep/wake schedules. Most people have inborn preferences to go to bed early and rise early (larks), while others stay up late and get up late (owls). Since owls and larks vary on levels of alertness throughout the day and night, it is important to take advantage of this natural tendency to maintain alertness at work especially in 24/7 operations. For example, people with night owl personality who biologically require less sleep are better candidates for shift work compared to morning people (Humphries, 2009). Moreover the need for sleep and circadian physiology can also depend on gender, chronotype, and age. Sleep requirement can change across the life span; older people may need less sleep but may have difficulty making adaptation to changes to their schedules (Haight, 2003).

## Sleep Deprivation

Sleep deprivation is a state caused by inadequate quantity or quality of sleep, including voluntary or involuntary sleep loss and sleep disturbances. Sleep disruption, can cause fragmented sleep which has the same effect as sleep deprivation on waking behavior (Durmer, & Dinges, 2005). Sleep loss can result from a combination of both *acute* and *chronic sleep deprivation*. Acute sleep deprivation involves the complete lack of sleep, typically resulting from missing a single night's sleep. While, chronic sleep deprivation is

an outcome of regularly losing sleep over many nights involving at least a week of restricted sleep (Drummond, & McKenna, 2005). Chronic lack of sleep is a more common phenomenon in today's world where healthy individuals voluntarily reduce sleep durations in order to achieve extension of the daily wakefulness period. Chronic sleep deprivation gets even more dangerous when it is obtained repeatedly on consecutive occasions. The effects of such accumulated sleep loss create a *sleep deficit or debt* that requires greater amounts of restorative sleep to recover normal levels of performance. Thus, the danger of an error due to sudden overwhelming sleepiness increases progressively with continued sleep debt. Studies have compared the effects of acute and chronic sleep restriction and found that chronic reduction of sleep, leads to disruption of sleep cycle (Bonnet & Arand, 2001). This may result in low levels of attention and cognitive functioning similar to those of severe acute sleep deprivation (Van Dongen et al., 2003) (Banks, & Dinges, 2007) (Orzel-Gryglewska, 2010). In other words, decreasing sleep time gradually for several consecutive nights (e.g. 4 or 6 hours of sleep opportunity) can have comparable performance effects to staying up continuously for between 24 and 48 hours (Whitmire et al., 2009).

Yet, several other laboratory studies indicate that rapid sleep loss condition (no sleep for one night) produces greater and more rapid decrements in performance and alertness than when the same amount of sleep was lost more gradually over days of sleep restriction (Van Dongen et al. , 2003) (Belenky et al., 2003) (Durmer & Dinges, 2005). Surprisingly, while these studies clearly show low levels of performance during sleep restriction, subjects with reduced amount of sleep whom suffered performance impairments reported

feeling only slightly sleepy. This indicates that there may be some adaptation to chronic sleep deprivation and subjects may have no longer been aware of their performance deficits and risky behaviors. (Van Dongen et al., 2003).

**Sleep Drunkenness & Neurobehavioral Performance**

The most obvious and common effect of insufficient sleep is daytime sleepiness. Daytime sleep propensity makes human brain shift spontaneously from wakefulness to sleep in order to meet its physiological need for sleep. As sleep deficiency accumulates, an individual disengages perceptually from the external environment and slips into stage 1 of sleep regardless of the time and situation in order to recover from sleep deficiency (DeArmond & Chen, 2009). Such brief episodes of sleep, called *micro sleeps*, can be associated with forgetfulness, inattention and performance lapses during which people do not typically report being asleep, yet their reactions to external information are diminished (Dinges, 1988). Both acute and chronic sleep deprivation can lead to an increased probability of experiencing lapses of attention and sleep onset. As lapses increase in frequency, they increase in duration and eventually progress to full and sustained sleep attacks such as involuntary naps (Lim & Dinges, 2009). Micro sleeps, brief episodes of unintended sleep, last only a few seconds but can result in significant performance lapses and inattention, leading to serious accidents. Furthermore, individuals without adequate sleep may experience decreased vigilance, vision disturbances as well as double vision and thought distractions (Thomas et al., 2003). Additionally, intrusion of sleep into wakefulness causes longer and more sleep inertia and as it was stated before,

sleep inertia is characterized by confusion, disorientation, and increased response latencies which can all lead to degraded waking performance and alertness.

Sleepiness can also impair physical and psychomotor coordination (Belenky et al., 2003). *Automatic behavior syndrome* is an intermediate state between sleep and wakefulness which involves performing a routine task for several minutes or more, with no active cognition. This state has also been termed as sleep drunkenness and characterized by a purposeless motor behavior to provide semi-automatic responses to stimuli; another characteristic of sleep drunkenness is that often the individual is not even aware of these short lapses in alertness and has no memory of it afterwards. Thus it can be particularly hazardous and lead to increased number of errors when individuals perform long, routine, highly over-learned tasks especially in an unchanging environment (Czeisler, 2006). Therefore, sleepiness can impair performance from the simplest to the most complex behaviors. Behavioral lapses can manifest as both *errors of omission* and *errors of commission*. Error of omission is defined in the form of delayed responses to external stimulus while error of commission is responding to a wrong stimulus or responding when no stimulus is present or failure to respond (Durmer & Dinges, 2005) (Chee & Tan, 2010) (Gaultney & Collins-McNeil, 2009). It should be taken into consideration that such lapses of attention and errors can occur while people engage in vigilance based tasks where inattention would put an individual at risk and cause serious industrial catastrophes, transportation accidents, or medical errors (Dinges, 1995) (Barger et al., 2006) (Philip & Akerstedt, 2006).

With regard to such parameters as lapses of attention, and neurobehavioral impairments, the effects of sleep deprivation has been shown to be similar to those induced by alcohol consumption at or above the legal limit (Goel, Rao, Durmer, & Dinges, 2009). In fact, recent studies indicate that on average, performance with a blood alcohol level of 0.05% remained equivalent to performance after being awake for 18 hours. Moreover, impairment of neurobehavioral performance caused by 24 hours of sleep deprivation was comparable with impairment observed at a blood alcohol concentration of roughly 0.1% (Orzeł-Gryglewska, 2010) (Czeisler, 2006). Thus, the effects of a chronic sleep loss may cause a drowsy person to be as dangerous as a drunk person. Such affects can hinder the correct performance at work and in extreme cases, may pose hazard to the workers themselves and their environment. Similar studies that compare performance after a time of sleep deprivation to performance with elevated blood alcohol levels have confirmed these results (Arnedt, Wilde, Munt, & MacLean, 2001).

**Sleep Deprivation Affects Cognitive Performance**

Sleep also appears to play an important role in *neurocognitive performance*. Improved understanding of cognitive deficits caused by acute or cumulative sleep deprivation has been achieved through many laboratory-based studies. These studies have revealed probable neurocognitive explanations for the observed behavioral decrements in different operational environments (Asaoka et al., 2010). Yet, cognitive performance measures can differ greatly in response to sleep deprivation due to individual variability (Durmer &Dinges, 2005). Generally, several days of continuous sleep deprivation increases the probability of neurocognitive performance errors on tasks involving memory (Durmer &

Dinges, 2005) (Banks & Dinges, 2007) (Lockley et al., 2004), and attention (Durmer & Dinges, 2005) (Czeisler, 2006) (Lockley et al., 2004). The impacts of such attentional failures are increased to a level comparable to that seen with acute total sleep deprivation (Czeisler, 2003). Impaired attention slows responses and reaction times which can yield to making mistakes and errors of omission (Gaultney & Collins-McNeil, 2009). A laboratory based study shows that the duration of simple reaction time averages three times longer after 24 hours of wakefulness compared to non-sleep deprived individuals (Cajochen, Khalsa, Wyatt, Czeisler, & Dijk, 1999). Sleepiness and decreased alertness can also disrupt numerous other aspects of cognitive functions including judgment (Killgore, Lipizzi, Kamimori, & Balkin, 2007), information processing, logical reasoning (Blagrove & Akehurst, 2001), Problem-solving (Harrison & Horne, 2000) as well as learning (Stickgold & Walker, 2007), communicating (Harrison & Horne, 2000) and concentration.

Challenging tasks involving flexible thinking are delicately sensitive to sleep deprivation. This is because inadequate sleep may lead to lapses in concentration and cause cognitive tunneling which makes the individual pay too much or insufficient attention to nonessential tasks. Cognitive tunneling can also make the individual choose the same solution when presented with a series of situations that each includes a changing element (Orzeł-Gryglewska, 2010). Additionally, without adequate sleep, memory lapses increase and reasoning process become schematic. This can compromise lateral thinking and creativity (Harrison & Horne, 1999) (Killgore, Balkin, & Wesensten, 2006) (Durmer & Dinges, 2005), as well as decision making (Killgore et al., 2007) (Harrison, & Horne,

1999). Decision making can be more vulnerable to safety when individuals tend to take more risks. The increased tendency to accept risks due to sleep loss (Killgore et al., 2006) (Durmer & Dinges, 2005), can be particularly critical for workers such as chief commanders, military personnel, or medical workers who must make fast decisions which might influence other peoples' lives.

**Psychological and Physical Effects of Sleep Deprivation**

Other than cognitive functions, sleep deprivation has been shown to negatively affect performance by decreasing emotional intelligence and deteriorating of interpersonal relations. During periods of intense sleepiness people experience a wide range of negative emotions and are more likely to report feelings of stress, sadness, anger (Orzeł-Gryglewska, 2010), as well as anxiety, depression (Lanier, 2003), mania and aggression (Kahn-Greene, Killgore, Kamimori, Balkin, & Killgore, 2007). Sleep deprived individuals tend to become more irritable, easily frustrated and have poor morale in general. Such changes in emotional regulation can decrease one's control over performance which may result in serious consequences when involved in risky tasks. Insufficient sleep can amplify emotional difficulties and lead to increased disruption of sleep (Dahl, 1999). Moreover, insufficient sleep and the inability to control emotional responses can impair social relationship and cause low motivation as well as less satisfaction in personal life (Killgore, 2008). Feelings of life dissatisfaction and social isolation can be particularly problematic and a potential safety hazard when sleep deprived individual is encouraged to sacrifice sleep in order to spend time with family and friends. It is remarkable that, there is bidirectional relationship between sleep and

physical/emotional wellbeing. Just as poor health and negative emotions disrupt sleep quality, poor sleep can decrease emotional intelligence and compromise health by causing illnesses. Sleep deprivation can contribute to physiological sleep disorders such as sleep apnea, insomnia, narcolepsy, restless leg syndrome, heart diseases, and even poor general health. Research shows that resistance to disease is degraded and immune function is decreased when deprived of sleep (Lange, 2003). A range of poor health problems such as diabetes, high blood pressure, stomach problems and weight gain also correlates with sleeplessness (Drake, Roehrs, Richardson, Walsh, & Roth, 2004).

## Safety and Catastrophic Consequences

A better understanding of neurobehavioral and neurocognitive performance impairment reveals how a lack of sleep can jeopardize workplace safety. Sleep deprivation may lead to errors or mistakes and jeopardize safety in terms of injuries and in a greater degree causing catastrophic accidents. In other words, the extent to which sleepiness affects an individual can range from slight to disastrous. As sleep deprivation accumulates the risk of human-error related incidents and accidents, especially with vigilance-based tasks and safety-sensitive operations grows (Ulmer, Wolman, & Johns, 2009) (Lockley et al., 2004) (Luckhaupt et al., 2010). Today many industries and transporting modes are technologically advanced and have maintained safe operations by utilizing detection and warning systems. As a result, individuals' role is mainly focused on monitoring and taking action in critical situations. Therefore, awareness and responsiveness play an important role to prevent system failures and ensure that safety procedures are employed in a timely manner (Van Dongen et al., 2011). Several studies have reached to the

conclusion that sleep durations that are longer or shorter than seven to eight hours in a 24 hour period are associated with automobile and workplace accidents (Pack et al., 2006) (Connor et al., 2002) (Lockley et al., 2004). On the contrary, recent research analyses show that average sleep duration has generally declined among workers over the last two decades (Luckhaupt et al., 2010). Researchers have studied a wide range of fields with the high prevalence of short sleep duration such as transportation (truck drivers and airline pilots), military, medicine (Drummond, & McKenna, 2005) (Durmer & Dinges, 2005), manufacturing and public administration industries (Luckhaupt et al., 2010), to show an increased risk of crashes and near misses. Majority of these studies indicate that insufficient sleep and uncontrolled sleep episodes can make operational performances more dangerous due to memory lapses, attentional failures and slowed reaction time. Regardless of how shift-working, long working hours or sleep disorders can be the reason in explaining short sleep deficits, their adverse consequences on workplace safety and job performance cannot be neglected (Hanowski, Hickman, Fumero, Olson, & Dingus, 2007) (Lockley et al. 2004). The predominant amount of literature on sleep related accidents is in the context of driving. Those studies that have specifically focused on truck drivers have concluded that less sleep can lead to either crashes or near crashes (Hanowski et al., 2007). Moreover there is a significant relationship between quality and quantity of driver's sleep and the number of road accidents. Studies of drowsy drivers revealed that prolonged micro sleeps significantly reduce driving safety (Thomas et al., 2003). Yet, other forms of transportation, including railway and aviation, are not immune to the effects of sleep deprivation. Airline pilots and crews may suffer from jet lag that alters

body's circadian rhythms hence carry a major risk for operational lapses (Carskadon, 2004).

Inadequate sleep poses a potentially severe risk to safety and can be very dangerous not only to the individual but also to others who may be impacted by the actions of the sleep deprived. High profile incidents provide examples of how lack of sleep can create unsafe work settings and endanger considerable large segments of population and environment. Several major nuclear accidents including Three Mile Island, Chernobyl, Rancho Seco and the Exxon Valdez oil spill were found to be linked to human sleepiness and/or fatigue as a major contributory factor to the incident (Folkard & Lombardi, 2006) (Spencer, Robertson, & Folkard, 2006). Investigations into the grounding of the Exxon Valdez oil tanker, collision of two Burlington-Northern freight trains as well as the explosion of the Space Shuttle Challenger have identified sleep deprivation as the root cause of the accidents. In both cases, those in charge of the operations and required to make critical decisions were severely sleep deprived. Accident investigations of Space Shuttle Challenger revealed that some key managers had been on duty for long hours and had obtained less than two hours of sleep (Mitler et al., 1988). Therefore the contribution of human error and poor judgment resulting from sleep loss plus shift work during the early morning hours increased the potential for such mishap. In some other cases, fatigue was not the only primary cause but still played a critical role in the accident. Rather, there was an initial malfunction and since the operators were sleep deprived they did not manage the situation effectively and the situation escalated to an accident. For example, human error of omission and the subsequent defective reactions were cited to be the main

cause of the near meltdown of the Three Mile Island plant. Human errors have also been involved in two other serious incidents. The automatic shutdown of the Davis-Besse reactor which was due to a technical fault became even more critical when an operator pushed the wrong buttons in the control room; fortunately, corrective action eventually stabilized the reactor. In another case in Rancho Seco nuclear, a combination of equipment failure, human errors of omission and commission and inadequate operator training led to slow reactions in regaining control of the plant (Mitler et al., 1988).

It has been estimated that about 65% of catastrophes found to be the result of human error occurred during peak hours of sleepiness, between midnight to 6 a.m. (Krauss, Chen, DeArmond, Moorcroft, 2003). The nuclear accidents at Three-Mile Island and Chernobyl; the Exxon Valdez oil spill , the Estonia ferry; and the catastrophic chemical leak in Bhopal, India, all occurred in the early hours of the morning (Spencer et al., 2006) (Folkard and Lombardi, 2006). It seems to be more than coincidental that such serious accidents happened at a time when human performance is diminished. As pointed out before, the period from 2 to roughly 7 a.m. constitutes a time span of peak circadian sleepiness when individual is at a greater risk for making critical errors and performance catastrophes are far more likely to happen. A secondary and less pronounced zone of vulnerability also occurs in the afternoon from 2 to 5p.m. Studies of sleep-related vehicular accidents show that the peak occurrences of accidents caused by sleepiness are around 2 a.m., 6 a.m., and 4 p.m. (Horne & Reyner, 1995). In this regard, the risk of sleep related accidents at 6 a.m. is 20 times greater and at 4 p.m. three times greater than risk of an accident at 10 a.m. (Moorcroft & Belcher, 2005). As a result, changes in sleep time

across the circadian pattern can be hazardous to workers and their environment. Although, performance variability due to sleep loss does not necessarily cause an accident, it can jeopardize safety and lead to an accident in the long run (Van Dongen & Hursh, 2010). A recent study focusing on why sleep loss related accidents tend to be rare but catastrophic has suggested that stochastic performance variability under sleep deprivation need to be present at the same time to cause an accident. This study has used the Swiss cheese model of accident causation to better describe how multiple potential vulnerabilities need to be aligned in time and ultimately result in an accident (Van Dongen & Hursh, 2010). For example, a combination of several factors such as excessive overtime and insufficient sleep aligned with irregular working hours and led to the critical decisions which caused the fatal launch of the space shuttle Challenger in 1986.

## Occupational Stimulators

In addition to understanding the effects of sleep deprivation on performance, it is also important to study the work demands that can influence one's sleep quality or quantity. The impact of poor sleep on workplace performance may be direct, through occupational factors such as work environment, task characteristics, and job motivation, or indirect, through life style choices, sleep hygiene or medical disorders. Therefore, how sleepy individuals are at work, is not only influenced by their work characteristics but also their personal life habits and medical conditions. Subjective workplace sleepiness is triggered by a variety of work-related conditions. Unfortunately, in today's lifestyle, work environments are prone to both continuous and sustained conditions that lead to sleep deficit. Non-standard working hours, extended periods of wakefulness, as well as work

isolation (Czeisler, 2006) and shift work (Basner et al., 2007) can impact both quantity and quality of sleep and decrease workplace safety. *Task characteristics* are further mediators in the effect of sleep on performance. Vigilance based tasks which require sustained alertness are particularly susceptible to the effects of sleep loss. Monotonous and repetitive tasks worsen the performance process and increase the likelihood of errors when one has been deprived of sleep. This is a cause for concern particularly in the process and transportation industries where so many operational tasks such as monitoring can be monotonous but critical for safety. In addition, the time spent on a task constitutes decrements in cognitive performance and attention as the duration of the task extends (Durmer & Dinges, 2005). This progressive decline in performance involving longer reaction times and greater number of errors more is more noticeable in vigilance performance tasks (Van Dongen et al., 2011). A recent study explains this matter with neuronal activities in brain and concludes that neurocognitive deficits due to sleep deprivation are task dependent. Therefore, working on a particular task over a period of time increases the use of specific neuronal groups (Van Dongen et al., 2011). For this reason, rest breaks and task switching which shift particular neuronal use for cognitive processing to different neuronal groups, reset the poor effects and reduce the risk of incidents.

Furthermore, the amount of work assigned to an individual can physically or/and mentally affect one's performance while sleep deprived. The relationship between workload and performance has been described by an inverted 'U' which states that performance is impaired throughout periods of both high and low workload (Spencer et

al., 2006). Studies on medical and aviation industries show that an increasing number of errors during sleep deficit periods were associated with higher workload levels (Barger et al., 2006). Along with physical workload which can cause pain and fatigue, mental workload can lead to feelings of worry, stress, (Burgard & Ailshire, 2009) and excitement that may trigger alertness at work (Humphries, 2009) and contribute to poor social conditions. Several research studies support that decrements in *motivation* is one of the major determinants in workplace sleepiness and low efficiency (Krause,1999) (DeArmond & Chen, 2009). Motivation, up to a point, can temporarily overcome deficits of sleep loss. There is some evidence that sleepiness diminishes due to motivation in team working rather than working individually (Baranski et al., 2007). It is likely that highly stimulating activities particularly those involving physical activity or emotional arousal such as surgeon's motivation during a surgical operation can partially mask the effects of sleepiness (Thomas et al., 2003) (Orzeł-Gryglewska, 2010).

More to the point, the quality and quantity of sleepiness that individuals encounter at work depends particularly on their work schedules. In spite of those working part-time and full-time, many people are working extended workdays or doing shift. As the workforce moves increasingly toward unusual working hours, including early morning start times (Tucker, Macdonald, Folkard, & Smith, 1998), night shifts (Luckhaupt et al., 2010), rotating shifts (Pilcher, Lambert, & Huffcutt, 2000) plus long work hours (Kalish & Latif, 2005) (Basner et al., 2007) and unpredictable work hours, such as call-outs, the potential for short sleep duration increases. This in turn leads to fatigue and may cause accidents both on and off the job. Researchers have identified several consistent trends in

injuries or accidents associated with various shift-system features, including, time of day, hours per shift, number of consecutive shifts, and rest break intervals (Folkard & Lombardi, 2006). Studies of medical interns exhibit increased number of sleep related medical errors and attentional failures due to intense and long working hours (Barger et al., 2006) (Lockley et al., 2004). Interns working extended duration shifts are likely to make five times as many serious diagnostic mistakes. In addition to these harmful effects on patient safety, the risk of motor vehicle crashes were found to be more than doubled while driving home from work after such shifts (Czeisler, 2006). Therefore, the risk of injury and accident grows with increased hours on duty. Outcomes of a study show that after 10 hours and 12 hours on duty, the relative risk increases by roughly 90% and 110% respectively (Folkard & Lombardi, 2006).

It is clear that working in our 24-hour non-stop world is an occupational risk factor. Shift workers who typically sleep contrary to the body's natural wake/sleep cycle, get less amount of sleep than that required for full restoration. During abnormal work hours, disruption of the body’s circadian rhythm results in chronically reduced performance and alertness (Folkard, Lombardi, & Tucker, 2005). The outcome, thereby, can range from serious performance errors to long-term health decrements and accident risks (Whitmire et al., 2009). As many studies have highlighted, the lowest level of performance is during the early morning hours (3 A.M. to 6 A.M.) when workers are likely to blame for low productivity rate and increased number of errors. Hence, working through the night, long shifts, and short rotations increase the likelihood of sleepiness and jeopardize job performance. In addition, workload, physical environment, work activity, shift timing and

duration, as well as direction of rotation and the number of breaks during shifts are the key risk factors in shift schedules which can threaten employee welfare and safety. It should be noted that, human body can better adapt to circadian shifting when people have non-fluctuating shift work schedule, which is when one stays with the same timetable every day, even though it is during untraditional work hours. Also performance is likely to be better on a permanent non-fluctuating pattern rather than a rotating system. This can be a reason why studies suggest that slowly rotating shifts had the least detrimental effects on sleep length (Pilcher et al., 2000).

Last but not least, sleepiness in workplace increases when the subjects perform long, compulsory, difficult, sitting activities. This situation can be aggravated in an unchanging environment with limited lighting, little supply of sound, and low motivation (Bonnet & Arand, 2003). Poor environmental conditions such as loud noise, poor lighting, excessive heat or cold, as well as vibration, distracting colors and humidity can increase sleepiness and reduce organization's safety. These elements involve both the psychological and physiological wellbeing of people, causing such conditions as eyestrain, fatigue, headache, and nausea (Quible, 2000). However, although too many environmental stimulants (e.g. sound from equipment, tools, and peoples conversation) may prevent concentration on the job or cause sleepiness; yet lack of environmental stimulants (e.g. silent environment) certainly does not help drowsy individuals stay alert and can make the job boring. This is the reason why social interaction and conversation can be a useful strategy to maintain vigilance. Studies indicate that the lack of conversation is a predictor of declining physiological alertness (Rosekind et al., 1997). Therefore, managers and

ergonomists can improve working conditions by arranging a work environment where individuals are actively involved in the conversation to maintain alertness. In brief, it is clear that all these internal and external factors can affect performance in combination with one another. As motivation or exposure to bright light (Cajochen, 2007) temporarily improves performance, on the contrary, anxiety or too much noise can have transient adverse effects on performance. Therefore, in order to determine the overall risk on a system all the factors should be taken into consideration as a whole. Most importantly, although different operations may face different safety risks due to sleep deprivation yet the risks can have pervasive impact across families, communities, organizations, and societies.

## Conclusion

Generally, people tend to underestimate the importance of sleep. As with alcohol intoxication, chronically sleep-deprived individuals can be totally unaware of their impaired performance and unable to judge when it is no longer safe to work. The dangers of cumulative sleepiness can even be more intensified when individuals get so accustomed to sleepiness that may not recognize their sleepy condition (Rosekind, 2005). Therefore, there is a need to develop awareness about complex nature of sleep and its potentially powerful impact on individuals' wellbeing and safety. Organizations and industries have an ethical responsibility to develop policies and provide training and education on the risks associated with sleepiness. To prepare safe work design and prevent any possible chance of hazard, individuals need to be encouraged to monitor not only their own level of alertness but also watch out for symptoms of sleepiness in their

coworkers. Organizations can benefit from technological innovations to measure risks and monitor any sleep related error, especially for jobs that are sensitive to decreased attention due to sleepiness. In addition, a variety of operational countermeasures and coping strategies such as exercise, nap, proper lighting, healthy diet as well as caffeine, medication and good sleep hygiene can maintain alertness and minimize detrimental impact of sleepiness on workplace. Managing sleepiness in workplace not only improves morale, health and safety of individuals but also significantly minimizes costs due to maximized productivity, decreased accidents and injuries plus lower absenteeism and turnover. However, all the following approaches provide temporary relief from the symptoms of sleep deprivation and cannot be substitute for sufficient sleep. The only primary solution to overcome biological sleep deficiency is to maintain sleep. In the end, it is hoped that this literature review can be beneficial in better understanding the severity of possible sleep related risks and thereby assist in identifying potential incidents and presenting more solutions to better manage sleep deprivation in the workplace.

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# SECTION

# 2. CONCLUSION

The purpose of this thesis is to form a better understanding of the effects of sleep deprivation on workplace safety and job performance. Findings indicate that sleep is an essential key factor to our daily performance which our physical and mental health as well as social interests rely on it. However, the level of workplace sleepiness might vary contingent upon personality, lifestyle, circadian rhythm, type of task, work schedule, work environment, or type of job stressor. Our review further suggests that sleep deprivation is a serious matter that can cause a chain of various negative effects. Insufficient sleep, not only leads to physiological weariness but also causes a significant disruption in functioning, by influencing a variety of physical, mental and emotional factors. These influences often occur without our awareness of them and affect us more profoundly than we realize. Decrements in vigilance can hinder the correct performance at work, and in extreme cases may pose hazard to the workers themselves and their environment. Accordingly, sleep deprivation is a serious problem that should not be neglected, it affects almost every aspect of human functioning; it compromises emotional well-being, impairs physical health, jeopardizes work performance, public safety, and even contributes to mortality. The costs associated with consequences of poor sleep can be astronomical due to lost productivity, litigation, accidents and health care and the impacts can be pervasive across families, organizations, and societies as a whole.

Although the findings of this study provided insight into the link between sleep deprivation, performance, well-being and safety, the relationship between workplace sleepiness and occupational injuries might be more complex than originally assumed.

Some sleep-related hazards are more likely to happen in some work spaces than others, some may pose more serious threats to employee welfare, and many others may result in work inefficiency and cause economic losses. It is important to assess the possible damaging hazards associated with sleepiness and implement effective strategies to better manage the known risks. While it is not possible to avoid 24-hour operations, we can manage them to minimize their effects on health and safety. More research, better education, formal policies, better assessment and predictive tools and even non-pharmacologic and pharmacologic interventions can help individuals to function better within these limitations. Additionally, carefully designed human-machine systems and work environments may help to reduce the likelihood of errors and accidents by reducing the adverse effects of sleepiness.

In spite of work schedules and policies, the personal behavior of others cannot be controlled by organizations. The effects of sleepiness can only be countered when every individual recognizes the essential role of sleep. Managers need to raise the awareness level on the impact of poor sleep and what people can do in their personal lives to improve their sleep. Undoubtedly educating and training employees about the risks associated with sleepiness and how to cope with them via available approaches will contribute to better performance. To conclude, sleepiness on the job is a prevailing occupational health problem that requires attention from various stakeholders including employers, employees, policy makers, and managers as well as researchers.

In the end, this literature review is a small step toward understanding the relationship between sleep deprivation and performance decrements, with the goal of improving the prediction of errors and injury risks in workplace. Further research needs

to be done to better understand the coping mechanisms of sleepiness and how the consequences of sleep deprivation on performance could be measured and managed in order to improve both sleep patterns and the overall quality of life.

# APPENDIX

## SLEEP SURVEY

**Consent Form**

**Missouri University of Science and Technology**
**Engineering Management & Systems Engineering Department**

We appreciate your participation in this research at Missouri University of Science and Technology. This project is being conducted by Neda Khalafi under supervision from Dr. Susan Murray.

The survey is designed to help in improving workplace safety, productivity and performance which are affected by workers' fatigue or lack of sleep. It involves answering some general demographics questions and some questions about your experiences regarding your usual sleep habits and your workplace activities. It will take about 10-15 minutes to complete this survey.

Your participation is completely voluntary, and your responses will be completely anonymous. Your name will not be associated with the data or the results of this project. A confidential code number will be assigned to your data file for data collection and analysis. If you decide to participate, you are free to discontinue participation at any time without prejudice. You will have the opportunity to enter in a drawing to win one of three 100$ gift certificates redeemable at Amazon.com. Your information will not be associated with your responses.

If you would like additional information about this project, you may contact Dr. Susan Murray by phone at 573-341-4038 or email at murray@mst.edu .We would be happy to answer any question you may have about this study.

**Statement of Consent**

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

- ○ Agree
- ○ Disagree

**What is your gender?**

- ○ Male
- ○ Female

**How old are you?**

| 20-24 | 25-29 | 30-39 | 40-49 | 50-59 | 60 or more |
|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ |

**What type of company or organization do you work for?**

**How long have you been in your current position in the company or your organization?**

| Less than 6 month | 1 to 2 years | 2-5 years | More than 5 years |
|---|---|---|---|
| ○ | ○ | ○ | ○ |

**What type of job do you primarily perform? (Check all that applies)**

- [ ] Supervising
- [ ] Monitoring
- [ ] Operating
- [ ] Intellectual and Creative

**How many hours do you usually work each day, including any overtime or extra hours?**

| Less than 6 hours | 6 to 9 hours | 9 to 12 hours | More than 12 hours |
|---|---|---|---|
| ○ | ○ | ○ | ○ |

**What is your typical work schedule throughout a week?**

- ○ Fixed work schedule (typically 8 hours per day)
- ○ Flexible work schedule (employees are able to set their own hours to some extent)
- ○ Rotating shifts (i.e., two weeks on first shift then two weeks on second shift)
- ○ Variable work schedule (multiple, changing work schedules)

**What is your usual work schedule?**

Start AM/PM [ ] ☐ Stop AM/PM [ ] ☐

**How often does your shift rotate?**

| Weekly | Bi-weekly | Monthly | Greater than monthly |
|---|---|---|---|
| ○ | ○ | ○ | ○ |

**Over the past month, how would you rate your sleep quality overall?**

| Very good | Fairly good | Fairly poor | Very Poor |
|---|---|---|---|
| ○ | ○ | ○ | ○ |

**During the past month, how long did it usually take you to fall asleep each night?**

| Less than 5 minutes | 5-15 minutes | 15-30 minutes | More than 30 minutes |
|---|---|---|---|
| ○ | ○ | ○ | ○ |

**During the past month, how many hours of actual sleep did you get at night and not time in bed?**

- ○ Less than 5 hours
- ○ 5-7 hours
- ○ 7-9 hours
- ○ More than 9 hours

**During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?**

- ○ Not during the past month
- ○ Less than once a week
- ○ Once or twice a week
- ○ Three or more times a week

**During the past month, how often have you had trouble sleeping because you . . .**

| | Not during the past month | Less than once a week | Once or twice a week | Three or more times a week |
|---|---|---|---|---|
| Cannot get to sleep within 30 minutes | ○ | ○ | ○ | ○ |
| Wake up in the middle of the night or early morning | ○ | ○ | ○ | ○ |
| Have to get up to use the bathroom | ○ | ○ | ○ | ○ |
| Cannot breathe comfortably | ○ | ○ | ○ | ○ |
| Cough or snore loudly | ○ | ○ | ○ | ○ |
| Feel too cold or too hot | ○ | ○ | ○ | ○ |
| Had bad dreams | ○ | ○ | ○ | ○ |
| Have pain | ○ | ○ | ○ | ○ |
| Other reason(s), please describe | ○ | ○ | ○ | ○ |

**Have you experienced sleep interruptions due to following reasons? (Check all that apply)**

- ☐ Children
- ☐ Pets
- ☐ Environmental factors (trains,phone calls, neighbors ...)
- ☐ No interruptions

**How often have you taken medicine to help you sleep?**

| Not during the past month | Less than once a week | Once or twice a week | Three or more times a week |
|---|---|---|---|
| ○ | ○ | ○ | ○ |

**What is your height and weight?**

(ft/in) ☐ (lbs) ☐

**Do you have any significant health problems or medical conditions?**

- ○ Yes
- ○ No

**What is your health problem?**

**Has anyone including a bed partner or roommate told you about any of the following?**

| | Not during the past month | Less than once a week | Once or twice a week | three or more times a week |
|---|---|---|---|---|
| Loud snoring | ○ | ○ | ○ | ○ |
| Long pauses between breaths while asleep | ○ | ○ | ○ | ○ |
| Legs twitching or jerking while you sleep | ○ | ○ | ○ | ○ |
| Episodes of disorientation or confusion during sleep | ○ | ○ | ○ | ○ |
| Other restlessness while you sleep; | | | | |

**On how many work days would you say "I had a good night's sleep"?**

| Every night | Almost every night (5-6 nights a week) | Usually (3-4 nights a week) | Rarely (1-3 nights a week) | Never |
|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ |

**On how many days you did not work would you say "I had a good night's sleep"?**

| Every night | Almost every night (5-6 nights a week) | Usually (3-4 nights a week) | Rarely (1-3 nights a week) | Never |
|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ |

**Have you ever experienced any of the following because you were fatigued or too sleepy?**

| | Often | Sometimes | Never | Not applicable (never sleepy) |
|---|---|---|---|---|
| Not alert enough to perform your job | ○ | ○ | ○ | ○ |
| Continue your work in a semi-automatic manner | ○ | ○ | ○ | ○ |
| Had not enough enthusiasm to get things done | ○ | ○ | ○ | ○ |
| Napping at work | ○ | ○ | ○ | ○ |
| Fallen asleep on the job | ○ | ○ | ○ | ○ |
| Missed a day of work to get more sleep | ○ | ○ | ○ | ○ |

**How long is your lunch break at work?**

| None | As I can | 30 minutes | 30-60 minutes |
|---|---|---|---|
| ○ | ○ | ○ | ○ |

**Do you get breaks during your shift?**

- ○ Yes, at set time
- ○ Yes, as I can
- ○ No

**During breaks at work, do you normally nap?**

- ○ Yes, often
- ○ Yes, some times
- ○ No

**Which of the following have you performed to stay alert at work? (Check all that apply)**

- ☐ Changing temperature
- ☐ Stretching and changing position
- ☐ Walking
- ☐ Talking to coworkers
- ☐ Listening to music
- ☐ Drinking caffeine

**How often do you use caffeine (e.g. coffee, soda, energy drinks) at work?**

- Never
- Less than once a week
- 1-4 times a week
- 4-7 times a week
- More than 7 times a week
- Several times a day

**How likely have you or any of your colleagues experienced any of the following incidents at work because of fatigue or sleepiness?**

| | Not likely | Somewhat Likely | Very Likely | Severely | I don't know |
|---|---|---|---|---|---|
| Misinterpretation | | | | | |
| Decreased memory | | | | | |
| Decreased reaction times | | | | | |
| Anxiousness | | | | | |
| Low concentration | | | | | |
| Forgetfulness | | | | | |
| Failure in required act performance | | | | | |
| Performing task at the wrong time | | | | | |
| Performing task in the wrong order | | | | | |
| Decreased attention | | | | | |
| Taking unnecessary acts | | | | | |
| Increased false alarms | | | | | |

**How often do you notice making more mistakes than usual in performing an activity because of fatigue or sleepiness?**

| | Always | Usually (several times/week) | Rarely (several times/year) | Never |
|---|---|---|---|---|
| Minor mistake (near miss) | | | | |
| Error | | | | |
| Accident (injury) | | | | |
| Serious mistakes with potential of life loss | | | | |

**How much of an impact did "not getting adequate sleep" have on the following?**

| | Major Impact | Some Impact | No Impact |
|---|---|---|---|
| Your work | | | |
| Your social life | | | |
| Your mood | | | |

**What was the most significant error you or any of your co-workers have made affecting your job performance?**

**What do you think were the major contributors to the situation?**

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