POLICE OFFICER FATIGUE: THE EFFECTS OF CONSECUTIVE NIGHT
SHIFT WORK ON POLICE OFFICER PERFORMANCE

By

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Police officers frequently work long, irregular and fatiguing shifts, including night shifts. The effects of night shift work on both waking alertness and ability to sleep during the day may result in degraded police officer performance during operational tasks such as driving and decision making, especially in ambiguous and fast-paced situations. Such decrements in performance by police officers can have catastrophic effects on officers, police departments, municipal governments, and the public through increasing the risk of accidents and injuries.

This study examined the effects of consecutive night shift work on police officer performance using a unique research design combining controlled laboratory measures of performance and police officers working actual night shifts in the field. Measures included simulated routine driving, psychomotor vigilance, and simulated deadly force decision making as well as subjective sleepiness. N=30 police patrol officers were studied on two separate occasions during their normal duty cycle: in the morning immediately following five consecutive night shifts, and at the same time in the morning following three days off duty. Mixed-effects analysis
of variance (ANOVA) revealed degraded simulated driving ($F_{1,78} = 6.78; P = 0.011$), vigilance
($F_{1,161} = 14.06; P < 0.001$), and increased subjective sleepiness ($F_{1,84} = 96.99; P < 0.001$) following
five consecutive night shifts on duty compared to three days off duty. Repeated measures
ANOVA also showed significantly different false alarm rates ($F_{1,53} = 4.82; P = 0.033$) with higher
instances of false alarms occurring following the night shift condition, and sensitivity, or ability
to detect a threat presented, ($F_{1,53} = 5.94; P = 0.018$) with increased signal sensitivity seen during
the control condition.

Police officers experienced degraded simulated driving and psychomotor vigilance,
impaired simulated deadly force decision making performance, and higher subjective sleepiness
following consecutive night shifts on duty. These results indicate that police officers are
suffering the effects of night shift work on operational performance, creating a safety risk for
themselves and the public. Additionally, the success of this study, involving combined
laboratory and field data collection, indicates that the study is a useful approach for investigating
the relationship between shift work induced fatigue and operational performance.
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Dedication

For my mother and my father.
“The primary purpose of the police is to protect life.

All policy follows from that.”

~ James J. Fyfe
CHAPTER 1: INTRODUCTION

Statement of the Problem

Police officers frequently work long, extended, and irregular shifts, a substantial proportion of which occur at night (Vila, 2000, 2006; Vila, Kenney, Morrison, & Reuland, 2000; Vila, Morrison, & Kenney, 2002). These working conditions often result in shift-work related fatigue and associated performance impairments. Shift-work related fatigue may increase the risk of on duty accidents, impair decision making in fast-paced, ambiguous situations, and affect the mood of officers (Vila, 2006). Degraded operational performance associated with shift-work related fatigue can create safety risks for police officers, as well as the communities they serve and protect.

This study breaks new ground in experimentally assessing the impact of shift-work related fatigue on police officer operational performance. Using a unique study design involving simulated job-relevant tasks, performance decrements associated with real world levels of shift-work related fatigue in actual police officers are measured in a controlled laboratory setting. Assessing the extent to which shift-work related fatigue affects operational performance is a first step towards improving the management of fatigue among police officers.

Importance of the Study

Police officers across the United States have been shown to experience high levels of fatigue. This fatigue among officers can be attributed to a multitude of factors such as shift work,
long work hours, and irregular schedules, large amounts of overtime, working second jobs, and the demands of life outside of work (Vila, 2000; Vila et al., 2000; Vila et al., 2002; Vila, 2006). A major source of police officer fatigue is the biological dysrhythmia caused by shift work, especially night shift work. Night shift work requires officers to remain awake at a time when it is natural for the body to sleep, and to sleep when it is natural for the body to be awake. This desynchronization of the biological clock to the officer’s work schedule, common among all shift workers, can lead to adverse neurobiological effects on nighttime performance and truncated sleep during the day (Durmer & Dinges, 2005). Human performance deficits and increased fatigue due to shift work can be seen in those professions are responsible for the safety, health, and security of the public (Vila, 2006) such as physicians (Barger, et al., 2005; Landrigan, et al., 2004; Lockley, et al., 2004), pilots (Van Dongen, Caldwell, & Caldwell, 2006; Rosekind et al., 1996), and military personnel (Wesensten, Belenky, & Balkin, 2005). Police officers are needed 24-hours a day, seven days a week to maintain the safety and integrity of the communities they serve and protect. The scope and power of police officers’ duties makes them a particularly problematic occupational group in terms of fatigue risk (Vila, 2006).

The duties of a police officer encompass a wide variety of tasks ranging from simple to complex performed in various situations and environments. Tasks asked of police officers include but are not limited to: confronting, and possibly arresting suspicious persons, using force (even deadly force) on community members, enforcing traffic laws (directing traffic, writing tickets, etc.), mediating disputes, assisting people in emergency situations, writing incident reports and providing a general level of security to the community. Police officers decide when and how to do many of these tasks on a day-to-day basis. Many of the most dangerous tasks they are asked to perform are done using broad discretionary power and carry grave consequences if
errors in decision making are made by the officers. In the United States, police officers are granted great discretionary power for carrying out the duties and responsibilities of their job. While large of discretionary power can lead to abuses of its use, it is fundamental to the process and execution of justice by police officers by enabling flexibility and common sense to temper police decision making (Vila, 2010).

   Specifically, two of the tasks that are performed by police officers generate concern in terms of officer and community safety: driving emergency vehicles; and decisions to use force, especially deadly force. These two tasks have the potential to lead to detrimental and catastrophic outcomes. Driving by police officers, which for many encompasses a large portion of their daily shift duration, is typically done at high speeds in highly distracting environments with expensive government owned vehicles. Decisions to use force, which are complex decisions under any circumstance, are frequently made under fast-paced ambiguous circumstances in which flexibility of thought, creativity of action, and adaption to uncertainty or unexpected events is vital to the success of the officer making the decision (Vila, 2006; Vila, 2010). These emotionally charged situations carry with them the risk that lives, property, and liberty could be lost at a given moment, and are often lost in a split second (Vila, 2006). Poor performance and impaired decision making during either of these critical job tasks can result in unintended deaths of police officers or community members, enormous monetary costs to cities, counties, departments, and communities, and broken relationships between the community and the police department.

   Many of the tasks performed on a daily basis by police officers are tasks that show sensitivity to the effects of fatigue, such as driving motor vehicles, decision making, and interacting with community members. Research indicates that driving while fatigued is very
dangerous and often results in accidents and fatalities (Åkerstedt, Philip, Capelli, & Kecklund, 2011; Horne & Reyner, 1999; Williamson et al., 2011). Given the already difficult and complex task of police driving and the increased level of distraction within a police vehicle, the effects of fatigue on driving performance may be adding to an already high risk of an accident or vehicle related fatality. Despite the declining motor vehicle fatality rate for the general public (Longthorne, Subramanian, & Chen, 2010), rates among police officers have trended upward for the past two decades (Noh, 2011) and account for roughly one-third of all police fatalities (Federal Bureau of Investigation [FBI], 2010).

Decisions to use force are already difficult and carry high consequences for officers and departments without the added effect of fatigue. Fatigue has been associated with impaired decisions making when decisions require flexibility in thought process, deal with uncertain or unexpected events, and involve using current information to overrule usual strategies (Harrison & Horne, 2000), which can impact a police officers’ decision making ability in all actions and tasks, but especially decisions to use deadly force in ambiguous situations under time pressure (Vila, 2010). Given what researchers have found and are continuing to find regarding links between cognitive processes, decision making and fatigue, night shift work induced fatigue is likely to play a major role in decisions to arrest and use deadly force, possibly increasing the already high risk of both of these job related tasks for officers.

Community-police relations have been the source of discussion for decades and remain near the center of efforts to reform policing and law enforcement policy. Positive encounters with police officers tend to foster a community opinion of trust and reliance that can be beneficial to officers, departments and community members. However, the mood of officers during community-police interactions can have an impact on the interaction in an unintended
way turning a positive interaction opportunity into a negative interaction. Maintaining consistent positive community-police interactions can be a difficult task for officers and departments especially in certain parts of the United States, a task that is only made more difficult under conditions of fatigue due to the mood effects of fatigue. Mood changes, such as increased irritability, and impatience, and reduced communication skills have been associated with high levels of fatigue (Harrison & Horne, 2000; Pilcher & Huffcutt, 1996).

Research supports the notion that performance of tasks such as driving, decision making, and effective social interactions are impacted by fatigue. Police officer operational performance is likely to be sensitive to the effects of fatigue. This study provides evidence that police officers are experiencing levels of shift work related fatigue severe enough to contribute to job relevant performance decrements. Police officers are not immune, as a group, to the effects of fatigue on performance. The impact of performance errors by police officers can have far reaching and catastrophic outcomes, possibly resulting in loss of life, and/or high costs for municipal governments and departments. Fatigue induced performance decrements can increase the safety risk for officers and community members. Fatigue among police officers must be managed in a more efficient and all-encompassing way to minimize the risk and cost of decision making errors and accidents by police officers. Standard operating procedures and departmental policies designed to incorporate sleep, shift work, fatigue, and performance research would enhance police officer fatigue management.
Framework of this Study

The purpose of this research is to explore the relationship between shift-work related fatigue and police officer operational performance. More specifically, this effort intends to provide job-relevant performance data collected in a controlled laboratory setting from actual police officers who have worked real world night patrol shifts. Decrements in police officer performance of job-relevant tasks, such as driving and decision making, can have serious implications for the safety of officers’ and the public they serve. In an attempt to expand the scholarly knowledge of the effects of police officer fatigue, this study aims to answer the question: Does shift-work related fatigue due to working consecutive night shifts impact police officer simulated real-world operational performance?

This dissertation will include the use of terms that are frequently used in various research areas but often carry differing meanings. It would be beneficial at this point to define some of those terms based on their use in this study. For the purpose of this dissertation, what is commonly referred to as fatigue, will be more specifically called shift-work related fatigue. Shift-work related fatigue will be defined as fatigue induced as a result of shift work. This study will specifically look at one type of shift-work related fatigue, consecutive night shift work. The term shift duration, within the context of this study will refer to the length in hours of a particular shift within a 24-hour period. Likewise, shift cycle will be used to describe the number of consecutive days on duty as they relate to the number of consecutive days off duty, which is also referred to as shift pattern or duty cycle.

Answering the research question requires an understanding of the literature regarding policing, fatigue, performance, and policy. This interdisciplinary literature review will be the
focus of Chapter II. First, the sleep, fatigue and performance research literature will be discussed to give a background of the research in the field of sleep and performance. This section will include a basic description of the sleep/wake cycle, followed by research on both total sleep deprivation and chronic sleep restriction also known as partial sleep deprivation. Second, shift work and performance literature will be discussed with a focus on the short term, and long term effects of shift work on health, safety, and job performance. The first two sections will provide a basic background on key issues related to sleep, shift work and performance. From this background, a discussion about fatigue among police officers will begin with a section about the sources of police officer fatigue identified in the literature. Then, the research regarding the effects of police officer fatigue on their performance, health and safety will be explored in depth. Finally, the state of current practice and policies designed to manage fatigue among police officers will be discussed to opening the door for suggestions and implications for policy in Chapter V.

Chapter III presents a detailed explanation of the research methodology and design of this interdisciplinary study. This research design takes a novel and innovative approach to addressing the research question that involves a combination of field and laboratory data collection. Discussion of the research question, hypotheses, participants, study design, data collection procedures, and operationalization of performance measures will also be included in this chapter.

Analysis and results of the data collected in the study will be presented in Chapter IV. Following discussion of the data reduction methods, a detailed description of statistical analysis involving mixed-effects analysis of variance will be provided. Mixed-effects ANOVA allows both within individual and between individual differences to be taken into account. This chapter will also describe methods of signal detection analysis be used to measure performance of some
of the decision making tasks. Closing this chapter, will be the discussion of the actual results from this study.

Chapter V, the discussion, implications for policy, and future directions of research, will begin with a short summary of the findings and how those findings relate to the research question and hypotheses laid out in the methods chapter. A discussion of the implications of these findings for criminal justice policy will follow, leading directly into ideas for future research on police officer fatigue. This chapter will finish with a discussion of the strengths and limitations of the study.
CHAPTER 2: LITERATURE REVIEW

Fatigue, a seemingly simple phenomenon experienced by every human, can result from multiple biological and social factors including, circadian rhythm, lifestyle, and task workload. More specifically, the fatigue level of an individual can result from sleep loss, time of day of wake and sleep periods, and duration and mental difficulty of the tasks. These factors can influence fatigue individually or interact with each other to have a compounding effect. However the factors interact to affect fatigue levels of humans, the consequences of fatigue can have large impacts on performance and safety.

The goal of this chapter is to provide a background in sleep, fatigue, shiftwork and the effect that these factors can have on the operational performance of workers, specifically police patrol officers. This chapter will present the literature regarding sleep, fatigue, and the effects on performance both in the laboratory and in the field setting. Following this introduction to sleep and performance, shiftwork-related fatigue, which is a specific type of work-related fatigue, will be discussed in some detail along with the effects of shiftwork-related fatigue on operational performance in various industries. Finally, policing as a particular shift working occupational group will then be explored to gain some insight into the tasks and responsibilities of police officers along with the risk that shiftwork-related fatigue can have on the operational performance of police officers. The current state of police fatigue research and attempts to manage police officer fatigue will also be presented.
Sleep, Fatigue and Performance

The human sleep-wake cycle is regulated by a circadian pacemaker in the brain that drives many of the body’s physiologic and behavioral systems (Åkerstedt, 2003; Barger, Lockley, Rajaratnam, & Landrigan, 2009; Durmer & Dinges, 2005). In a very simplified description of this cycle, there are two processes: the homeostatic process, which represents that drive for sleep, and the circadian process, which modulates the homeostatic process (Borbély, 1982). As the number of hours a human is awake increases, so does the pressure of the homeostatic drive for sleep. This increase in homeostatic drive to sleep will continue to increase as the number of hours awake increases until it reaches a threshold at which sleep is activated. During sleep, the homeostatic drive begins to decrease and once this decrease reaches another threshold, wakefulness is activated. The circadian process, a roughly 24 hour rhythm, modulates these thresholds through daily oscillations keeping humans on a 24-hour sleep-wake cycle (Czeisler et al., 1999). This endogenous cycle results in decreased alertness during the day and truncated sleep during the night which poses a challenge for those functioning on adverse schedules (Van Dongen & Dinges, 2005).

It has been well-stated in research that fatigue can lead to decreased performance. Early studies indicated that sleep loss is associated with decreases in reaction time and vigilance, as well as cognitive distortions and changes in affect (Krueger, 1989). Laboratory based studies have shown that both total sleep deprivation and chronic or partial sleep restriction for an extended period of time can result in degraded performance. In a meta-analytic review of the subject, Pilcher and Huffcutt (1996) found that sleep deprivation has an effect on human motor and cognitive performance, as well as mood. Reaction times on simple vigilance or attention
tasks is one of the most commonly studied performance deficits associated with sleep
deprivation or sleep loss (Williamson et al., 2011). Sleep deprivation is also associated with
slower reaction times and increased incidents of complete lapses of attention (Killgore, 2011;
Lim & Dinges, 2008). Additionally, sleep deprivation has been shown to result in decrements
during working memory tasks that yield deficits in accuracy and time of responses (Killgore,
2011; Lim & Dinges, 2010). Total sleep deprivation has also been shown to have a negative
impact on other high complexity tasks such as verbal learning, serial subtraction, and divided
attention tasks (Williamson et al., 2011). Harrison and Horne (2000) indicate that sleep
deprivation can impair decision making when such decisions involve the unexpected, innovative
thinking, plan revising, distraction from secondary tasks or the environment, and effective
communication. In one landmark study comparing impairment from alcohol intoxication
(measured as blood alcohol concentration, or BAC) to impairment from total sleep deprivation,
Dawson and Reid (1997) found that cognitive deficits of individuals sleep deprived for 24
consecutive hours were equivalent to those seen in individuals with a BAC of 0.10%, which is
higher than the current legal limit in the United States. This is a brief description of the
laboratory research on performance deficits associated with total sleep deprivation. Consensus
among research remains that sleep deprivation can manifest itself in performance decrements.

Results from studies involving partial sleep restriction conducted in the laboratory reveal
similar decrements in performance. In fact, one review suggested that partial sleep deprivation
has more of an effect on cognitive performance and mood than long-term or short-term total
sleep deprivation (Pilcher & Huffcutt, 1996). Additionally, studies conducted by Belenky et al.
(2003) and Van Dongen, Maislin, Mullington, and Dinges (2003) suggested that cognitive
performance decrements associated with partial sleep deprivation accumulate over successive
days of sleep restriction and can rise to levels equivalent to those seen in total sleep deprivation. Specifically, Van Dongen et al. (2003) found that deficits in performance seen following 14 days of chronic sleep restriction of 4-hours time in bed equate to levels seen following two nights of total sleep deprivation, and two weeks of chronic restriction of 6-hours time in bed leads to deficits equivalent to one night of total sleep deprivation. These results indicate performance decrements due to chronic sleep restriction appear in a sleep dose-dependent manner (Belenky, et al., 2003; Van Dongen et al., 2003). Thus, as indicated in the research on the subject, chronic or partial sleep deprivation can have similar if not magnified impacts on human performance in terms of decision making, vigilance, alertness, and overall mood.

There is also a substantial body of research exploring the effects of sleep deprivation and fatigue on motor vehicle accidents. Fatigue has been found to play a large role in motor vehicle accidents and accident risk (Horne & Reyner, 1995, 1999; Williamson et al., 2011). Research indicates that sleep deprivation among shift workers, truck drivers, medical residents and airline pilots is associated with increases in accident risk and incidents involving near misses (Durmer & Dinges, 2005). Night shift work has been a factor that makes people increasingly vulnerable to sleep related vehicle accidents (Horne & Reyner, 1999), with night driving or no sleep during the night prior to driving inducing increased incidents and accidents (Åkerstedt et al., 2011). In a simulated driving study, Åkerstedt, Peters, Anund, and Kecklund (2005) found that post night shift driving leads to impaired alertness and driving performance. Falling asleep at the wheel has been one factor tied to sleep related vehicle accidents (Horne & Reyner, 1999). Simulated driving performance under sleep deprived conditions has also been compared to impairment associated with blood alcohol concentrations showing impairment due to sleep deprivation at similar levels of impairment of BAC’s over the legal limit (Arnedt, Wilde, Munt, & Maclean,
2001). Consensus among researchers is that driving under conditions of fatigue can be very dangerous, and result in increased vehicle accidents and accident risk.

Sleep and fatigue have serious implications for occupational performance and safety. Fatigue has been implicated in contributing to multiple catastrophic on the job accidents including: Exxon Valdez (Åkerstedt et al., 2011), Chernobyl, Three Mile Island, and the Challenger (Mitler et al., 1988). Many of these events were further tied not only to the general concept of fatigue, but the consequences of night work or extended/long work hours. The catastrophic nature of these events and the association of fatigue, sleepiness or work schedules combined with an increased understanding of the effects of fatigue on performance have turned the focus of some research toward workers, scheduling, and fatigue.

Sleep is a complicated issue, and much remains unknown about it. What we do know is that sleep loss and fatigue can lead to performance deficits such as impaired driving, and decision making, slower reaction times, decreased vigilance and changes in mood and affect. These types of deficits could be detrimental to those working in safety sensitive positions or whom we place a substantial amount of responsibility for keeping community members and communities safe (Barger et al., 2009). These are also the types of occupations that require shift work which contributes in its own ways to fatigue and can have serious implications the safety of workers and the general public. The next section will provide a background in the sleep, shift work and performance literature.
Shiftwork and Performance

Understanding of the effects of sleep loss, fatigue, and performance has focused concern and research toward workers in fields that require extended and irregular work periods. There is a growing body of research exploring the impact of specific types of fatigue, such as shiftwork, on occupational performance, accident risk, human errors, and safety among workers. Shiftwork can cause fatigue for several reasons such as time of day, duration of prior sleep, and time on task. The effects of these kinds of fatigue on safety and performance of operational tasks can be far reaching. People working shift work, especially those working at night, may be at an increased risk of operational injuries and accidents as well as short and long term health consequences from issues related to sleep, sleep loss and fatigue induced by shift work. Additionally, most occupations using shift work schedules, such as doctors, pilots, police officers, firefighters, and emergency responders, require such schedules because there is a need to have workers on duty 24-hours a day for the safety of community members. The high risk of accidents and fatalities to shift workers because of sleep and fatigue related issues is not something that can be decreased by not working when it is unsafe to work. Fatigue among shift workers, then, must be managed through hours of service regulations and better scheduling tools that rely on for the research on accident risk and shift work induced fatigue. This section will start with a brief description of why shiftwork and scheduling can lead to increased levels of fatigue and then discuss the safety and performance implications of shiftwork-related fatigue.

Sleep, sleep loss and fatigue and the subsequent impact they have on performance, as mentioned in the previous section, can be a function of time of day, duration of prior sleep, quality of prior sleep, total time awake, and time on task. Shift workers experience the effects of
these kinds of fatigue but are particularly sensitive to the time of day effects on both alertness and sleep. One of the most significant ways that shift work can induce fatigue in humans is through circadian misalignment, or a disruption of the natural biological sleep/wake rhythms. Shift work typically requires alertness at times of the day in which it is natural to sleep, as well as sleep at times of the day when it is natural to be awake (Van Dongen & Dinges, 2005). Circadian misalignment can create issues for performance and sleep because of the time of day (within a 24-hour period) in which activities are taking place. This misalignment of the body’s natural rhythms, commonly seen in night shift workers, leads to performance decrements due to decreased levels of alertness as well as truncated sleep usually resulting in reduced sleep duration (Åkerstedt, 2003; Barger et al., 2009; Van Dongen & Dinges, 2005). The natural 24-hour biological clock found in all humans causes additional problems in terms of fatigue and performance for those attempting to work out of phase with a normal diurnal day. Especially in safety sensitive occupations, decreased alertness combined with short sleep durations can have an impact on job performance that leads to increased risk to workers and the public.

One of the major complaints from shift working populations is diminished sleep or excessive daytime sleepiness (Costa, 2003). Circadian misalignment can lead to shorter sleep durations as well as diminished sleep quality due to the nature of daytime sleep. Sleeping during the day, which is common for shift workers, results in shorter than normal sleep durations (Åkerstedt, 2003; Knauth et al., 1980). Åkerstedt (2003) estimated these sleep durations to result in nearly a 2- to 4-hour loss of sleep per day. Shorter sleep duration is linked to reports of disturbed sleep among shift working populations, with high levels of complaints of disturbed sleep coming from night shift workers (Åkerstedt, 2003; Åkerstedt, Fredlund, Gillberg, & Jansson, 2002b; Costa, 1996, 2003; Knauth et al., 1980). Common sleep disturbances seen in
shift workers include frequent awakenings, restlessness during sleep and waking up feeling tired. Disturbed sleep can have an effect on daytime sleepiness as well as cognitive functioning during the next day. Short sleep duration and daytime sleepiness have been linked with poor job performance and increased risk of drowsy driving (Scott et al., 2007), which will be discussed in more detail later in this section. Shift work can induce circadian misalignment that can lead to decreased sleep durations and disturbed sleep which may be result in an increased risk of injuries and accidents due to decreased alertness from shift work induced fatigue.

While some may argue that those working permanent night shifts will adjust to there schedules, research indicates that it is rare for shift workers to make a complete adjustment to their respective shifts for various biological and social reasons (Åkerstedt, 2003; Costa, 1996). The general biology behind circadian misalignment makes an adjustment to shift work difficult because of the natural decrease in alertness during the night and truncated sleep during the day. Additionally, the social nature of human beings creates responsibilities for most shift workers trying to sleep during the day. Family and domestic responsibilities, doctor’s appointments, and trying to function socially in a diurnal world will cut into the day time sleep opportunity for most shift workers. Adjustments to shift work, even when shifts are permanent, are difficult and extremely rare. Thus, circadian misalignment can have a significant impact on the performance and life of a shift worker often times resulting in safety and health concerns.

Research shows that shiftwork is associated with increased accident and injury risk (Åkerstedt, Fredlund, Gillberg, & Jansson, 2002a; Åkerstedt et al., 2011). It has been indicated in research that night shift work can increase the risk of automobile accidents (Horne & Reyner, 1999), truck accidents, and train crashes (Milia et al., 2011). In some of the most influential work on the subject, Folkard and Tucker (2003) concluded that relative injury and accident risk
increases over the course of successive night shifts and increases as the number of hours on shift increases. These trends in accident and injury risk have also been documented in other research (Åkerstedt, Ingre, Broman, & Kecklund, 2008; Folkard, 2008a; Williamson et al., 2011). General injury rates have also been found to be highest at night (Folkard, 2008a), with injury risk also being highest at night compared to other shifts (Folkard, Lombardi, & Spencer, 2006; Folkard & Tucker, 2003). There has also been documentation in the research showing that most night shift workers admit to involuntarily falling asleep during their shift (Åkerstedt et al. 2008). Involuntary sleeping can increase the risk for workers as well as contribute to decreased levels of performance.

An interesting trend in accident risk that has been discussed in the research is that it appears that relative risk decreases over the course of a night shift, with the maximum risk landing around midnight (Folkard et al., 2006; Williamson et al., 2011). While there is an initial increase in risk from the first to the second hour of a night shift, risk begins to decrease in an almost linear fashion (Folkard et al., 2006; Folkard & Tucker, 2003). This implies that there may be some time of day effects, or circadian rhythm seen in accident or injury risk of night shift workers. Predictive models or prior assumptions on the subject conversely imply that the performance would continue to decrease throughout a night shift resulting in increased risk.

The effects of shift work and work schedules on specific aspects of operational performance among various occupational groups have also been explored. In one study of shift workers, it was found that male shift workers had lower levels of cognitive performance, with decreased performance on a memory task over the course of a night shift when compared to those who had never been exposed to shiftwork (Rouch, Wild, Ansiu, Marquie, 2005). In a meta-analysis conducted by Philibert (2005), it was found that sleep deprivation negatively
impacted cognitive functioning, working memory, vigilance, fine motor skill, and mood of physicians. Percutaneous exposures due to lacerations and needle sticks appear to be associated to fatigue or decreased vigilance in self-reports from physicians and appear to be more frequent during the night shifts (Ayas et al., 2006). Research has also shown that medical residents working extended or on-call shifts were getting less sleep and suffered changes in working memory capacity (Gohar et al., 2009), as well as experiencing impaired reaction times and decreased vigilance (Saxena & George, 2005). Drowsy driving episodes among nurses have also been linked to shorter sleep durations and working at night (Scott et al., 2007). Residents working traditional extended shifts were shown to have cognitive and driving performance equivalent to impairment of a blood alcohol content of 0.04% or 0.05% (Arnedt, Owens, Crouch, Stahl, & Carskadon, 2005). Additionally, the risk of motor vehicle crashes among medical residents was found to be increased 9.1% per month that residents were working extended shifts (Barger et al., 2005). Finally, on the positive side, eliminating extended work hours for medical residents resulted in increased sleep, decreased attentional failures, and reductions in medical error rates (Landrigan et al., 2004; Lockley et al., 2004). It can be implied from the research among medical professionals that sleep and fatigue due to extended or adverse work schedules may be contributing to decreased safety, in terms of increased injury exposure and motor vehicle crash risk, as well as decreased performance possibly resulting in on the job errors. The link between shift work, particularly night shift work, and accidents and injuries is widely seen in the research on shift work, performance, and risk. Shift workers, in general, suffer from fatigue and short sleep durations which increase the risk of on the job accidents and injuries.

Shift work can also have an impact on workers’ overall health and well-being. Shiftwork is associated with higher levels of sleep disorders than the general public. While shiftwork is not
listed or directly associated as a cause of sleep disorders, research shows that shift workers have high levels of reported insomnia and obstructive sleep apnea, as well as shift-work disorder (Barger et al., 2009). One estimate lists the prevalence of sleep disorders among shift workers between 60-80% of all workers (Barger et al., 2009). Research also indicates that shift workers are subject to digestive disturbances, and increased anxiety and irritability (Costa, 1996, 2003). The effects of shift work have also lead to the identification of circadian rhythm disorders such as shiftwork disorder. Additionally, shiftwork has been linked to health effects such as increased obesity risk, gastric ulcers, cardiovascular disease and cancers (Barger et al., 2009). While the long-term consequences of shift work are less well understood, shift workers appear to be at an increased risk for several health conditions that could be a function of their work schedules.

Shift work, while a necessity for many safety sensitive professions causes circadian misalignment resulting in decreased alertness during the night, and truncated sleep during the day. The effects of shift-work induced fatigue on performance can create safety risks for workers and the public through increased risk of accidents and injuries of workers. Shift work may also have an impact on the overall health of workers.

Sources of Police Officer Fatigue

Research indicates that police officers are a tired occupational group (Vila, 1996, 2000, 2006; Vila et al., 2000; Vila et al., 2002). It is highly likely that the nature of police work creates an operational environment that induces high levels of fatigue or sleepiness. One of the major reasons for these higher levels of fatigue among police officers is because police work involves shift work. The necessity to have police officers on duty 24 hours a day, seven days a week to maintain public safety and security requires officers to work long, often extended, shifts at
adverse times of the day which can lead to increased safety risks. Shift work, especially night shift work, requires officers to be awake and functioning at times when their bodies may be struggling to stay awake (Vila et al., 2002). Additionally, shift work will affect the amount of sleep an officer is able to get during the day. Research on other shift workers shows that daytime sleep duration is decreased for night shift workers and that social and family responsibilities can interfere with possible sleep opportunities of during the day. The general biology of sleep will induce some fatigue in officers, especially those working night shifts.

Shift work, especially night shift work, can lead to extended wake periods or truncated sleep due to off-duty, family, and social responsibilities of officers. Off-duty responsibilities of officers such as daytime court appearances and in-service training require officers to either remain awake or reduce their sleep in order to participate in day time activities (Vila et al., 2002). One study found using police department interviews that off-duty court appearance created the most frustration and complication for officers and managers due to the lack of control in scheduling such appearances (Senjo, 2010; Senjo & Dhungana, 2009). Similarly, family and social responsibilities of officers such as childcare, doctor’s appointments, and domestic duties can have the same impact on sleep duration or wake period during the day. The extended wake periods and sleep loss due to added daytime responsibilities can affect performance in a negative way leading to safety risks for officers.

Police administrators and departments have almost complete discretion in creating, choosing and implementing work schedules and work hours for officers (Amendola, Weisburd, Hamilton, Jones & Slipka, 2011). Other industries that involve shift work among safety sensitive professions have detailed hours-of-service regulations, and standard scheduling practices to attempt to increase the safety of their workers (Vila, 2000). Police departments most commonly
use eight-, ten- and twelve-hour shift durations (Barger et al, 2009), with one study reporting that 48% of officers in their sample work 8-10 hour durations and 31% work 11-13 hour durations (Rajaratnam et al., 2011). There is also some variation in duty cycles, or consecutive days on duty, as well as in shift schedule or whether shifts are permanent, rotating or fixed (Barger et al., 2009). The nature of discretion in scheduling among police departments creates a challenge for researchers attempting to gather data in the field because the variability makes comparing departments difficult. This could provide a possible explanation for the low numbers of high quality studies dealing with police fatigue and operational performance.

Another contributing factor to the fatigue level of officers may be short sleep durations, which can be a function of shiftwork. Research also generally agrees that police officers are getting less than the recommended eight hours of sleep a night. It has been suggested that eight hours of sleep a night is generally required to maintain cognitive function (Belenky et al., 1998). In the most recent study, Charles, Andrew, Violanti, Fekedulegn, and Burchfiel (2011) determined that 11% of officers surveyed were getting at least eight hours of sleep a night while close to 70% of officers were getting six hours of sleep or less a night. Another study conducted by Vila et al. (2000) indicated that the average amount of sleep police officers surveyed were reporting was 6:37 hours with only 17% of officers getting eight or more hours, 30% of officers getting between seven and eight hours, 34% of officers getting between six and seven hours, and 18% of officers getting less than six hours of sleep per night (Vila, 2000; Vila et al., 2000). Research that examined sleep per night by type of shift using survey data show that officers working morning shifts get roughly six hours of sleep a night, while those working evening shifts and those working night shifts get roughly between seven and eight, and between five and six hours of sleep a night, respectively (Eriksen & Kecklund, 2007). In another recent study by
Neylan et al. (2010), it was found using actigraphy that sampled officers slept on average 6:15 minutes a night. The final study that indicated total sleep time of police officers showed that officers slept between 7:21 and 7:52 hours per night depending on shift duration (Amendola et al., 2011). Generally speaking, all of these studies with the exception of the work by Amendola et al. (2011) indicate that a large percentage of police officers are getting six or less hours of sleep a night. It could be said that it is not uncommon for police officers to have extended wake periods of more than 17 hours, a wake period in which performance is degraded to equal that of impairment from a BAC of 0.05% (Dawson & Reid, 1997). Based on the research regarding police officer sleep duration, it is likely that officers are not getting adequate sleep, which could be contributing to fatigue and on the job performance errors.

Research indicates that police officers are getting a decreased quality of sleep and reporting increased levels of subjective sleepiness. Vila (1996) revealed that police officers on average are scoring twice as high as the general public on the Pittsburg Sleep Quality Index (PSQI), a well-validated questionnaire used to diagnose sleep disorders (Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989). Similar results from another more recent study indicate that police officers are getting significantly high scores on the PSQI when compared to the control group (Neylan et al., 2002). Higher scores on the PSQI are associated lower quality of sleep as well as increased sleep disturbances (Buysse et al., 1989). Research among officers also indicates that nearly 14% of those surveyed reported being always or usually tired at the being of their shifts with nearly 16% reported having trouble staying awake while driving, eating, or during social activities (Vila et al., 2002). These results are in agreement with other research indicating high levels of officer reported problems with fatigue (Cochrane, 2001). Charles, Burchfiel, Fekedulegn, Vila, and Violanti (2007) report a high prevalence of police officers reporting being
tired upon waking. Shift work among officers has also been associated with complaints about sleep as well as a reduced quality of sleep (Gerber, Hartmann, Brand, Holsboer-Trachsler & Puhse, 2010). While no difference in sleep quality was found between shift lengths, research has found that officers working 12 hour shifts experience higher levels of reported sleepiness when compared to officers working 8-hour shifts (Amendola et al., 2011). Thus in addition to inadequate sleep durations, police officers may also be getting a decreased quality of sleep which could be contributing to the high levels of police officer fatigue.

High levels of sleep disorders are also prevalent among police officers as an occupational group. The most recent study on the subject found that 40% of police officers sampled screened positive for at least one sleep disorder, with obstructive sleep apnea accounting for 34% of the sample of officers that screened positive (Rajaratnam et al., 2011). These results were consistent with prior findings by the same research group that indicated 38% of officers possibly having at least one sleep disorder, with an obstructive sleep apnea prevalence of 35% (Rajaratnam, Barger, Lockely, 2007). Additionally, the previously mentioned high scores on the PSQI among officers found by Vila (1996) and Neylan et al. (2002) while not diagnostic indicate that officers are at high risk for having a sleep disorder. While not indicating the prevalence values of sleep disorder among a sample of police officers, Amendola et al. (2011) found that there were no differences in rates of sleep disorders when compared across three shift durations. Sleep disorders can lead to decreased sleep duration and decreased quality of sleep, which can impact waking performance. There is some association in the research about sleep disorders and performance, particularly obstructive sleep apnea and driving, showing decreased driving performance in patients with obstructive sleep apnea (Williamson et al., 2011). The high prevalence of sleep disorders among police officers could be contributing to the high levels of fatigue among
officers. More importantly, sleep disorders among police officers could be contributing to an increased risk of injuries and accidents—creating safety concerns for officers and the public.

It is also very common for police officers to work large amounts of overtime, extended shifts and/or working second jobs (Senjo, 2010; Senjo & Dhungana, 2009; Senjo & Heward, 2007; Vila, 2000, 2006; Vila et al., 2002; Vila et al., 2000), which can add to already high levels of fatigue. It has been seen in the research on the subject that officers work large amounts of overtime to compensate for low salaries, sick co-workers, and demands for service (Vila, 2000, 2006; Vila et al., 2002; Vila et al., 2000). Research indicates that the trend in overtime among large urban departments ranges from 15 and 40 hours of overtime in a one month period (Vila, 2000; Vila et al., 2002; Vila & Taiji, 1999). Toward the extreme end of the spectrum of overtime hours a month, there are some officers who work nearly 80 hours of overtime per month in addition to 40-50 hour work weeks (Vila et al., 2002). An assessment of overtime hours taken among a group of officers reported that officers working 8-hour shifts were working significantly more overtime when compared to officers working 10- and 12-hour shifts (Amendola et al., 2011). This overtime and moonlighting (secondary employment) can lead to increased fatigue by increasing the number of hours officers are working in a row, cutting into sleep opportunities necessary for recovering from long work hours, and disrupt currently kept-to schedules to interact with sleep when it comes (Vila, 2010). Overtime, extended shifts and second jobs among police officers could be contributing to their fatigue levels.

There appears to be no argument within the research community that police officers as an occupational group experience high levels of fatigue. This fatigue could be a function of the nature of police work requiring shift work, short sleep durations, extended wake periods, decreased quality of sleep, high prevalence of sleep disorders, extended and irregular shifts, and
or large amounts of overtime. It is also possible that all of these things are contributing together to create high levels of police officers fatigue. Regardless of how police officers are getting these high levels of fatigue, it is quite possible that these high levels of fatigue are leading to decreased operational performance in terms of driving, decision making, and interacting with community members. Given the already difficult nature of police work and the impact that officers have on society as a whole, fatigue induced performance decrements can have catastrophic effects for officers, departments, municipal governments, and the public.

Effects of Police Fatigue on Performance, Safety and Health

Very few studies to date have explored the topic of the effects of police officer fatigue on performance, accidents, or on-the-job errors. While the implications of research in other fields leads to some major implications about the effect fatigue could have on officers performance, objective data collection on such performance is quite limited. Recent research by Neylan et al. (2010) exploring the relationship between psychomotor vigilance performance and prior night sleep duration among police academy recruits reported that the probability of a lapse of attention on the PVT decreased by almost 4% per additional hour of sleep on the prior night. Decreased median reaction times on the PVT were also associated with longer prior night sleep durations (Neylan et al., 2010). Rajaratnam et al. (2011) found that officers who screened positive for sleep disorders were more likely to make a serious administrative error, fall asleep while driving, or make another error or safety violation as well as exhibit uncontrolled anger toward a suspect, increased levels of absenteeism, or fall asleep during meetings.
In contrast to most of the previous research, one of the most recent studies conducted by Amendola et al. (2011) found no difference in performance or safety of police officers when comparing officer performance across three different shift durations, but indicated that 12-hours shifts resulted in lower levels of subjectively reported alertness when compared to 8-hour shifts. However, these differences in alertness were not seen in objective measurements taken using the psychomotor vigilance task administered during the study. Performance was assessed using a computerized desktop driving simulator, a shooting performance assessment, a simulated interpersonal interaction as well as reported self-initiated activity. However, this study employed limited objective measurement of police officer performance, focusing mostly on subjective and survey data from officers. It also appeared that the goal of the study was to find an adequate shift type for officers when a more important question is what types of decrements in job performance are induced by police officer fatigue.

A large portion of the research on police officer fatigue employs survey data measuring self-report sleep/wake periods, job stress, overtime, accidents, and injuries. Few studies have looked at objective performance data such as psychomotor vigilance (Amendola et al., 2010; Neylan et al., 2002, 2010) or driving performance (Amendola et al., 2010). Implications stemming from sleep research and research conducted in other industries when applied to the occupation of policing lead one to speculate about the possible operational performance deficits police officers may experience under conditions of fatigue. Tasks, such as driving and decision making show performance decrements induced by fatigue. Mood has also been associated with changes in fatigued subjects.

Police officers spend a significant amount of time during their shift driving motor vehicles. As already indicated, driving risk and motor vehicle accidents are highly associated
with fatigue (Horne & Reyner, 1995, 1999). Additionally, research indicates that 85% of police officers have reported driving on the job while drowsy (Vila, 2000). Interestingly, motor vehicle crashes account for more than one-third of all police officers fatalities (FBI, 2010). More specifically from 2000 to 2010, motor vehicle crashes were responsible for 37% of line-of-duty deaths of police officers in the United States. Rates for motor vehicle related fatalities among police officers have also trended upward for the past two decades (FBI, 2010), while similar rates for the general public have been declining (Longthorne et al., 2010). In a recent report by the National Highway Transportation Safety Administration (NHTSA) exploring the characteristics of police officer fatalities in motor vehicle accidents, it was reported that 42% of fatal crashes involving police officers occur between midnight and 08:00 (Noy, 2011), despite the fact that less than one-third of police officers work night shifts. While many may attribute the higher rates of police officer motor vehicle fatalities to pursuit driving by police officers chasing suspects, the collision characteristics for these fatal accidents indicated that most officers are colliding with other vehicles and fixed objects due to lane deviation or excessive speeds for the roadway during routine driving (Noy, 2011). With research indicating that fatigue is commonly a factor in traffic accidents (Horne & Reyner, 1999), and night driving leads to increased risks of accidents (Åkerstedt et al., 2005) combined with the research indicating that night shift workers, specifically in the medical field, report drowsy driving and falling asleep at the wheel (Barger et al., 2009; Scott et al., 2007), there is good indication that police officers, especially those working night shifts may be suffering the consequences of fatigue on driving performance. Night shift work may be a possible explanation for the high rates and upward trend of motor vehicle related fatalities among police officers. Thus, it is very possible that police
officers suffer the effects of shift work induced fatigue on driving performance, a common job related task.

Police and community member encounters can also suffer the ill effects of performance degradation induced by fatigue in terms of general decision making by police officers. Police officers are asked to make difficult decisions in variable and complex situations that can be very dangerous. On the other hand, police officers have enormous amounts of discretion and autonomy for on the job decision making which opens the door for misuse of power. According to Federal Bureau of Investigation statistics (2010), 1259 police officers in the United States have been killed in the line of duty from 2000-2010. Felonious killings of police officers account for roughly 43% of those deaths over the same time period. Interestingly, 43% of the felonious killings occurred between the hours of 16:01 and midnight. Although the shift that officers were working when these deaths occurred is not known, it appears the time period would include officers getting off of day shifts, in the middle of swing or afternoon shifts, and those starting night shifts. While fatigue works very differently in all of those shift possibilities, given the high level of police officer fatigue across the range of shifts, it is highly likely that fatigue could have contributed to some of these line-of-duty deaths of police officers. More important than speculating the extent to which fatigue may have played a role in officer’s deaths, the statistics regarding line-of-duty deaths due to felonious assaults bring to light the ever present danger that police officers face every day. Police officers have dozens of encounters with community members during each shift and each interaction carries with it the possibility of serious injury or death (Vila, 2006). Policing rarely happens in a simple, clear-cut, all-or-nothing manner (Vila, 2010), which can have an impact of officer decision making. Safety for the officers themselves and the community members they are serving must always be at the forefront of a police
officer’s mind when encountering community members. Vila (2010) stated decisions to use force often happen in fluid, ambiguous, and emotionally charged situations in which over the course of a split second property, liberty and even life can be lost. These difficult and complex decisions to use force require quick, flexible, and creative decision making combined with higher level problem solving and information processing. Decision making research shows that under fatigued conditions decisions involving unexpected situations, and innovative thinking are impaired (Harrison & Horne, 2000). Additionally, Killgore (2007) indicated fatigue may contribute to hasty moral decisions and riskier decision making behavior. Both of these types of performance decrements seen in fatigued conditions can have serious implications for police officer and public safety.

The other side of the issue regarding police officer decision making relates to the amount and possible misuse of discretion. When interacting with community members, especially suspicious persons, officers make decisions about whom to talk with, whom to arrest, and when to use force; most of these decisions happen in highly variable environments. In order to provide the necessary flexibility for police officers to make decisions in highly variable situations in which they find themselves, large amounts of discretion are granted to each police office in carrying out their duties (Vila, 2010). While safety is one of the main concerns for police officers and administrators, the proper use of discretion by police officers is vital in determining the strength of policing as a function in our democratic society and should be used in a manner that is efficient but most importantly fair and effective (Goldstein, 1967). The improper use and/or abuse of discretion can result in injustice and corruption (Vila, 2010). Police officers, who are acting on the authority of the state or city, are the only community members authorized to use deadly force on another community member in their given jurisdiction. This ability to take a life
and the decision making process that accompanies it magnifies the impact of improper decisions and misused of discretion. Discretion or decision making by police officers becomes a highly publicized and political issue due to the short term and long term consequences of such decisions by police officers. Police officers who are fatigued may be experiencing impaired decision making that could contribute to abuse of authority and discretion.

General interaction with community members during their shift can also be impacted by fatigue creating a mode for changing the public opinion of police officers in the community in a positive or negative manner. Each time a police officer interacts with a member in the community, they have an opportunity to leave that person with a positive account or memory of interacting with the community’s police department. Police-citizen encounters also have the potential to create negative opinions of the police officers that linger for years and even decades based on the decisions made by officers. Additionally, efforts such as community policing that focus on police and citizen interactions to promote trust in police officers and departments can suffer greatly from negative police-citizen encounters in which mood would play a large role.

Fatigue has been linked to irritability and anger and general negative affect. Mood has been shown in research to be something that is sensitive to fatigue, especially chronic sleep restriction (Pilcher & Huffcutt, 1996).

Sleep and fatigue among police officers could also be contributing to low levels of overall health and well-being. Research indicates that police officers have higher cholesterol levels, pulse rates, and diastolic blood pressure when compared to the general public (Violanti et al., 2009). These findings appear to be consistent with the research that has been conducted on shiftwork and health which indicated that several health problems are associated with shiftwork (Costa, 1996, 2003; Barger et al., 2009). Additionally, research has also found that police
officers experience higher mortality rates due to health problems when compared to a non-law enforcement control group (Violanti et al., 2009). Specifically, Charles et al. (2011) found sleep durations of less than five hours and greater than 8 hours to be associated with higher leptin levels among police officers. A finding that leads support to the implication that sleep duration may contribute in some manner to obesity-related conditions (Charles et al., 2011). Fatigue and shift work may be contributing to high levels of health problems seen among police officers.

**Summary**

Research regarding police officer fatigue shows that fatigue among officers is highly prevalent. Based on the laboratory results and results from other industries, it is likely that police officers are working in highly fatigued states that could be contributing to performance degradation. Barger and colleagues imply, police officers working night shifts may suffer the effects of circadian misalignment, total and chronic sleep deprivation and cumulative sleep debt on performance and alertness resulting in more accidents, and poor decision making (Barger et al., 2009). Police officers may experience increased levels of fatigue and/or sleepiness due to the shift-working nature of their work schedules. This increased fatigue is likely to impact the operational performance of officers, especially those working night shifts, possibly resulting in increased vehicle accidents and fatality rates among police officers. Police officer fatigue due to extended work hours and shift work could be causing impairment levels close to those seen in people impaired near or equal to the legal limit for blood alcohol concentration. Based on research, there is also reason to believe that decision making, especially in fast-paced ambiguous situations is degraded under conditions of fatigue, implying that decisions to arrest and use force
may be altered among fatigue police officers. Police officers’ mood during police-citizen interactions can impact the reputation of officers and departments within the community and have lasting effects on the relationship between officers and community members.

Police officers are doing already risky tasks, under conditions in which high levels of fatigue are highly probable, which increases the risks of accidents or injuries. Accidents and injuries of police officers due to the nature of their work have far reaching effects for cities, communities, and fellow police officers.
CHAPTER 3: METHODOLOGY AND RESEARCH DESIGN

Research Question

As indicated in the literature and prior research on police officer fatigue, police officers are a highly fatigued, shift-working occupational group. Fatigue, which has been shown to degrade many cognitive processes as well as alertness, may be having a significant impact on the ability of police officers to perform job-relevant tasks in a safe and efficient manner. To explore this issue in more depth using experimental data collection, this study set out to answer the following broad research question: Does shift-work related fatigue due to working consecutive night shifts affect police officer simulated operational performance?

For the purpose of this study, simulated operational performance was measured using specific job-relevant tasks. While not all job-relevant tasks are explored in this study, two of the major tasks police officers conduct during the execution of their duties, driving and deadly force decision making, were simulated in this study. These tasks were chosen because errors in performance can have catastrophic effects felt by individual officers, entire departments, and the communities in which they occur. Errors in performance in either of these tasks can result in loss of life and decreased public safety, making them important tasks to determine the effects of fatigue. This study defined simulated operational performance to include: simulated driving, psychomotor vigilance, and simulated deadly force decision making. Subjective level of self-reported sleepiness was also measured.

With a more specific definition of simulated operational performance, the research question considered in this study can be operationalized as: Does shift-work related fatigue due
to working consecutive night shifts affect simulated driving, psychomotor vigilance, and/or simulated deadly force decision making performance among police officers?

Hypotheses

The detailed research question was then developed into a set of hypotheses explored by this research. The following null hypothesis, derived from the research question was used in this study:

\[ H_0 = \text{There is no difference in psychomotor vigilance, simulated driving, or simulated deadly force decision making performance among police officers following five consecutive night shifts compared to after three consecutive days off duty.} \]

From this null hypothesis, the four following alternative hypotheses were tested in this study design:

\[ H_1 = \text{Simulated driving performance of officers is worse following five consecutive night shifts on duty when compared to after three consecutive days off duty.} \]

\[ H_2 = \text{Psychomotor vigilance performance of officers is degraded following five consecutive night shifts on duty when compared to after three consecutive days off duty.} \]

\[ H_3 = \text{Subjective sleepiness of officers is higher following five consecutive night shifts on duty when compared to after three consecutive days off duty.} \]
$H_4 =$ Simulated deadly force decision making performance of
officers is degraded following five consecutive night shifts
on duty when compared to after three consecutive days off
duty.

These four alternative hypotheses served as the basis for the statistical analyses portion of this
study, which will be described in more detail in a later section of this chapter (see Table 3).

**Subjects**

Healthy police patrol officers were recruited to participate in this repeated measures study
design. All officers were recruited from a single police department in the state of Washington
using flyers distributed during shift roll calls. Inclusion in the study required officers to be fit for
duty based on their department’s standards. Additionally, only officers working night shift patrol
assignments beginning between 19:00 and 20:00 were eligible to participate. Participation in the
study was voluntary and officers were paid for their participation at an hourly rate. Due to the
sensitive nature of the data collected and the occupational group characteristics of the subjects, a
National Institute of Health (NIH) Certificate of Confidentiality was obtained to protect all data
collected in this study. All officers had the right to withdraw from participation at any point
without repercussions and would be compensated for all time served prior to withdrawing from
the study.
A total of 30 officers were run through this repeated measures study design. However, one subjects’ data were excluded in its entirety due to a deviation in the study procedure involving consumption of caffeine immediately prior to testing session. N=29 police officers’ data were used in the analyses. Of the group of officers, 27 were males while 2 were females. All were healthy and fit for duty based on their department’s standards. Mean age of the officers who participated was 37 years old (± 6 years) with a range of 28 years old to 49 years old. All officers had a minimum level of education equivalent to a high school diploma with 41% (12 officers total) having completed two years of college, and 52% (15 officers total) having completed four years of college. The majority of the officers who participated self-reported their race to be white (90%; 26 officers total) while 10% (3 officers total) reported being Hispanic or Latino. A copy of the demographic form used to collect the above data can be seen in Appendix A. Table 1 (below) summarizes the demographic information about the officers who participated in this study.

Subjects also filled out a series of sleep questionnaires during their study screening session including the Pittsburg Sleep Quality Index (PSQI), the Epworth Sleepiness Scale (ESS), and the Multivariate Apnea Prediction Scale (MAPS). The PSQI asks subjects a series of questions regarding their sleep patterns and sleep quality over the past four weeks and yields a total sleep quality score ranging from 0-21. PSQI scores higher than 5 represent disturbed sleep, which may be indicative of a sleep disorder (Buysse et al., 1989). The officers in this study had a

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1 A power analysis was conducted using an effect size calculated from data collected in a previous laboratory study involving simulated night shift work and driving performance to determine the number of subjects necessary to complete this study. The analysis determined that at least 21 subjects need to be run in this repeated measures design to show an effect of fatigue on driving performance. Due to the need to counterbalance the condition order of participation among subjects, the initial study design involved running 22 subjects. Following completion of both testing sessions by 10 subjects, data was run through preliminary analyses. This analysis indicated that data collection was successfully picking up the signal of fatigue effect on police officer operational performance. Thus, the decision was made to run a total of 30 officers instead of the originally determined 22 officers.
mean and standard deviation for PSQI of 6.03 (2.64) with values ranging from 2-12. The ESS contains a series of situations and asks how likely a subject is to fall asleep during each of those situations. ESS scores range from 0-24 and gives an overall indication of the subjects’ level of daytime sleepiness (Johns, 1991). Officers sampled in this study had an ESS range of 3-12, with a mean and standard deviation of 8.00 (2.67), respectively. The MAPS is a screening tool for predicting the risk of obstructive sleep apnea. Subjects are asked a series of questions about their sleep which, when scored, give a prediction value between 0-1. MAPS values of 0.5 or greater may indicate the presence of obstructive sleep apnea (Maislin et al., 1995). The mean and standard deviation of MAPS for the officers in this study was 0.32 (0.20) with a range of 0.03-0.85. Both the mean PSQI and the mean MAPS, along with the range of scores for both surveys found in this sample of police officers are high compared to values seen among the general public. However, the values from this sample support the prior research on police officer sleep disorder prevalence (Barger et al., 2009; Rajaratnam et al., 2011; Vila, 1996). A summary of the demographic and screening questionnaire data can be found in Table 1 (below).

The Institutional Review Board of Washington State University reviewed and approved the study. Each officer gave written informed consent prior to participation in the study. The rights and responsibilities with regard to the NIH CoC were also explained to each officer prior to them giving consent for participation.
Table 1: Demographic and Screening Questionnaire Data

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean (Std.)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender: (N=29)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education: (N=29)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School Diploma</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 yrs. College</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 yrs. College</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race/Ethnicity: (N=29)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic or Black</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>29</td>
<td>37 (6) years</td>
<td>28.0 – 49.0 years</td>
</tr>
<tr>
<td>Sleep Quality (PSQI)</td>
<td>29</td>
<td>6.03 (2.64)</td>
<td>2 – 12</td>
</tr>
<tr>
<td>Daytime Sleepiness (ESS)</td>
<td>29</td>
<td>8.00 (2.67)</td>
<td>3 – 12</td>
</tr>
<tr>
<td>Apnea Prediction (MAPS)</td>
<td>29</td>
<td>0.32 (0.20)</td>
<td>0.03 – 0.85</td>
</tr>
</tbody>
</table>

Study Design

Officers first participated in a screening session to determine eligibility to participate. During this screening session, officers were given a series of questionnaires and the informed consent required for participation. Officers also completed a 5-minute practice psychomotor vigilance task, and were screened for simulator adaptation syndrome (SAS). SAS is a syndrome associated with participation in simulated activities in which the eyes and brain recognize that the body should be in motion while the inner ear does not detect any G forces induced by motion. Symptoms of SAS include nausea and dizziness, and it has been compared to seasickness in terms of effect on humans. All officers were screened using a test drive in the simulators to ensure that the simulated driving task would not induce SAS. At the conclusion of
the screening session, eligibility for participation was determined and those officers who wanted to participate filled out and signed the informed consent document.

Officers participated in two separate laboratory based testing sessions during their normal night shift duty cycle of five consecutive nights on duty followed by four or five consecutive days off duty. In the post-shift condition, officers reported to the laboratory for performance testing immediately following the last of five consecutive 10-hour and 40-minute night shifts. In the control condition, the same subjects reported to the laboratory for performance testing at the same time in the morning following three consecutive days off duty. The order of condition participation was randomized among subjects. Additionally, caffeine use was not allowed during or in the hour prior to the testing sessions.

Duration of testing, regardless of condition, was approximately 3 hours in the laboratory. Testing began between 06:00 and 07:30 for all subjects, and ended between 08:30 and 09:30. Following completion of control condition testing officers were free to gather their belongings, and drive home. However, due to the roughly 3 hour extension of their already long wake period, officers were required to get 6 hours of recovery sleep in the laboratory prior to driving home following the post-shift condition. This was added to the study design to ensure the safety of all participating officers on their drive home after testing.

All of the experimental testing was completed in the sleep and simulation laboratory of the Sleep and Performance Research Center at Washington State University in Spokane. The residential sleep side of facility contains four identical private bedrooms which are used by subjects for sleeping. The simulation side of this facility contains two deadly force decision making simulation ranges, and two high fidelity driving simulators for experimental testing of simulated performance. The sleep and the simulation laboratories are connected by an exam
room in which other testing procedures and medical checks can be done. The connected nature of these two facilities enables complete control of environmental and procedural variables relevant to performance testing of fatigued individuals. Light levels in the entire laboratory were set to just below 50 lux for the duration of this study. Ambient temperature was kept to 21°C ± 1°C. Subjects were not allowed access to any source of communication outside of the laboratory during testing sessions (no cell phones, radio, live television, phone calls, visitors, email etc.). Subjects were monitored at all times during the testing sessions by research assistants. When subjects were sleeping following the night shift condition, research assistants monitored them via cameras equipped with infrared light to enable recording in darkness.

**Measurements**

In each of the two conditions, officers performed two 30-minute driving sessions in a high fidelity driving simulator, and four 10-minute psychomotor vigilance test (PVT) bouts. Officers also completed the Karolinska Sleepiness Scale (KSS) twice. To examine decision making performance, a 20-minute simulated deadly force decision-making task was incorporated into the study design. Figure 1 (below) depicts the testing sequence used in this study design for both conditions. As indicated in the figure, testing sessions began at either 06:00 or 07:00, depending on the time the officers’ shift ended and concluded roughly between 08:30 or 09:30 depending on the start time of testing. The testing sequence was KSS, PVT, deadly force simulation, PVT, driving simulation, PVT, driving simulation, PVT, KSS, as shown in Figure 1 (below). Officers also wore heart rate monitors throughout both testing sessions. Testing procedures and sequence were kept the same for both testing conditions and for each of the
participating officers. Detailed minute-by-minute study protocols were used by research assistants in order to maintain this continuity in study design.

Driving performance was tested using a PatrolSim IV high fidelity driver training simulator (MPRI; Salt Lake City, UT) adapted to enable research data collection. These particular simulators were developed for training various professional drivers such as long haul truck drivers, police officers, firemen, and military personnel. Adaption of the simulators involved both the development of a software program (Pulsar Informatics Incorporated; Philadelphia, PA) and the creation of custom driving scenarios. Simulator adoptions were done for the purposes of a previous study but used in the current study design. The standardized driving scenarios involved driving on low-traffic rural highways for a period of roughly 30 minutes. Subjects were instructed to drive a constant speed of 55 miles per hour and remain in the right hand lane throughout the drive. During each driving scenario, 5 to 7 events were randomly placed throughout the driving course. Events involved pedestrians or animals walking out into the road and subjects were asked to brake to avoid hitting them. Driving scenarios also contained 10 straight segments in which no events occurred. These segments were used to

Figure 1: Sequence of Tasks in Testing Session

<table>
<thead>
<tr>
<th>06:00/07:00</th>
<th>KSS</th>
<th>PVT</th>
<th>DF</th>
<th>PVT</th>
<th>Drive</th>
<th>PVT</th>
<th>Drive</th>
<th>PVT</th>
<th>KSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:30/09:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
extract driving metrics frequently associated with drowsy driving. (Van Dongen, Belenky & Vila, 2011)

Lane deviation, calculated as the standard deviation of lateral lane position, was used to measure simulated driving performance (Boyle, Tippin, Paula, & Rizzo, 2008; Van Dongen et al., 2011). Lane deviation is a frequently used measure of simulated driving performance (Boyle et al., 2008), and was calculated for each of the 10 straight segments of each driving session. Additionally, average and variability of speed in straightaways, and fuel consumption over the straight segments were extracted as secondary simulated driving performance metrics. Two subjects’ driving simulator data were discarded because these subjects crashed (in the post-shift condition), which ended the driving simulation prematurely.

The PVT is a widely used, well-validated assay of sustained attention, which is sensitive to circadian rhythm and to varying levels of sleep restriction (Dorrian, Rogers, & Dinges, 2005; Van Dongen & Dinges, 2005). This simple reaction time test involves subjects responding to a stimulus by pressing a button and has a stimulus-response interval varying randomly between 2 and 10 seconds (Dorrian et al., 2005). Reaction times are recorded for each stimulus presented.

The 10-minute PVT was administered to officers on a hand-held smart-phone device running the Walter Reed PVT software (Thorne, Johnson, Redmond, Sing, & Belenky, 2005). PVT performance can be measured using variables such as mean reaction time (RT), the reciprocal of mean reaction time (1/RT), mean fastest 10% RT, mean slowest 10% RT, or total number of lapses among other things. The primary outcome measure of PVT performance used in this study was the total number of lapses of attention (reaction times greater than 500ms). PVT data for five subjects were discarded because they performed an abbreviated 5-minute version of the PVT instead of the full 10-minute version.
The deadly force decision making simulations were conducted using the PRISim Suite© (Advanced Interactive Systems; Seattle, WA), an interactive training simulator used by many police departments to train officers to use deadly force. These deadly force decision making simulators are housed in ranges that are 28-feet (8.53 meters) long and 18-feet (5.49 meters) wide. Pre-recorded, interactive scenarios are projected in high definition onto a screen that is 10-feet (3.05 meters) high and 18-feet (5.49 meters) long, mounted at the front end of each range. Performance in these simulators required the use of a modified Glock handgun. This handgun had been modified using an infrared laser inside the barrel to fire a laser beam at the screen when the trigger was pulled. The simulator software was programmed to respond to the laser beam hitting the screen as an indication that a shot was fired by the subject. Light and sound on each range were held constant to control for any effects the devices, lighting, or sound quality may have had on performance during the simulations. Each range was also equipped with cameras to record each participant’s performance during their deadly force decision making simulation for use in the analysis of the data.

This study involved the use of custom developed deadly force decision making scenarios. Developed based on roughly 30 years of deadly force encounter data, these scenarios involved situations, weapons, and people most typically encountered by police officers around the United States (FBI, 2010). Three main types of encounters were used in developing these scenarios: domestic disturbances, vehicle stops, and suspicious persons. Roughly 35% of the scenarios require no use of force and involve suspects with innocuous objects such as wallets, cell phones, vehicle licenses, or beer bottles. The other 65% of the scenarios involve suspects who threaten officers with knives or handguns. Race of the suspect was also varied based on representative proportions of involvement in officer-involved shootings (FBI, 2010) and included African
American, Caucasian, and Hispanic suspects. Scenarios were filmed using real actors and real scripted scenarios to create a more realistic and a more controlled set of scenarios for use in research regarding deadly force decision making. Each scenario was between 1-3 minutes in length. Each scenario involved decision making regarding whether to shoot a potential suspect or not to shoot a potential suspect.

Relative difficulty of each scenario was varied using an adaptation of Normal Accidents Theory (NAT: Perrow, 1999), in which deadly force encounters are thought of as social systems (Klinger, 2005). NAT maintains that for systems that are tightly coupled, or in which a change in one part of the system forces an immediate change in the other, and highly complex, or possessing large number of components, feedback loops, and circuitry, it is relatively normal to have accidents due to the design and structure of the system. Perrow (1984) states however, that these seemingly normal accidents can have disproportionately catastrophic outcomes. Klinger (2005) proposed that NAT be applied to the way researchers and practitioners think about deadly force encounters for police officers. Following this line of thinking, deadly force encounters experienced by police officers would be thought of as social systems in which the officers were participating. Characteristics of encounters, such as, the number of people involved in the encounter and number of weapons present at the encounter would be factors that affected the complexity of the social system, while factors such as distance between people, speed of the movement of people in the system, and lethality would represent the level of coupling in the system. The application of NAT to deadly force would then specify that in systems with high complexity or high numbers of people or weapons, and tight coupling, or quick rates of change within the system, would be more likely to suffer from unintended consequences due to the dynamics of the system. Klinger (2005) indicated that thinking about deadly force encounters as
systems would provide a way to understand unintended outcomes of encounters such as unarmed suspects getting killed by police officers. During the filming of the custom scenarios, variables thought to impact both complexity and coupling were varied to create a range of scenario difficulty.

Drawing from a larger set of 60 custom scenarios, this study used 40 expert and intermediate level scenarios to measure deadly force decision making among officers. During each condition, officers participated in five simulated deadly force decision making scenarios involving shoot/don’t-shoot decisions randomized from a list of 40 intermediate and expert level scenarios. Each subject responded to three scenarios involving suspects wielding weapons, which were considered threat scenarios, and two scenarios involving suspects not wielding weapons, which were considered non-threat scenarios. The level of difficulty presented to each officer was held constant such that subjects responded to three expert level decision making scenario and two intermediate decision making scenarios in each condition.

Performance during the deadly force decision making simulations was measured using signal detection theory, and will be described in greater detail in the next section. Signal detection theory allowed for errors in performance to be converted into values that represent the success subjects had at noticing when threats were present. It also allowed for assessment of any bias in response for each subject, for instance, a subject favoring to shoot versus not shooting. One subject’s simulated deadly force decision making data were excluded because this subject was given the same scenarios during both testing sessions.

Subjective sleepiness was measured using the Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990), which is a self-reported sleepiness scale frequently used in sleep research. The KSS yielded a subjective sleepiness score ranging from 1 (very alert) to 9 (very
sleepy). Subjects were asked to report their subjective sleepiness prior to and immediately following each testing session.

A summary of the measures taken in the study design is included in Table 2 (below). Each of the four performance tasks are listed along with the total number of subject data sets (column N), the number of times the test was performed during each testing session (sessions per condition), the primary outcome variable, and secondary outcome variables for each performance task.

### Table 2: Measures of Performance Variables (Dependent Measures)

<table>
<thead>
<tr>
<th>Performance Task</th>
<th>N</th>
<th>Sessions (per condition)</th>
<th>Primary Outcome Measure</th>
<th>Secondary Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. simulated driving</td>
<td>27</td>
<td>2</td>
<td>lane deviation</td>
<td>steering wheel angle speed variability fuel usage</td>
</tr>
<tr>
<td>2. PVT</td>
<td>24</td>
<td>4</td>
<td>total lapses</td>
<td>mean RT 1/RT</td>
</tr>
<tr>
<td>3. simulated deadly force decision making</td>
<td>28</td>
<td>5</td>
<td>hit rate false alarm rate discriminability response bias</td>
<td>none</td>
</tr>
<tr>
<td>4. KSS</td>
<td>29</td>
<td>2</td>
<td>subjective sleepiness score</td>
<td>none</td>
</tr>
</tbody>
</table>
**Statistical Analysis**

Statistical analysis of this repeated measures design involved consideration of both within and between subjects comparison of simulated driving performance, PVT, and subjective sleepiness. Mixed-effects analysis of variance (ANOVA) was used to analyze the effects of condition and testing session on the three primary variables. Order of condition participation (post-shift first versus control first) and subjects’ driving simulator assignment (simulator 1 versus simulator 2) were included in the analysis as covariates to control for any potential differences in order of participation or simulator hardware.

Simulated deadly force decision making performance was analyzed first using signal detection theory (SDT: Green & Swets, 1966). SDT is a frequently used method of analysis in psychological research to assess the ability of subjects to distinguish between two types of stimuli presented at the same time. For the purposes of this analysis, SDT was used to distinguish performance on a yes/no task. The yes/no tasks involved presenting subjects with one of two forms of stimuli during a decision making task: signal trials and noise trials (Stanislaw & Todorov, 1999). Signal trials involve decisions in which a correct decision would be “yes” and noise trials involve decisions in which correct decisions would be “no”. For each iteration of a decision making task, there will be two outcomes: a stimulus (absence or presence of a signal) and a response (yes or no). The relationship between the two outcomes during the decision making task can be seen in Figure 5 (below).
Figure 2: Stimulus-response matrix for a yes/no task

<table>
<thead>
<tr>
<th>Signal</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>HIT</td>
<td>FALSE ALARM</td>
</tr>
<tr>
<td>no</td>
<td>MISS</td>
<td>CORRECT REJECTION</td>
</tr>
<tr>
<td>absent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hits are defined as correct “yes” responses when the signal is present, while misses are defined as incorrect “no” responses when a signal is present. Likewise, false alarms are defined as incorrect “yes” responses when there is no signal present, while correct rejections are defined as correct “no” responses when there is no signal present (Green & Swets, 1966). Based on the number of iteration of a decision task given to subjects rates for each of the signal-response categories can be calculated using the Equation 1 (below): 

\[
f = \frac{\text{# of responses (signal or noise)}}{\text{# of times stimuli was presented (signal or noise)}}
\]

Equation 1: Frequency of response to stimuli equation

---

2 Adapted from original matrix in Green & Sweets (1966).
3 Adapted from Wickens (2002)
Ratios of responses to presented stimuli can be used to calculate probabilities of responses based on repeated completions of a certain task. Two types of probabilities are typically used for this part of the process, a measure of sensitivity and a measure of response bias. Sensitivity represents the probabilistic measurement of a subject’s ability to distinguish the signal trials from the noise trials that were presented, which is visually represented when graphing the signal distribution against the noise distribution as the degree of overlap of the two distributions (Stanislaw & Todorov, 1999). Response bias represents the general tendency of the subject to respond “yes” or “no” (Stanislaw & Todorov, 1999). It should be noted that the above description of SDT was a very simple description. For more detail on the general process or other types of SDT analysis see the sources cited in this paper.

For the purposes of this study, hit rates, false alarm rates, correct rejections, and misses were calculated for each subject’s simulated deadly force decision making performance during each condition. Shots fired during scenarios involving a threat (suspect wielding a weapon) were coded as hits, while shots fired during scenarios involving no threat (suspects not wielding weapons) were coded as false alarms. Additionally, correct rejections involved no shots being fired during scenarios in which no threat was present, while misses occurred when no shots were fired during scenarios in which threats were present. Using SDT (Stanislaw & Todorov, 1999), hits and false alarms in each condition were converted to measures of discriminability (d') and response bias (c). Repeated measures ANOVAs were then used to examine the effect of condition (post-shift condition versus control condition), of hit rate, false alarm rate, discriminability, and response bias.

In summary, this study tested four alternative hypotheses using mixed-effects ANOVAs and repeated measures ANOVAs to gain insight into the effects of shift-work related fatigue on
police officers’ job-relevant task performance. Simulated driving, psychomotor vigilance, subjective sleepiness, and simulated deadly force decision making were all explored in this repeated measures study design. Table 3 (below) provides a summary of the four hypotheses, the statistical test used, the primary dependent variable, and the covariates run in the analysis of each of the four hypotheses. All statistical analysis was conduct using SAS version 9.3 (SAS Institute Inc., Cary, NC). For the SAS code and a description of the data used in this study see Appendix B.

Table 3: Study Hypotheses and Statistical Methods

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Statistical Test</th>
<th>Dependent Variable</th>
<th>Covariates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Simulated driving performance was significantly worse following 5</td>
<td>Mixed-Effects</td>
<td>lane deviation</td>
<td>order of condition simulator</td>
</tr>
<tr>
<td>consecutive night shifts on duty when compared to 3 consecutive days off</td>
<td>ANOVA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>duty.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Psychomotor vigilance (PVT) was significantly degraded following 5</td>
<td>Mixed-Effects</td>
<td>total lapses</td>
<td>order of condition</td>
</tr>
<tr>
<td>consecutive night shifts on duty when compared to 3 consecutive days off</td>
<td>ANOVA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>duty.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Subjective sleepiness was significantly higher following 5</td>
<td>Mixed-Effects</td>
<td>KSS score</td>
<td>order of condition</td>
</tr>
<tr>
<td>consecutive night shifts on duty when compared to 3 consecutive days off</td>
<td>ANOVA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>duty.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Simulated deadly force decision making was degraded following 5</td>
<td>SDT/ANOVA</td>
<td>hit rate false</td>
<td>order of condition range</td>
</tr>
<tr>
<td>consecutive night shifts on duty when compared to 3 consecutive days off</td>
<td></td>
<td>alarm rate</td>
<td></td>
</tr>
<tr>
<td>duty.</td>
<td></td>
<td>discriminability</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>response bias</td>
<td></td>
</tr>
</tbody>
</table>

50
CHAPTER 4: RESULTS

This study explored simulated driving performance, psychomotor vigilance performance, simulated deadly force decision making as well as subjective sleepiness of police officers working five consecutive night shifts compared to three days off duty in a repeated measures design. Primary dependent variables of interest in these data analyses were: lane deviation for simulated driving, total lapses of attention for psychomotor vigilance, subjective sleepiness rating, hit rate, false alarm rate, discriminability of signal, and response bias for simulated deadly force decision making. Secondary variables of interest were: steering wheel angle, speed variability, and fuel usage for simulated driving, as well as, mean reaction time, and 1/mean reaction time for psychomotor vigilance. Additionally, some covariate analyses were conducted to explore the possible relationships between some of the primary and secondary variables of interest.

All data were plotted to check for normality and outliers prior to analyses. Distribution boxplots for each variable can be found in Appendix C. Most of the variables considered in this study did not have normal data distributions and contained points that could have been considered outliers. However, no data points were excluded as such.

Simulated driving performance, psychomotor vigilance, and subjective sleepiness were analyzed using mixed-effects ANOVAs. Simulated deadly force decision making was first analyzed using signal detection theory and then compared by condition using repeated measures ANOVA. All statistical analyses were run in SAS 9.3 (SAS Institute Inc., Cary, NC). For the SAS code used in this study, see Appendix B.
Simulated Driving Performance

The primary outcome measure used to assess simulated driving performance was lane deviation (meters), measured as the standard deviation of lateral lane position of the simulated vehicle within the right hand lane. Additionally, four secondary outcome measures were also calculated: speed variability, steering wheel angle, and fuel usage. All primary and secondary outcome measures were calculated during 10 straight segments dispersed within the 30-minute drive. These calculated values were then averaged over the straight segment to get one numerical value for that particular straight segment. Thus, each drive produced 10 values for each driving measure. To simplify analysis, an additional aggregation was done to reduce the 10 values down into one single value for each drive. Equation 1 (below) shows the mathematical equation used for this reduction:

\[ f(x) = \sqrt{\frac{\sum x^2}{n}} \]

Equation 2: Aggregation equation

In this equation, \( x \) represents the mean value of the performance variable and \( n \) represents number of straight segments ranging from 1-10 that were used in the summation of mean values. Reduction was done for all four primary and secondary outcome measures calculated during straight segments: lane deviation, speed variability, steering wheel angle, and average fuel usage. Mixed-effects analysis of variance (ANOVA) was used to analysis the main effect of condition (night shift versus control), session (first drive versus second drive), and condition by session
interaction on simulated driving performance. Individual mixed-effects ANOVA were run for each of the four driving metrics. Data from 27 officers was used for this analysis. Table 4 (below) shows the main condition means and standard deviations for the simulated driving performance variables.

Table 4: Summary of Means (Std.Dev.) by Condition for All Primary Variables

<table>
<thead>
<tr>
<th>Primary Outcome</th>
<th>N</th>
<th>Night Shift Condition [M(std.)]</th>
<th>Control Condition [M(std.)]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simulated Driving:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>lane deviation</strong></td>
<td>27</td>
<td>0.18 (0.06)</td>
<td>0.17 (0.04)</td>
</tr>
<tr>
<td><strong>steering wheel angle</strong></td>
<td>27</td>
<td>0.01 (0.004)</td>
<td>0.001 (0.004)</td>
</tr>
<tr>
<td><strong>speed variability</strong></td>
<td>27</td>
<td>0.39 (0.22)</td>
<td>0.33 (0.17)</td>
</tr>
<tr>
<td><strong>fuel usage</strong></td>
<td>27</td>
<td>0.03 (0.001)</td>
<td>0.03 (0.00)</td>
</tr>
<tr>
<td><strong>PVT:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>total lapses of attention</strong></td>
<td>24</td>
<td>4.23 (5.96)</td>
<td>2.29 (3.55)</td>
</tr>
<tr>
<td><strong>reaction time (ms)</strong></td>
<td>24</td>
<td>310.48 (83.22)</td>
<td>278.49 (56.36)</td>
</tr>
<tr>
<td><strong>1/reaction time</strong></td>
<td>24</td>
<td>0.003 (0.00)</td>
<td>0.004 (0.00)</td>
</tr>
<tr>
<td><strong>Simulated Deadly Force Decision Making:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>hit rate</strong></td>
<td>28</td>
<td>0.92 (0.03)</td>
<td>0.96 (0.03)</td>
</tr>
<tr>
<td><strong>false alarm rate</strong></td>
<td>28</td>
<td>0.32 (0.06)</td>
<td>0.14 (0.06)</td>
</tr>
<tr>
<td><strong>response bias</strong></td>
<td>28</td>
<td>-0.30 (0.06)</td>
<td>-0.19 (0.06)</td>
</tr>
<tr>
<td><strong>sensitivity</strong></td>
<td>28</td>
<td>1.31 (0.13)</td>
<td>1.75 (0.13)</td>
</tr>
<tr>
<td><strong>Subjective Sleepiness</strong></td>
<td>29</td>
<td>6.62 (2.10)</td>
<td>4.09 (1.74)</td>
</tr>
</tbody>
</table>

**Primary Outcome.** For lane deviation, mixed effects ANOVA revealed a significant effect for condition (F1,78=6.78; P=0.011) and testing session (F1,78=10.43; P=0.002). No significant effect for condition by session interaction was found. Both order of condition participation and simulator device were not significant as covariate variables. Figure 3 (below) shows a line graph of the condition by session interaction for lane deviation. Testing session is shown on the horizontal x-axis, while lane deviation is shown on the vertical y-axis. The solid
line represents the mean lane deviation for both testing sessions during the night shift condition. The dashed line shows the mean lane deviation for both testing sessions during the control condition. The mean lane deviation for the night shift condition (M=0.183, SE=0.0084) was significantly higher than the mean lane deviation for the control condition (M=0.168, SE=0.008). The mean deviation for testing session one (M=0.184, SE=0.008) was lower when compared to testing session two (M=0.166, SE=0.008). The condition by session interaction is represented by the slope or the rate of change across the two testing sessions of each condition line and was not significant.

Figure 3: Mean lane deviation by condition and testing session
**Secondary Outcomes.** For steering wheel angle, mixed effects ANOVA revealed a significant effect for condition (F1,78=18.50; P=<0.001) and testing session (F1,78=8.82; P=0.004). No significant effect for condition by session interaction was found. Both order of condition participation and simulator device were not significant as covariate variables. Figure 4 (below) shows a line graph of the condition by session interaction for steering wheel angle. Testing session is shown on the horizontal x-axis, while steering wheel angle is shown on the vertical y-axis. The solid line represents the mean steering wheel angle for both testing sessions during the night shift condition. The dashed line shows the mean steering wheel angle for both testing sessions during the control condition. The mean steering wheel angle for the night shift condition (M=0.011, SE=0.001) was significantly higher than the mean steering wheel angle for the control condition (M=0.009, SE=0.001). The mean steering wheel angle for testing session one (M=0.009, SE=0.001) was lower when compared to testing session two (M=0.010, SE=0.001). The condition by session interaction is represented by the slope or the rate of change across the two testing sessions of each condition line and was not significant.
For fuel usage, mixed effects ANOVA revealed a significant effect for condition \((F_{1,78}=5.60; P=0.021)\) and condition by session interaction \((F_{1,78}=10.68; P=0.002)\). No significant effect for testing session was found. Order of condition participation was not significant as a covariate. However, simulator device was significant as a covariate \((F_{1,78}=4.50; P=0.040)\) indicating a relationship between simulator device and fuel usage. Figure 5 (below) shows a line graph of the condition by session interaction for fuel usage. Testing session is shown on the horizontal x-axis, while fuel usage is shown on the vertical y-axis. The solid line represents the mean fuel usage for both testing sessions during the night shift condition. The dashed line shows the mean fuel usage for both testing sessions during the control condition. The mean fuel usage for the night shift condition \((M=0.0254, SE=0.00008)\), while the mean fuel usage for the control condition \((M=0.02523, SE=0.00008)\). The condition by session interaction is represented by the

Figure 4: Mean steering wheel angle by condition and testing session
slope or the rate of change across the two testing sessions of each condition line. As shown in Figure 5, the slope of the night shift condition line depicts a positive relationship, indicating that during the night shift condition more fuel was used in the second testing session (M=0.02567, SE=0.00001) compared to the first testing session (M=0.02524, SE=0.00001). Conversely, the slope of the control condition line depicts a negative relationship indicating that during the control condition less fuel was used in the second testing session (M=0.0251, SE=0.00001) compared to the first testing session (M=0.0253, SE=0.00001). The opposing direction of the relationship between condition and fuel usage may have important economic implications for police officers driving while fatigued.

Figure 5: Mean fuel usage by condition and testing session
Figure 6 (below) shows the scatter plot distribution of mean fuel usage plotted against simulator device which depicts the relationship between fuel usage and simulator device. Simulator device is shown on the horizontal x-axis while fuel usage is shown on the vertical y-axis. Each subject’s fuel usage mean for each drive is represented as a single point on the graph based on which simulator they performed on during testing. Additionally, night shift condition means are represented as a dot, while control condition means are represented as a diamond.

![Figure 6: Mean fuel usage by simulator device](image)

For speed variability, mixed effects ANOVA revealed no significant effect for condition, session or condition by session interaction. Line graphs of each of these three analyses can be found in Appendix C.
Analyses using mixed effects ANOVAs revealed that three of the four driving performance metrics were sensitive to the effects of condition in this study design. Lane deviation, steering wheel angle, and fuel usage were all significantly different when compared across condition. Results indicate that driving performance was significantly degraded following five consecutive night shifts when compared to three consecutive days off duty.

**Psychomotor Vigilance Performance**

For psychomotor vigilance performance, the primary outcome measure was total number of lapses of attention, defined as reactions times greater than 500ms (Dorrian et al., 2005). Secondary measures of performance included: mean reaction time and 1/mean reaction time. Each officer completed four 10-minute PVT’s during each testing session. Again, mixed-effects ANOVA were used to determine condition (night shift versus control), session and condition by session interaction effects on psychomotor vigilance performance. Individual ANOVAs were run for each primary and secondary performance measure. PVT data from 24 officers were used in this analysis.

**Primary Outcome.** For total lapses of attention, mixed effects ANOVA revealed a significant effect for condition (F\(_{1,161}=14.06; \ P<0.001\)) and testing session (F\(_{1,161}=7.32; \ P<0.001\)). No significant effect for condition by session interaction was found. Order of condition participation was not significant as a covariate variable. Figure 7 (below) shows a line graph of the condition by session interaction for total lapses. Testing session is shown on the horizontal x-axis, while the number of total lapses is shown on the vertical y-axis. The solid line represents the mean number of total lapses for all four testing sessions during the night shift.
condition. The dashed line shows the mean number of total lapses for all four testing sessions during the control condition. The mean number of total lapses for the night shift condition (M=4.23, SE=0.730) was significantly higher than the mean number of total lapses for the control condition (M=2.22, SE=0.730). The mean number of total lapses when compared across testing session were significantly different from each other one (session one: M=2.02, SE=0.822; session two: M=1.92, SE=0.822; session three: M=4.54, SE=0.822; session four: M=4.42, SE=0.822), with testing session three being the highest, testing session four being the second highest, testing session one being the third highest, and testing session two being the lowest in mean number of total lapses. The condition by session interaction is represented by the slope or the rate of change across the two testing sessions of each condition line and was not significant.

Figure 7: Mean number of lapses of attention by condition and testing session
Secondary Outcomes. For mean reaction time, mixed effects ANOVA revealed a significant effect for condition ($F_{1,161}=16.40; \ P<0.001$) and testing session ($F_{1,161}=10.30; \ P<0.001$). No significant effect for condition by session interaction was found. Order of condition participation was not significant as a covariate variable. Figure 8 (below) shows a line graph of the condition by session interaction for mean reaction time. Testing session is shown on the horizontal x-axis, while the mean reaction time is shown on the vertical y-axis. The solid line represents the mean reaction time for all four testing sessions during the night shift condition. The dashed line shows the mean reaction time for all four testing sessions during the control condition. The mean reaction time for the night shift condition ($M=310.48, SE=10.044$) was significantly higher than the mean reaction time for the control condition ($M=278.49, SE=10.044$). The mean reaction time when compared across testing session were significantly different from each other one (session one: $M=268.96, SE=11.494$; session two: $M=276.58, SE=11.494$; session three: $M=313.58, SE=11.494$; session four: $M=318.80, SE=11.494$), with testing session four being the highest, testing session three being the second highest, testing session two being the third highest, and testing session one being the lowest in mean reaction time. The condition by session interaction is represented by the slope or the rate of change across the two testing sessions of each condition line and was not significant.
For the reciprocal of mean reaction time (1/RT), mixed effects ANOVA revealed a significant effect for condition ($F_{1,161}=28.93; P<0.001$) and testing session ($F_{1,161}=17.95; P<0.001$). No significant effect for condition by session interaction was found. Order of condition participation was not significant as a covariate variable. Figure 9 (below) shows a line graph of the condition by session interaction for mean 1/RT. Testing session is shown on the horizontal x-axis, while the mean 1/RT is shown on the vertical y-axis. The solid line represents the mean 1/RT for all four testing sessions during the night shift condition. The dashed line shows the mean 1/RT for all four testing sessions during the control condition. The mean 1/RT for the night shift condition ($M=0.0034, SE=0.00009$) was significantly higher than the mean 1/RT for the control condition ($M=0.0037, SE=0.00009$). The mean 1/RT when compared across testing session were significantly different from each other one (session one: $M=0.0038,$

**Figure 8: Mean reaction time (ms) by condition and testing session**
SE=0.0001; session two: M=0.0037, SE=0.0001; session three: M=0.0034, SE=0.0001; session four: M=0.0033, SE=0.0001), with testing session four being the lowest, testing session three being the second lowest, testing session two being the third lowest, and testing session one being the highest in mean 1/RT. The condition by session interaction is represented by the slope or the rate of change across the two testing sessions of each condition line and was not significant.

![Graph](image)

**Figure 9: Mean reciprocal reaction time (1/ms) by condition and testing session**

All three of the PVT performance metrics analyzed here yielded significant main effects for condition. Results from this study indicate that the vigilance performance of officers was decreased following five consecutive night shifts when compared to three days off duty.
Subjective Sleepiness

The primary outcome used for measuring subjective sleepiness was Karolinska Sleepiness Scale (KSS) score. A mixed-effects ANOVA was used to explore the effects of condition, testing session and condition by session interaction on subjective sleepiness. Each officer completed two KSS questionnaires during each study condition. Data from 29 officers were used in this analysis of subjective sleepiness.

**Primary Outcome.** For subjective sleepiness, mixed effects ANOVA revealed a significant effect for condition \((F_{1,84}=96.99; P<0.001)\), testing session \((F_{1,84}=70.13; P<0.001)\), and condition by session interaction \((F_{1,84}=8.30; P=0.005)\). Order of condition participation was also significant as a covariate variable \((F_{1,84}=10.11; P<0.002)\) indicating a relationship between the condition an officer completed first and subjective sleepiness. Figure 10 (below) shows a line graph of the condition by session interaction for mean subjective sleepiness. Testing session is shown on the horizontal x-axis, while the subjective sleepiness is shown on the vertical y-axis. The solid line represents the mean subjective sleepiness for both testing sessions during the night shift condition. The dashed line shows the mean subjective sleepiness for both testing sessions during the control condition. The mean subjective sleepiness for the night shift condition \((M=6.62, SE=0.207)\) was significantly higher than the mean subjective sleepiness for the control condition \((M=4.09, SE=0.207)\). The mean subjective sleepiness for testing session two \((M=6.43, SE=0.207)\) was higher when compared to testing session one \((M=4.28, SE=0.207)\). The condition by session interaction is represented by the slope or the rate of change across the two testing sessions of each condition line. As shown in Figure 10 (below), the slope of the night shift condition line indicates that during the night shift condition subjective sleepiness was higher in
the second testing session (M=8.07, SE=0.275) compared to the first testing session (M=5.17, SE=0.275). Similarly, the slope of the control condition line indicates that during the control condition subjective sleepiness was also higher in the second testing session (M=4.79, SE=0.275) compared to the first testing session (M=3.38, SE=0.275). With both condition lines yielding positive relationships between condition and subjective sleepiness, results indicate that the rate of change during one condition was higher when compared to the other condition. Figure 10 shows the night shift condition having higher subjective sleepiness. Thus, the rate of change across testing sessions during the night shift condition was significantly greater when compared to the rate of change across testing sessions during the control condition.

Figure 10: Subjective sleepiness by condition and testing session
Figure 11 (below) shows the scatter plot distribution of mean subjective sleepiness plotted against order of condition participation which depicts the relationship between subjective sleepiness and order of condition participation. Order of condition participation is shown on the horizontal x-axis while subjective sleepiness is shown on the vertical y-axis. Each subject’s subjective sleepiness for each testing session is represented as a single point on the graph based on which condition they participated in first. Additionally, night shift condition means are represented as a dot, while control condition means are represented as a diamond.

Figure 11: Subjective sleepiness by order of participation

Overall results for subjective sleepiness indicate that officers were more subjectively sleepy following five consecutive night shifts compared to three consecutive days off duty. Additionally, officers’ rate of change of sleepiness across testing sessions was higher during the
night shift condition indicating that they were getting sleepier at a faster rate following five consecutive night shifts compared to following three consecutive days off duty.

**Simulated Deadly Force Decision Making Performance**

Simulated deadly force decision making performance was assessed by translating correct responses and response errors into probabilistic measures of performance using signal detection theory. Variables of interest used to measure performance were hit rate, false alarm rate, sensitivity to detect a signal measured using D-prime, and response bias measured using c. A two-way repeated measures ANOVA was used to determine the effect of condition on hit rate, false alarm rate, response bias, and sensitivity. Order of participation was used as a covariate for each of the four primary performance variables. Data from 28 officers were used in this analysis.

*Primary Outcomes.* For hit rate, repeated measures ANOVA revealed no significant effect for condition. However, for false alarm rate, repeated measures ANOVA revealed a significant effect for condition ($F_{1,53}=4.82; P=0.033$), with a higher rate of false alarms occurring during the night shift condition. Order of condition participation was not significant as a covariate variable. Figure 12 (below) shows a bar graph depicting mean false alarm rate by condition. Condition is shown on the horizontal x-axis, while false alarm rate is shown on the vertical y-axis. The night shift condition mean false alarm rate is represented as the black bar, while the control condition mean false alarm rate is represented as the white bar. The mean false alarm rate for the night shift condition ($M=0.32, SE=0.057$) was higher when compared to the mean false alarm rate for the control condition ($M=0.14, SE=0.057$), indicating a more frequent
occurrence of false alarms, or shooting unarmed suspects, during the night shift condition when compared to the control condition.

Figure 12: Mean false alarm rate by condition

For response bias, repeated measures ANOVA revealed no significant effect for condition. However, for sensitivity to the signal, repeated measures ANOVA revealed a significant effect for condition ($F_{1,53}=5.94; P=0.018$), with a lower sensitivity to the signal occurring during the night shift condition. Order of condition participation was not significant as a covariate variable. Figure 13 (below) shows a bar graph depicting mean sensitivity to the signal by condition. Condition is shown on the horizontal x-axis, while sensitivity is shown on the vertical y-axis. The night shift condition mean false alarm rate is represented as the black bar, while the control condition mean false alarm rate is represented as the white bar. The mean
sensitivity for the night shift condition (M=1.31, SE=0.127) was lower when compared to the mean sensitivity for the control condition (M=1.75, SE=0.127), indicating subjects were less likely to detect the signal, or a suspect presenting a threat, during the night shift condition when compared to the control condition.

**Figure 13: Mean sensitivity by condition.**

Officers experienced higher levels of false alarms representing instances in which decisions to shoot were made when no actual threat was present during these simulated encounters on the night shift conditions. Additionally, sensitivity to detecting the presence of a threat was lowered during the night shift conditions. To the extent that these results are generalizable to the real world, it appears that simulated deadly force decision making performance was decreased following five consecutive night shifts on duty when compared to
three consecutive days off duty. However, it should be noted that the sample size of this study was small compared to the samples sizes usually used in signal detection analysis. Results from these analyses of simulated deadly force decision making should be interpreted with caution.

Secondary Analyses of Covarying Variables

**Covariate Analyses.** Additional mixed-effects ANOVAs were run on dependent variables that yielded main condition effects with additional covariate variables. The dependent variable of most interest for this additional analysis was simulated driving performance measured as lane deviation. Models were run to explore the relationship between lane deviation and the following covariates: pre-drive PVT lapses, post-drive PVT lapses, subjective sleepiness, MAPS prediction score, and PSQI value. The covariate relationships between total number of PVT lapses and subjective sleepiness, MAPS prediction score, and PSQI value were also explored, as well as the covarying relationships between subjective sleepiness and MAPS prediction score and PSQI value.

Lane deviation was shown to covary with the number of pre-drive PVT lapses ($F_{1,62}=11.22; P=0.001$). Figure 14 (below) shows the scatter plot distribution of lane deviation plotted against pre-drive PVT lapses, which depicts the relationship between lane deviation and number of pre-drive PVT lapses. Lane deviation is shown on the horizontal x-axis, while pre-drive PVT lapses are shown on the vertical y-axis. Each subject’s mean lane deviation during the first drive and mean total lapses of attention on the PVT immediately prior to the first drive is graphed against their mean lane deviation on during the second drive and mean total lapses of attention on the PVT immediately prior to the second drive. Additionally, night shift condition
means are represented as a dot, while control condition means are represented as a diamond. This
distribution shown in the Figure 14 (below) indicates a positive covarying relationship in which
the increased number of pre-drive lapses matches to increased levels of lane deviation.

Figure 14: Lane deviation by pre-drive PVT lapses

Lane deviation was shown to covary with the number of post-drive PVT lapses
\((F_{1,62}=4.17; \, P=0.045)\). Figure 15 (below) shows the scatter plot distribution of lane deviation
plotted against post-drive PVT lapses, which depicts the relationship between lane deviation and
number of post-drive PVT lapses. Lane deviation is shown on the horizontal x-axis, while post-
drive PVT lapses are shown on the vertical y-axis. Each subject’s mean lane deviation during the
first drive and mean total lapses of attention on the PVT immediately following the first drive is
graphed against their mean lane deviation on during the second drive and mean total lapses of attention on the PVT immediately following the second drive. Additionally, night shift condition means are represented as a dot, while control condition means are represented as a diamond. This distribution shown in the Figure 15 (below) indicates a positive covarying relationship in which the increased number of post-drive lapses matches to increased levels of lane deviation.

![Figure 15: Lane deviation by post-drive PVT lapses](image)

None of the other additional models yielded significant covariate results. All other distribution graphs for the various analyses can be seen in Appendix C.
Summary

Results indicate that police officers in this study exhibited degraded driving and vigilance performance following five consecutive night shifts on duty when compared to three consecutive days off duty. Officers also reported higher levels of subjective sleepiness during the night shift condition, as well as differences from the beginning of each testing session to the end of each testing session. Additionally, the rate of change in subjective sleepiness see across each testing session was significantly higher during the night shift condition compared to the control condition. The results also indicated that deadly force decision making is impaired following the night shift condition when compared with the control condition, officers had higher instances of false alarms and differing levels of sensitivity to the signal during the night shift condition. Table 5 (below) provides a summary of the mixed-effects ANOVA and repeated measures ANOVA for all dependent variables.
Table 5: Summary of Condition Results for All Primary Variables

<table>
<thead>
<tr>
<th>Condition</th>
<th>N</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulated Driving:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lane deviation</td>
<td>27</td>
<td>1, 78</td>
<td>6.78</td>
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</tr>
<tr>
<td>steering wheel angle</td>
<td>27</td>
<td>1, 78</td>
<td>18.50</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>speed variability</td>
<td>27</td>
<td>1, 78</td>
<td>3.81</td>
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</tr>
<tr>
<td>fuel usage</td>
<td>27</td>
<td>1, 78</td>
<td>5.60</td>
<td>0.021 *</td>
</tr>
<tr>
<td>PVT:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total lapses of attention</td>
<td>24</td>
<td>1, 161</td>
<td>14.06</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>reaction time (ms)</td>
<td>24</td>
<td>1, 161</td>
<td>16.40</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>1/reaction time</td>
<td>24</td>
<td>1, 161</td>
<td>28.93</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>Simulated Deadly Force Decision Making:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hit rate</td>
<td>28</td>
<td>1, 53</td>
<td>1.11</td>
<td>0.300</td>
</tr>
<tr>
<td>false alarm rate</td>
<td>28</td>
<td>1, 53</td>
<td>4.82</td>
<td>0.033 *</td>
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<td>response bias</td>
<td>28</td>
<td>1, 53</td>
<td>1.41</td>
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<tr>
<td>sensitivity</td>
<td>28</td>
<td>1, 53</td>
<td>5.94</td>
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<td>Subjective Sleepiness:</td>
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<tr>
<td>KSS</td>
<td>29</td>
<td>1, 84</td>
<td>96.99</td>
<td>&lt;0.001 *</td>
</tr>
</tbody>
</table>
Officers experienced decrements in simulated driving performance, vigilance and subjective sleepiness following five consecutive night shifts on duty compared to three consecutive days off duty. Impairments in aspects of simulated deadly force decision making were also seen during the night shift condition compared to the control condition. Additionally, results indicated that this unique method combining controlled laboratory-based performance measures with actual police officer subjects, whose fatigue was obtained in their real world occupational setting was successful in detecting the effects of night shift work on operational performance. Performance decrements shown in this study have real world implications for police officers in terms of on-the-job safety when operating motor vehicles, as well as making high-impact decisions in difficult and variable situations. Management of police officer fatigue may decrease the risk of motor vehicle accidents as well as errors in decision making both of which are tied to shift-work related fatigue.

This chapter will present a discussion of the results including implications for real world police officers. Simulated performance in the laboratory can be applied to real world performance and this will be discussed with regard to the implications this study’s findings have for the everyday performance of night shift working police officers. The second section of this chapter will address the limitations of this study and suggest routes for future research. The final section will discuss the policy implications that can be derived from this study and suggest methods and strategies for managing police officer fatigue.
Discussion

This study’s results confirmed the usefulness of the study design to explore the effect of shift work on police officer performance as well as expanding its use to explore other shift working occupational groups. The high fidelity training simulators adapted for use in research were successful in collecting job related performance data. Additionally, logistics for carrying out the data collection were also shown to be successful given the added complication of using field induced fatigue in a specific occupational group. Officers from the department used in this study were interested in working with researchers. The study had an attrition rate of zero. No data sets were incomplete because of subjects not coming back for their second data collection day, which can be a challenge in conducting repeated measure study designs with occupational groups. Overall, this study was successful in showing the utility and effectiveness of this type of design for studying the effects of shift work related fatigue on officer performance.

The success of this design begins to bridge the gap between the controlled data collection conducted in a laboratory and the realism of data collected in the field. Integrated designs, like the one used in this study, provide a lower cost, highly effective and less invasive way to study the problem of operational performance and shift-work related fatigue. One of the more common methods for collecting operational performance data is through field data collection. However, these types of data collection remain relatively uncontrolled which lead to high levels of variable contextual factors and measurement errors (Williamson et al., 2011). This variability in the data collected in the field often times requires running larger numbers of subjects in order to see a main condition effect. On the other hand, full laboratory simulated sleep-wake-work cycles, or other forms of laboratory controlled data collection, can provide challenges to researchers as
well. First, laboratory study designs require taking subjects out of the field for an extended period of time, which depending upon the occupational group, can drive up the cost of the study and create problems for their employers in terms of manpower. Taking subjects out of the field may not always be feasible in occupational groups where understaffing is a problem due to the fact that removing a worker from the field would increase the work load for those remaining in the field or decrease the ability to respond to the service needs of that industry. Secondly, laboratory performance testing may lack applicability to actual real world occupational performance. While controlled laboratory settings result in less variability seen in the data which allows for lower numbers of subjects to be run, this lack of realism in performing tasks under real world occupational settings can lead to a lack of realism. This study attempted to overcome this lack of realism by using simulated operational performance tasks, as well as, validated performance tasks such as the PVT which are frequently used in sleep and performance research. Additionally, the study employed the use of simulators designed and manufactured for the purpose of training driving and deadly force decision making to occupational groups that had been adapted by researchers for use in data collection. This characteristic of our simulators starting as training simulators used in industry settings adds to the realism of our simulated performance measurement, as such adding to the face and potential real-world validity of our results. Our study design integrated advantageous characteristics of field and laboratory data collection, control and realism, providing a way combine the two types of study designs.

Additionally, results from this study indicated that night shift working police officers are not immune to the degraded performance induced by fatigue. Possible assumptions that policing is an occupation in which self-selection may weed out those who are not resilient to the effects of sleep deprivation or shift work induced fatigue do not hold up in the face of the results from this
study. Officers in this study reported high levels of subjective fatigue on validated self-report scales and exhibited significantly degraded simulated performance on job-related tasks. Driving performance and vigilance were degraded following five consecutive night shifts on duty when compared to following three consecutive days off duty as were some aspects of deadly force decision making. Prior research looking at police fatigue has had to rely primarily on survey data and/or field data collection and does not touch on the extent to which police fatigue becomes a problem for officers trying to complete operational tasks during their shifts. Results from this study show that simulated performance on tasks that officers perform during their shifts is in fact degraded when they are more fatigued.

The shift work induced fatigue effects similar to those seen in this study could be contributing increases in accident risk and on the job deaths for police officers. For instance, motor vehicle accidents are highly correlated with fatigue. Roughly, one-third of all police fatalities are attributed to motor vehicle accidents. Despite the declining motor vehicle fatality rates for the general public (Longthorne, Subramanian, & Chen, 2010), rates for police officers have trended upward over the past two decades (Federal Bureau of Investigation, 2010). Although less than one-third of police patrol officers work night shifts, 42% of fatal crashes involving police officers occur between midnight and 08:00 (Noy, 2011). Our results indicated the lane deviation during simulated driving was degraded following five consecutive night shifts compared to three days off duty. Night shift work by police officers could be a contributing factor to these increased motor vehicle accident and fatality rates among officers. Thus, fatigue induced by working night shifts may increase the risk of accidents and even death for officers on the job.
Our results also indicate that there may be some degradation of deadly force decision making among officers working consecutive night shifts. Over the past decade, roughly 43% of police officer line-of-duty deaths were felonious assaults on officers by community members (FBI, 2010). Decisions to arrest and decisions to use force, especially deadly force, are two types of decisions made by police officers that involve exercising their discretionary authority, which can result in unintended effects on the lives of community members. While the deadly force decision making results from this study were exploratory, there was indications that decision making under conditions of shift work induced fatigue is degraded among police officers. Degraded decision making during arrest procedures or deadly force encounters could result in police officer deaths as well as wrongful deaths in the community. This type of degraded decision making associated with shift work induced fatigue is of concern for the safety of the public in the communities the officers are working, and could increase the risk for the officers’ own safety. Poor decisions by police officers that result in deaths of community members can come at a great cost, both monetarily and socially, to municipal governments or cities, and community members themselves.

The consequences of degraded performance and decision making impairment of police officers can have far reaching, catastrophic effects for both officers and community members. Since fatigue induced by consecutive night shift work can contribute to this decreased performance and impaired decision making, fatigue among officers must be managed to minimize the risk for officers and the community. We cannot change the 24-hour nature of policing or the responsibilities of the officers in the field to enhance the safety of officers. Modifying, managing, understanding, and researching the human within the operational
environment, not changing the characteristics of the operational environment, is the more effective way to impact performance and safety.

Limitations

Despite the success of this innovative study design, this study is not without limitations. First, this design did not encompass any objective measures of sleep or sleep/wake cycles of the officers, such as actigraphy or sleep diaries. Wrist actigraphs, used regularly in sleep and fatigue research, collect data about the overall activity of participants using wrist worn accelerometers, allowing for objective measures of sleep periods which are indicated by periods of low arm movement. Sleep diaries provide a subjective measure of sleep and wake times, along with records of date/time activities for participants. This study did not include actigraphy or sleep diary data in its effort to assess the effect of night shift work on police officer performance. Although there is not objective data about the amount of sleep each officer had prior to each testing session, all officers were tested on the same days within their nine day duty cycle: once following five consecutive night shifts on duty, and once following three consecutive days off duty. Actual time in bed or total sleep time isn’t known among this group of officers. However, relying on the research regarding the buildup of fatigue effects seen after consecutive days of chronic sleep restriction combined with what is known about night shift work, it is reasonable to assume that five consecutive night shifts on duty would induce high levels of fatigue. Maintaining identical placement within the nine day duty cycle of both testing conditions allowed for the comparison of performance on the instance in which fatigue was most likely at its highest to the instance in which fatigue was likely to be at its lowest within some safety
specifications. Thus, actigraphy or sleep diary data, while possibly providing interesting results, were necessary for this study design.

Another limitation of this study is that the results, while providing new objective data regarding police fatigue and performance, may not be generalizable. This study sampled performance among officers working for one department in one city in Washington state. Additionally, these officers were working one of the four possible shifts for that particular department. Thus, results are not to be thought to apply to all officers working at all times of the day across the country. These results are specific to night shift officers in Washington state. However, that does not mean that the results from this study can’t imply associations or contribute to hypotheses of other shift types or departments. Until further replicated studies confirm and expand on the results reported in this study, generalizing should be viewed with caution.

A second issue regarding the generalizability of these results has to do with the types of simulated performance that were conducted as part of this data collection effort. While the issue of police officer fatigue is generally spoken about in terms of operational performance, this study used simulated and laboratory tasks that had been previously used and validated as primary measures of officer performance. Performance on the simulated tasks used in this study may not directly correlate with real job performance in the field. The performance tasks used in this study were simplified versions of things that officers do when working a patrol shift such as driving, vigilance, and deadly force decision making. This simplification affects the generalizability of the results in terms of being able to speak directly to actual real world operational performance of officers. As a proof of concept that night shift work affects simulated performance of officers, the previously used and validated tasks provided a good starting place to infer that degraded real
world performance could be a result of high levels of fatigue among police officers. With this initial data collection completed and successful, future studies can begin to modify simulated tasks that are better representations of critical operational tasks for police officers.

Along the lines of generalizability of results, specifically, the deadly force decision making performance assessments pushed the limits of signal detection theory as a technique for measuring decision making due to the low number of subjects and trials used in this analysis. Standard uses of signal detection theory in the psychology literature, for example, tend to involve studies in which participants are completing hundreds of decision making trials prior to analysis. The low number of trials seen in this study could be a factor affecting trends in decision making by a small number of officers in the sample or the reason why significance was not found for some of the signal detection measures. There are alternative methods for measuring performance in these simulated deadly force decision making scenarios such as standard forms of error coding for correct and incorrect decisions. The simulators are also programmed to gather data such as reaction time to shoot, number of shots fired, and location of shot placement. Together these two types of performance measurement, error coding and simulator generated measures, could possible provide a more informative performance measurement during these simulated deadly force scenarios. This is not to say that results are not valid. However, results should be interpreted with caution because of the low number of deadly force decision making trials completed by each officer during each testing condition.
Policy Implications

Management of fatigue for any occupation, especially one with the characteristics of policing, can be a very complex problem (Rosekind, 2005). However, as research dealing with shift work, sleep, and performance continues to evolve into more advanced results and techniques, management of workers in the field will become easier. Despite the complex problem, this study can lend some beneficial value to police departments and officers in terms of how to manage police fatigue. As Vila (1996, 2000, 2002, 2010) has advocated, police administrators, as well as officers themselves, must begin to take responsibility for managing fatigue.

Education, Advocacy and Outreach. First, the most important insight that this study can lend to practitioners in the field is that police officers are not immune to the effects of fatigue. Prior to this study, it was widely accepted that officers were a highly fatigued operational group, but the extent to which this fatigue caused performance impairment was not systematically explored. Again as previously mentioned, results indicate that officers experienced degraded simulated performance and impaired decision making following the night shift condition when compared to the control condition. However, the message about the risk to officers working night shifts and long, irregular shifts that induce fatigue must be made known to department administrators and individual officers. In terms of helping to manage possible shift-work induced fatigue that is likely to be present among all officers nationwide, the first step is for researchers to serve as advocates, getting the message of the effects of fatigue to the practitioners, department administrators, and individual officers themselves (Rosekind, 2005; Vila, 2002, 2010). Education and knowledge regarding the prevalence of fatigue, and the associated risks
combined with data similar to what was collected in this study will help police officers and managers understand the scope of the problem which will in turn result in more efficient practices and policies regarding officer fatigue. In order to change the culture of policing, there must be some degree of acceptance by police officers that there is a problem that needs a solution. The more that individual officers understand and accept that the accident and injury risk increases and overall safety decreases as the extent to which they are fatigued, the more likely they may be to monitor their own schedules, overtime work, sleep time, and other factors contributing to sleep hygiene. Police officers as well as police administrators have the ability to control aspects of their work and life to manage fatigue (Vila, 2010). However, making the decision to take control is up to them.

Additionally, the more department administrators and mid-level managers know about the effects of fatigue on operational performance, the more policies can be designed to combat such effects. For example, consideration that time of day a particular job task is being conducted or the duration an officer has been performing a task can both lead to increased fatigue effects on officer performance leading to decreased performance and increased risk. Department administrators, mid-level managers and even individual officers can possibly find ways to decrease risk and increase safety by taking time of day, time on task, and consecutive shifts into account, and when possible, designing policies and schedules with those things in mind. The first step of such integration begins with overall knowledge and understanding of sleep and fatigue as well as its effect on performance.

**Use of Fatigue Countermeasures.** A second thing that could benefit the management of fatigue among police officers is the use of fatigue countermeasures, especially among those officer working adverse shifts. However, for effective use of fatigue countermeasures, officers
and department administrators must have a solid understanding of the use and effectiveness of those countermeasures. Again, education and knowledge of fatigue countermeasures and their use becomes vital for their proper employment (Rosekind, 2005). Countermeasures include but are not limited to: caffeine management, naps, self-monitoring sleep-wake schedules, light exposure, exercise, and breaks during shifts.

Sleep is the best method to counter the cognitive and performance effects from sleep deprivation (Wesensten, Belenky, & Balkin, 2006). As such, napping during work hours may provide some relief from the effects of shift work induced fatigue among police officers. Naps are a commonly suggested countermeasure to minimize the effects of fatigue on performance (Caldwell et al., 2008; Rosekind, 2005). A recent meta-analysis of the literature on the efficacy of napping conducted by Driskell and Mullen (2005) revealed that napping may reduce the effects on performance of sleep loss or extended wakefulness. There have been arguments that while napping may help reduce the effects of fatigue, the effect on alertness from sleep inertia or the grogginess and diminished cognitive function experienced immediately upon waking could render naps less useful than hypothesized (Rosekind et al., 1995). However, other researchers suggest that the effects of sleep inertia on waking alertness, especially in the operational setting, may not be a concern given the amount of improvement achieved by the nap itself (Driskell & Mullen, 2005). It has been suggested that factors such as duration and timing of naps should also be considered when assessing the effect of a nap on performance and alertness (Caldwell et al., 2008). Caffeine has also been suggested as a counter to sleep inertia issues resulting from napping (Van Dongen et al., 2001). The overall view is that planned napping can help to alleviate some of the consequences of fatigue on performance and alertness. Policies and practices allowing for scheduled sleep opportunities during extended or adverse shifts may
improve the alertness and performance of those workers suffering from shift-work induced fatigue. Scheduled napping has been accepted in some industries such as commercial aviation and other transportation industries. Scheduled napping during shifts could be integrated into departmental policies or standard practices for police officers if done so in a manner designed to minimize the possible unintended outcomes associated with napping. However, this suggested integration may pose a challenge due to the role that calls for service play for police officers. Proper integration will need to be well informed and well thought out.

Another method to temporarily diminish the effect of fatigue on performance is through scheduled breaks during on duty shifts. Research has shown a positive effect on performance and alertness following rest breaks (Heslegrave & Angus, 1985). Breaks have also shown to offset the accumulation of accident risk (Tucker, Lombardi, Smith & Folkard, 2006). Department administrators and mid-level managers could help manage the effects of fatigue among police officers through scheduling breaks for officers during long and adverse shifts. Along with policies and procedures supporting and even scheduling breaks for officers, administrators must monitor officers in a more efficient manner with regard to breaks and naps. However, it is important to remember that the effects of rest breaks are temporary and not long lasting.

Caffeine is a frequently used fatigue countermeasure among police officers, although the officers themselves may not realize it. Caffeine has been shown in research to help minimize and temporarily reverse fatigue effects on performance (Bonnet & Gomez, Wirth, & Arand 2005; Caldwell, Caldwell, & Schmidt, 2008). However, the effects of caffeine, as with any other stimulant substances, are only temporary and can have unintended consequences for users. Caffeine has the ability to interfere with sleep, and increase talkativeness, anxiety and jitteriness (Wesensten et al., 2006). Proper use of caffeine, in terms of dose and timing of dose, can help
temporarily mitigate the effects of fatigue. Police officers may benefit from a better understanding of the effects of caffeine and other stimulants on alertness, cognitive performance, as well as sleep and behavioral consequences of their use. Department administrators and mid-level managers may also be able to monitor and help officers who are on duty use caffeine in a more efficient and properly dosed way or regulate the intake of caffeine by line officers more carefully and effectively. That said, caffeine provides a widely used, immediate countermeasure to alleviate the effects of fatigue temporarily and could provide officers with some relief from shift work induced fatigue.

Countermeasures can be used to temporarily mitigate the effects of fatigue on police officers while on shift. Department based education programs and policies for the use of countermeasures such as caffeine, scheduled napping, and rest breaks during shifts, could help departments and individual officers to better manage fatigue. While countermeasures may provide some immediate relief from fatigue, such effects are only temporary. The best way to combat fatigue due to sleep loss or chronic sleep restriction is through sleep itself (Wesensten et al., 2006)

*Sleep Disorder Diagnosis and Treatment.* Research has indicated that there is a high prevalence of sleep disorders among police officers (Rajaratnam et al., 2011). The link between sleep disorders and increased vehicle crash risk and accidents has also been explored in research (Connor, Whitlock, Norton, & Jackson, 2001; Williamson et al., 2001). Additionally, reductions in crash incident and risk associated with treatment of some disorders have been shown in research (Horstmann, Hess, Bassetti, Gugger, & Mathis, 2000; Williamson et al., 2011). Given the high prevalence of sleep disorders among police officers, departmental practices that include screening for sleep disorders, and treatment for those presenting with such disorders may help to
decrease some safety risks on the job, specifically operating motor vehicles. Policies and practices tailored to identifying and diagnosing those police officers who are at risk of having a sleep disorder and referring them to doctors who can diagnose and if needed begin treatment could decrease risks for those officers as well as the public. Integration of occupational sleep medicine, a new area of sleep medicine that includes sleep science, performance measurement, and the clinical practice of sleep medicine in an attempt to reduce safety risks for workers (Belenky, Wu & Jackson, 2011), could provide a way for administrators and individual officers to incorporate sleep disorders and treatment into the manage fatigue among police officers.

**Data-driven Modeling and Scheduling Tools.** Data driven scheduling of officers and management of officer fatigue provides another approach to tempering the effects of fatigue on performance. Fatigue risk management systems are one way in which data can drive the management of fatigue among occupational groups (Belenky et al., 2011). These systems involve modeling fatigue risk based on performance predictions given knowledge of prior sleep-wake schedules. Fatigue risk management systems also commonly include scheduling tools designed to offer optimal scheduling schemes based on predicted levels of cognitive efficiency, which are calculated from sleep and performance prediction. One such management system, the Sleep Activity Fatigue and Task Efficiency (SAFTE) model in conjunction with its partner scheduling tool, the Fatigue Avoidance Scheduling Tool (FAST), has been widely used and accepted within many shift working industries as a fatigue risk management and scheduling tool (Hursh et al., 2004). This system provides software to help manage the fatigue of industry workers based on factors such as duration of prior sleep, task workload, time awake, and consecutive days of work. The tool takes such factors and provides performance efficiency based on predications of prior performance under similar circumstances (Hursh et al, 2004).
SAFTE/FAST, and other systems like it can be adapted to fit other types of operational groups and work demands given the right data necessary for model adjustment.

While standard fatigue management tools would provide some benefit to departments or officers looking for way to manage fatigue, individual models using police officer performance data would be far more beneficial. Performance data collected in studies such as the present one combined with data regarding the officers’ sleep-wake cycles and subsequent performance can be used to enhance current fatigue risk management systems by comparing the predicted performance calculated by the models to actual performance of the officers. Similar enhancements can be done to modify scheduling tools to meet the specific needs of police officers. This type of enhancement would allow for the creation of fatigue risk management systems specifically tailored to police officers, similar to those that are being developed for the aviation, trucking and railway industries.

Given the value of occupationally specific fatigue risk management systems, laboratory collected performance data using actual police officers becomes a high priority for the next step in managing police fatigue. Modification of any type of existing model requires an abundance of data from which predictions can be fine-tuned for the occupational group in question. Thus, researchers looking to help manage police officer fatigue must focus on collecting actual performance data from actual police officers. This study provides a successful design with which such data can be collected. However, the design must be expanded to include shifts encompassing all times of day, various shift durations, various duty cycles, more relevant simulated occupational tasks, and more performance tasks. Much can be taken from the effectiveness of this particular study design in terms of bridging the gap between laboratory and
field data collection, but there is still a lot that needs to be done in the research area before specific fatigue risk management systems can be created for police officers.

Department administrators and mid-level managers could also benefit from the integration of common fatigue assessment tools used in research into standard department practices. For instance, this could entail having officers wear actigraphs during their work cycles or recording sleep, wake, and subjective sleepiness levels in a sleep diary. Measuring and actively monitoring fatigue levels during duty cycles would allow those scheduling and managing officers to see how much fatigued officers were prior to shifts. This information could be used to assign officers to less safety-critical tasks during a given shift or indicate who may be at increased risk. Departmental policies or standard practices based on data regarding what police officer occupational tasks are sensitive to the effects of shift work induced fatigue could be created to dictate what tasks would be good options for those officers who are at a high level of risk. However, determining the time of day and under what levels of fatigue certain occupationally relevant tasks are safe for officers to perform requires research and data. Departments might also benefit from the integration of fatigue risk management system, even the current general systems, into policies and standard procedures.

The ultimate goal for fatigue management among police officers could be real time assessment of fatigue risk in the field using police specific models implemented in a non-invasive way An example might be a watch-like device that contains a real time assessment of fatigue risk that could be monitored by mid-level managers or individual officers during their shifts. While this ultimate goal is still a long way off, this study provides a first step at collection of quantitative and objective performance data necessary for working toward this ultimate goal. Fatigue is always going to be a part of policing as with all occupations involving 24-hour
operations. The key to combating police officer fatigue will be rooted in enhanced management and scheduling techniques and tools that focus on more accurate assessments of risk and methods for increasing safety.
REFERENCES


APPENDICES
Appendix A: Informed Consent

Washington State University Spokane – Sleep and Performance Research Center

CONSENT FORM

Study: Pilot Study of the Effects of Fatigue Due to Night Shift Work on Police Performance

Researchers:
Bryan Vila, Ph.D. (509) 358-7711 (principal investigator)
Hans P. A. Van Dongen, Ph.D. (509) 358-7755 (co-principal investigator)
Devon A. Grant, M.S. (509) 358-7754 (study coordinator)
Lauren Waggoner, M.A. (509) 994-3025 (co-investigator)
Gregory Belenky, M.D. (509) 358-7738 (physician of record)
24-hour emergency number: (509) 953-6035 (physician of record cell phone)

RESEARCHERS’ STATEMENT: We are asking you to participate in a research study. The purpose of this consent form is to give you the information you need to decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we will ask you to do, the possible risks and benefits of participation, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want to be in the study or not. This process is called “informed consent.” Your informed consent is necessary for you to participate in this study. Participation in this study is voluntary—it is your own choice whether you decide to participate or not. We will give you a copy of this form for your records.

PURPOSE: The purpose of this study is to examine police performance during simulated critical tasks (e.g., driving and deadly force judgment and decision making) and how they are affected by fatigue resulting from working consecutive night shifts in the field. Using this information, we hope to gain a better understanding of the performance of police officers who are fatigued from working night shifts, which could also lead to a better understanding of other types of night shift workers and their performance.

SELECTION OF SUBJECTS: You have been invited to participate in this study because of your expressed interest and availability, in addition to being a healthy, sworn Spokane Police Officer who is currently working 10-hour night shifts, meaning that you currently report to work for a 10-hour shift starting between the hours of 8:00pm and 11:00pm, in which you have been working for more than 3 months.

PROCEDURE: You will first attend a screening session at the Sleep and Performance Research Center of Washington State University Spokane. This screening session will take 2 hours, and will involve determining
whether you are eligible to participate in the study. At the beginning of the screening session, we will ask you to drive for 10-15 minutes in our high-fidelity driving simulator, which works just like a real car except that it doesn’t move (but through the windows and in the mirrors it looks as if it does move). You will be asked to perform basic driving skills, and we will verify that you are not susceptible to simulator adaption syndrome (a strong feeling of disorientation or nausea that some people experience in a high-fidelity simulator environment). If you are unable to drive in the high fidelity driving simulator, or if you have a strong negative response to the simulator environment, you will not be able to participate in the study. You will then be asked to fill out the following series of questionnaires in order to determine your eligibility to participate in the study: a list of personal information (such as date of birth), a confidential questionnaire regarding your health and medical history, and several questionnaires regarding your sleep. Your honesty is counted on in completing these questionnaires. You will also fill out a tax identification number form and an invoice voucher, which are needed to process the payment for your participation in the study. We will also ask you to perform a 10-minute practice psychomotor vigilance task (PVT) test bout. At the end of the screening session, we will ask you to drive for about 30 minutes in the high-fidelity driving simulator.

The laboratory phase of the study will consist of two study sessions, with will both be carried out in the Sleep and Performance Research Center at Washington State University Spokane. We will be testing you on a day in which you are rested and a day in which you have just worked a night shift, in order to see if there is a difference in your performance. Therefore, you will be asked to come into the laboratory on two separate days for testing: a day off condition, and a working condition. The day off condition will be conducted on one of your days off. For this day off condition, we will ask you to come in around the average time you typically get off your night shift. The working condition will be conducted after you have completed a full night shift, in which you have worked consecutive night shifts immediately prior to your testing day. The order of the testing sessions, meaning with condition you will be tested on first, will be randomly assigned (by flipping a coin).

Each study session will take place during the morning hours, starting between the hours of 7:00am and 8:00am depending on the time your normal night shift ends. Each testing session will last a total of 3 hours in the laboratory. Following the rested condition you will be free to drive yourself home immediately following testing. However, after you have completed the working condition testing session, you will be required to sleep in the laboratory for 6 hours before driving home. This will allow you to gain recovery sleep from being awake for an extended period of time.
In each study session, upon arrival to the laboratory, you will be asked to lock up any and all firearms or other weapons that you have on your person. This is a safety measure put in place because our simulators require the use of replica handguns, and other devices designed to look “real.” You will be asked to wear a heart rate monitor for the duration of your testing session. You will also fill out a Karolinska Sleepiness Scale questionnaire.

During each of the two study sessions, you will be testing for a period of about 3 hours. A trained staff member will be present at all times. First, you will take a psychomotor vigilance test (PVT). The PVT is a 10-minute long computerized task administered on a hand-held smart phone. The task requires you to press a button as soon as a stimulus, in the form of a bull’s eye, appears on the test device.

Next, you will taken to the deadly force judgment and decision making simulator. You will be fitted with a duty belt with a holster for a replica handgun, briefed about the rules of engagement, shown how the simulator works, and how to use the replica handgun. This familiarization should take approximately 15 minutes. Once this familiarization is completed, you will be asked to perform 5 deadly force judgment and decision making simulation tasks, with a one minute break between each simulation. For these simulations, you will be alone in the range and asked to respond appropriately to the action projected onto a screen in front of you by asking questions, issuing verbal commands and warnings, and making decisions about whether to use deadly force. You will act on those decisions in a manner in which you think will minimize threats to bystanders or yourself, yet neutralize assailants. If necessary and appropriate, you will “shoot” your replica handgun at an assailant. Your actions during the testing session will be recorded using digital audio and video technology. The deadly force judgment and decision making testing will take approximately 20–25 minutes to complete.

Once you have completed the deadly force judgment and decision making testing, you will be given a second 10 minute PVT task. Following the completion of the PVT, you will be taken to the driving simulator for a driving performance task. The driving performance task will consist of two 30 minute driving sessions separated by another 10 minute PVT task. Each 30 minute driving session consists of a pre-programmed driving course specially designed for data collection. During each 30 minute driving session, you will be asked to drive at a constant speed on a very rural course in which people will walk out into the roadway at random times throughout the drive. You will be asked to use the brakes to slow down to avoid a collision.
with the people in the roadway. After completion of the driving task, you will be asked to take a final 10-minute PVT. Following this PVT, you will be asked to fill out another Karolinska Sleepiness Scale questionnaire as well as an end of the study questionnaire. Testing should be finished between 10:00am and 11:00am; depending upon what time you normally finish a night shift and arrived in the laboratory.

Following the completion of laboratory testing on for the day off condition, you will be able to collect all your possessions that were locked up prior to testing, including weapons and firearms. You will then be able to leave the laboratory.

Following the completion of the testing for the working condition, you will be required sleep for 6 hours in the laboratory or in a hotel at the laboratory’s expense before driving home. You will have a bedroom in the lab or a hotel room to sleep in for this recovery sleep. You will be given a small meal in the laboratory immediately following testing. If you are sleeping in the laboratory at approximately 11:00am you will be taken into the sleep lab for your 6 hours of recovery sleep. You will be awakened at 5:00pm, get a chance to shower, and have a snack. Finally, you will be able to collect your possessions that were locked up prior to testing, including weapons, and firearms. You will then be able to leave the laboratory around 6:00pm. If you are going to sleep in a hotel, at approximately 11:00am a staff member will drive you to the hotel. You will be given a phone number to call when you are ready to be picked up from the hotel. You must remain at the hotel for at least 6 hours. Once, you are picked up you will be brought back to the lab to collect all your possessions that were locked up prior to testing, including weapons, and firearms.

Trained staff members will be present at all times to monitor your activities. They will be able to see you on a television screen via a camera while you are performing the computer tasks and while you are sleeping. The camera images will be recorded and kept available for about one month after the study, after which they will be automatically erased.

WITHDRAWAL: You are free to withdraw your consent and to stop participation in this study at any time by indicating your desire to withdraw to the research staff. You may withdraw from the study at any time without penalty. You will be allowed to get sleep in the laboratory before going home if withdrawal during the working condition. Withdrawal of participation will not affect any current or future connections you may have with Washington State University or Spokane Police Department in any way.
RISKS: Participation in this research study involves some risks that you should be aware of. These risks include:

1. During the morning in the laboratory you will not have access to live television, radio, or your cellular telephone. Also, except in case of emergency you will not be allowed to have visitors or make or receive any phone calls. You will further not be allowed to consume alcohol or caffeine, or to smoke.

2. You may become sleepy at times during the study sessions. A member of the research staff will be with you at all times to assist you in staying awake, and you may be asked to interact with the staff to avoid falling asleep. Should you feel that you are completely unable to stay awake, you are free to withdraw your consent to participate in the study and then go to sleep in a bedroom inside the laboratory.

3. You will be asked to perform a performance task in our deadly force judgment and decision making simulator. Sometimes the performance testing may be difficult, and may produce some distress. Due to the realistic nature of the scenarios you will be exposed to in the deadly force judgment and decision making simulation, you may have some physiological responses such as anxiety or excitement. These scenarios may also remind you of a traumatic event that you have experienced in your past. You will be asked to maintain your best effort to perform all tasks throughout the study. Should you feel that you are unable to perform the task during the course of the study, you are free to withdraw your consent to participate in the experiment and then go to sleep in a bedroom inside the laboratory.

4. You will be asked to perform a performance task in a high-fidelity driving simulator. You may experience disorientation or a mild feeling of nausea. If you find that you are experiencing a strong reaction to the simulator environment (simulator adaptation syndrome), you are free to withdraw your consent to participate in the experiment and then go to sleep in the laboratory to recover.

5. The investigators reserve the right to stop your participation in the study at any time they feel it is necessary for your welfare or for research purposes (for example, if you are not adhering to the study protocol).

6. You may also be concerned about the confidentiality of your data, and personal information. However, only deidentified data labeled with a code number will be used for data analysis. The university requires us to collect social security numbers and other identifiers in order to pay you for your participation. This information will only be stored in the dedicated, secure data storage room in the Sleep and Performance Research Center. Thus, risks related to a breach of confidentiality are no greater than normal.

CONFIDENTIALITY: Every precaution will be taken to preserve your privacy and confidentiality. The researchers will keep any personal information as well as all data collected confidential to the extent allowed
by State and Federal law. No publication results will identify you, and your name will not be associated with
the findings in any publications, presentations or discussions resulting from the study. Authorized
representatives of the Washington State University Institutional Review Board (IRB), a committee charged
with protecting the rights and welfare of research subjects, may be provided access to research records that
identify you by name.

To further help us protect your privacy, the investigators have obtained a Certificate of Confidentiality from
the Department of Health and Human Services.

With this Certificate, the investigators cannot be forced (for example, by court subpoena) to disclose
information that may identify you in any federal, state, or local civil, criminal, administrative, legislative or
other proceedings. Disclosure will be necessary, however, upon request of the DHHS for audit or program
evaluation purposes.

You should understand that a Certificate of Confidentiality does not prevent you or a member of your family
from voluntarily releasing information about yourself or your involvement in this research. Note however,
that if an insurer or employer, learns about your participation, and obtains your consent to receive research
information, then the investigator may not use the Certificate of Confidentiality to withhold this information.
This means that you and your family must also actively protect your own privacy.

Finally, you should understand that the investigator is not prevented from taking steps, including reporting to
authorities, to prevent serious harm to yourself or others, and the Certificate does not prevent the review of
your research under some circumstances (for example, under the Federal Food, Drug and Cosmetic Act or
during the course of an internal program audit or evaluation).

INJURY FROM RESEARCH PROCEDURES: In the event of major injury resulting from the research
procedures, you will be transported to a hospital emergency room. Medical and transportation expenses
resulting from a hospital emergency room visit may be at your own expense. Washington State University
and/or its researchers will not cover these expenses.

COSTS: You will not be required to pay for anything related to your participation in the study. However, no
reimbursement will be provided for the cost of transportation to and from the laboratory.
PAYMENT: You will be compensated for your participation in the study. You will receive $600 for completing the study. If you are unable to complete the study, or you choose to withdraw from the study, then you will receive payment for the time of participation, as follows: $80 for the screening session, and $120 for the rested condition, and $400 for the working condition. Your check will be available approximately 2 weeks after the end of the study.

BENEFITS: You are likely to benefit from occupationally relevant training because the deadly force judgment and decision making simulations to which you will be exposed during the course of this study are of substantially higher quality than those which are normally used in police training. Our scenarios were videoed using professional actors and were developed based on empirical data on officer-involved shootings in the United States during the past 30 years. The driving simulations also are likely to provide you with insight into your own vulnerabilities to fatigue-related collisions on the job and during your drive home from work. More police officers in the United States die each year from accidents—predominately traffic-related accidents—than from any other cause.

QUESTIONS: It is your right to be fully informed about the procedures to be followed, and to be aware of any attendant discomforts, risks and benefits to be expected. If you have any questions about the research study you may contact Dr. Bryan Vila, Dr. Hans Van Dongen, or Dr. Gregory Belenky at the telephone numbers listed above.

SUBJECT’S STATEMENT: This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions about the research I can ask one of the researchers listed above. If I have questions regarding my rights as a research participant, or if I wish to report a concern or complaint about this research study, I can contact the Washington State University (WSU) Institutional Review Board (IRB) at (509) 335-9661, or by e-mail at irb@wsu.edu. This project has been reviewed and approved for human participation by the WSU IRB. I will receive a copy of this consent form.

Printed Name of Subject: _______________________

Signature of Subject: _______________________

Date: __________
RESEARCHER’S SIGNATURE:

Printed Name of Researcher: ________________________________

Signature of Researcher: ________________________________  Date: __________
Appendix B: Statistical Analysis Code (SAS 9.3)

**B.1: Data Format Description.** Each dependent variable in this study required its own individual spreadsheet due to the varying numbers of complete data sets for each of the variables. Data was imported into excel spreadsheets for analysis that were then imported into SAS. Each spreadsheet was set up in the same manner with subject data and testing information going across the rows of the spreadsheet, and columns representing variables for analyses. Table 6 (below) shows a sample spreadsheet from this analysis.

**Table 6: Data spreadsheet example**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Condition</th>
<th>Session</th>
<th>&lt;Covariate Variable&gt;</th>
<th>&lt;Dependent Variable&gt;</th>
<th>&lt;Dependent Variable&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;SubjectID&gt;</td>
<td>Condition was coded 0 for control condition and 1 for night shift condition.</td>
<td>Session was coded 1, 2, 3, 4, or 5 for each testing session for each condition.</td>
<td></td>
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<td></td>
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<td>&lt;SubjectID&gt;</td>
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</tr>
</tbody>
</table>

There were a total of 27 complete driving data sets used in this analysis with each subject completing four drives, two in each condition. Subsequently, each driving produced ten rows of data, totaling 40 rows of data for each subject. The ten rows of driving data for each drive were aggregated down to one value for each of the four dependent variables for each drive. Thus, in the final spreadsheet each subject had four rows of data, for a total of 108 rows of subject data.
The PVT data used a total of 24 data sets, with each subject completing four PVT’s during each testing session for a total of 8 PVT’s. This created a spreadsheet with 192 rows of subject data. Subjective sleepiness was completed by 29 subjects, two each condition for a total of four questionnaires yielding a spreadsheet containing 116 rows of subject data. Finally, the deadly force decision making data set included 28 subjects data. Each subject completed five deadly force scenarios during each testing session for a total of ten rows of subject data. The SDT analyses completed on all subjects data aggregated each conditions rows of data down into one row leaving each subject with two rows of data in the final spreadsheet. The total number of rows for the deadly force decision making was 56.

**B.2: Driving Data Reduction Code**

*dependent variables: lane deviation, speed variability, steering wheel angle, fuel usage;*
*means aggregated across each of the 10 straights;*

```sas
proc import out=DriveRaw
datafile="C:\Lauren\PhD\Dissertation\Analysis\DriveStraightRAW.xlsx"
dbms=xlsx replace; getnames=yes;
run;
```

*means for lane deviation, speed variability, steering wheel angle, acceleration, and fuel usage by condition;*

```sas
proc sort data=DriveRaw;
   by Condition;
proc means data=DriveRaw;
   var AverageSpeed STDSpeed AverageAccel STDAccel AverageSteering STDSteering AverageLane STDLane AverageMPH FuelUsage;
   by Condition;
run;
```

*creates two data sets from DriveRaw split by condition;*

```sas
proc sort data=DriveRaw;
```

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by condition session;
run;

data DriveWork;
  set DriveRaw; *work data set;
    if Condition=1;
  data DriveRest; *rest data set;
    set DriveRaw;
    if Condition=0;
run;

* work session one data set;
  data DriveWorkOne;
    set DriveWork;
    if Session=1;
  run;

*work session two data set;
  data DriveWorkTwo;
    set DriveWork;
    if Session=2;
  run;

*rest session one data set;
  data DriveRestOne;
    set DriveRest;
    if Session=1;
  run;

*rest session two data set;
  data DriveRestTwo;
    set DriveRest;
    if Session=2;
  run;

*code to aggregate 10 straight segments into one value for work condition first drive;

data AggDriveWorkOne;
  set DriveWorkOne;
  by Subject;
  SqSTDLane=STDLane**2;
  SqSTDSpeed=STDSpeed**2;
  SqSTDSteer=STDSteering**2;
\( \text{SqFuelUsage} = \text{FuelUsage}^2; \)

\[ \text{if first.Subject then} \]
\[ \text{DO;} \]
\[ \text{AvgSTDLane} = 0; \]
\[ \text{AvgSTDSpeed} = 0; \]
\[ \text{AvgSTDSteer} = 0; \]
\[ \text{AvgFuelUsage} = 0; \]
\[ \text{cnt} = 0; \]
\[ \text{END;} \]
\[ \text{AvgSTDLane} + \text{SqSTDLane}; \]
\[ \text{AvgSTDSpeed} + \text{SqSTDSpeed}; \]
\[ \text{AvgSTDSteer} + \text{SqSTDSteer}; \]
\[ \text{AvgFuelUsage} + \text{SqFuelUsage}; \]
\[ \text{cnt} + 1; \]
\[ \text{AggSTDLane} = \sqrt{\frac{\text{AvgSTDLane}}{10}}; \]
\[ \text{AggSTDSpeed} = \sqrt{\frac{\text{AvgSTDSpeed}}{10}}; \]
\[ \text{AggSTDSteer} = \sqrt{\frac{\text{AvgSTDSteer}}{10}}; \]
\[ \text{AggFuelUsage} = \sqrt{\frac{\text{AvgFuelUsage}}{10}}; \]

\[ \text{if last.Subject then output;} \]

\[ * \text{code to aggregate 10 straight segments into one value for work condition second drive;} \]

\[ \text{data AggDriveWorkTwo;} \]
\[ \text{set DriveWorkTwo;} \]
\[ \text{by Subject;} \]
\[ \text{SqSTDLane} = \text{STDLane}^2; \]
\[ \text{SqSTDSpeed} = \text{STDSpeed}^2; \]
\[ \text{SqSTDSteer} = \text{STDSteering}^2; \]
\[ \text{SqFuelUsage} = \text{FuelUsage}^2; \]
\[ \text{if first.Subject then} \]
\[ \text{DO;} \]
\[ \text{AvgSTDLane} = 0; \]
\[ \text{AvgSTDSpeed} = 0; \]
\[ \text{AvgSTDSteer} = 0; \]
\[ \text{AvgFuelUsage} = 0; \]
\[ \text{cnt} = 0; \]
\[ \text{END;} \]
\[ \text{AvgSTDLane} + \text{SqSTDLane}; \]
\[ \text{AvgSTDSpeed} + \text{SqSTDSpeed}; \]
\[ \text{AvgSTDSteer} + \text{SqSTDSteer}; \]
\[ \text{AvgFuelUsage} + \text{SqFuelUsage}; \]
\[ \text{cnt} + 1; \]
\[ \text{AggSTDLane} = \sqrt{\frac{\text{AvgSTDLane}}{10}}; \]
AggSTDSpeed = sqrt(AvgSTDSpeed/10);
AggSTDSteer = sqrt(AvgSTDSteer/10);
AggFuelUsage = sqrt(AvgFuelUsage/10);
if last.Subject then output;

*code to aggregate 10 straight segments into one value for rest condition first drive;

data AggDriveRestOne;
  set DriveRestOne;
  by Subject;
  SqSTDLane = STDLane**2;
  SqSTDSpeed = STDSpeed**2;
  SqSTDSteer = STDSteering**2;
  SqFuelUsage = FuelUsage**2;
  if first.Subject then
    DO;
      AvgSTDLane = 0;
      AvgSTDSpeed = 0;
      AvgSTDSteer = 0;
      AvgFuelUsage = 0;
      cnt = 0;
    END;
  AvgSTDLane + SqSTDLane;
  AvgSTDSpeed + SqSTDSpeed;
  AvgSTDSteer + SqSTDSteer;
  AvgFuelUsage + SqFuelUsage;
  cnt + 1;
  AggSTDLane = sqrt(AvgSTDLane/10);
  AggSTDSpeed = sqrt(AvgSTDSpeed/10);
  AggSTDSteer = sqrt(AvgSTDSteer/10);
  AggFuelUsage = sqrt(AvgFuelUsage/10);
  if last.Subject then output;

*code to aggregate 10 straight segments into one value for rest condition second drive;

data AggDriveRestTwo;
  set DriveRestTwo;
  by Subject;
  SqSTDLane = STDLane**2;
  SqSTDSpeed = STDSpeed**2;
  SqSTDSteer = STDSteering**2;
  SqFuelUsage = FuelUsage**2;
if first.Subject then
    DO;
    AvgSTDLane=0;
    AvgSTDSpeed=0;
    AvgSTDSteer=0;
    AvgFuelUseage=0;
    cnt=0;
    END;
    AvgSTDLane+SqSTDLane;
    AvgSTDSpeed+SqSTDSpeed;
    AvgSTDSteer+SqSTDSteer;
    AvgFuelUseage+SqFuelUsage;
    cnt+1;
    AggSTDLane=sqrt(AvgSTDLane/10);
    AggSTDSpeed=sqrt(AvgSTDSpeed/10);
    AggSTDSteer=sqrt(AvgSTDSteer/10);
    AggFuelUseage=sqrt(AvgFuelUseage/10);
    if last.Subject then output;
    run;

*creates one data set with all aggregated driving data;

data drive;
    set AggDriveWorkOne AggDriveWorkTwo AggDriveRestOne AggDriveRestTwo;
    run;

B.3: Signal Detection Analysis Reduction Code

*Import spreadsheet;

proc import out=DFDMRaw
    datafile="C:\Lauren\PhD\Dissertation\Analysis\DFDMRaw.xlsx" dbms=xlsx
    replace; getnames=yes;
    run;

*Coded variables: nullcoded, difficultycoded, weaponcoded, shotsfired, shotmiss, signal, noise, hits, miss, false alarm, and correct rejection;

data DFDM;
    set DFDMRaw;
    if Null='Yes' then NullCoded=1;
    if Null='No' then NullCoded=0;
if Difficulty='I' then DifficultyCoded=1; *intermediate=1 and  
journeyman=2;  
if Difficulty='J' then DifficultyCoded=2;  
if Weapon='Knife' then WeaponCoded=1; *knife=1, gun=2, bottle=9;  
if Weapon='Gun' then WeaponCoded=2;  
if Weapon='Bottle' then WeaponCoded=9;  
if NumberShotsFired>0 then ShotsFired=1;  
if NumberShotsFired=0 then ShotsFired=0;  
if ReactionTime<=RThit then ShotMiss=1; *if first shot didn't hit  
suspect then shotmiss=1;  
if ReactionTime=RThit then ShotMiss=0;  
if Null='No' then Signal=1; *threat scenarios - signal=1;  
if Null='Yes' then Noise=1;  
if Signal=1 & ShotsFired=1 then Hit=1; *shots fired during threat  
scenarios;  
if Signal=1 & ShotsFired=0 then Miss=1; *no shots fired during non-  
threat scenarios;  
if Noise=1 & ShotsFired=1 then FalseAlarm=1; *shots fired during non-  
threat scenarios;  
if Noise=1 & ShotsFired=0 then CorrectRejection=1; *no shots fired  
during threat scenarios;
run;

*Means for reaction time to shoot, reaction time to hit, and number of shots  
fired by condition;

proc sort data=DFDM; 
  by Condition; 
run;  
proc means data=DFDM; 
  var ReactionTime RThit NumberShotsFired; 
  by Condition; 
run;

*Ratios of hits, misses, false alarms, and correct rejections;

data DFDMRest; *data set containing data from only rest condition; 
  set DFDM;  
  if Condition=0; 
run;

proc sort data=DFDMRest; 
  by Subject Session; 
run;
data DFDMWork; *data set containing data from only work condition;
   set DFDM;
   if Condition=1;
run;

*aggregates all rest sessions for each subject into single summation of hits, misses, false alarms, correct rejections, signals, and noise;

proc sort data=DFDMWork;
   by Subject Session;
run;

data SDTRest;
   set DFDMRest;
   by Subject;
   if first.Subject then
      DO;
         sumHit=0;
         sumMiss=0;
         sumSignal=0;
         sumNoise=0;
         sumFalseAlarm=0;
         sumCorrectRejection=0;
         cnt=0;
      END;
      sumHit+Hit;
      sumMiss+Miss;
      sumSignal+Signal;
      sumNoise+Noise;
      sumFalseAlarm+FalseAlarm;
      sumCorrectRejection+CorrectRejection;
      cnt+1;
   if last.Subject then output;
run;

*aggregates all work sessions into one single summation of hits, misses, false alarms, correct rejections, signals, and noise;

data SDTWork;
   set DFDMWork;
   by Subject;
   if first.Subject then

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DO;
    sumHit=0;
    sumMiss=0;
    sumSignal=0;
    sumNoise=0;
    sumFalseAlarm=0;
    sumCorrectRejection=0;
    cnt=0;
END;
sumHit+Hit;
sumMiss+Miss;
sumSignal+Signal;
sumNoise+Noise;
sumFalseAlarm+FalseAlarm;
sumCorrectRejection+CorrectRejection;
cnt+1;
if last.Subject then
    output;
run;

*combined data set of aggregated summations for both conditions and
   calculation of hit, false alarm, correct rejection and miss rates;

data SDT;
    set SDTRest SDTWork;
    HR=sumHit/sumSignal; *hit rate;
    FAR=sumFalseAlarm/sumNoise; *false alarm rate;
run;

*loglinear adjustment to account for extreme values in the calculation of
   probabilities. 0.5 added to hits and false alarms while 1 was added to signal
   and noise values PRIOR to calculating probabilities;

data aSDT;
    set SDT;
    aHit=sumHit+0.5; *adjusted hit;
    aSignal=sumSignal+1; *adjusted signal;
    aFalseAlarm=sumFalseAlarm+0.5; *adjusted false alarm;
    aNoise=sumNoise+1; *adjusted noise;
    aHR=aHit/aSignal; *adjusted hit rate;
    aFAR=aFalseAlarm/aNoise; *adjusted noise;
run;
*calculation of probabilistic measures of DFDM performance (d-prime, c, beta). calculated the probabilities base on adjusted hit and false alarm rates for each subject.

```r
data prob;
  set aSDT;
  dprime=probit(aHR)-probit(aFAR);
  beta=exp((probit(aFAR)**2-probit(aHR)**2)/2);
  C=-(probit(aHR)+probit(aFAR))/2;
run;
```

**B.4: Distribution Box Plot Code**

*generates boxplots for driving data variables;

```r
title "Boxplot: Land Deviation";
proc boxplot data=drive;
  plot AggSTDLane*Condition /
     boxstyle=schematicid
     cboxes=black
     cboxfill=empty
     idsymbol=plus
     idcolor=black
     caxis=black
     cframe=empty;
  id Subject;
  label AggSTDLane='Lane Deviation (m)' Condition='Condition';
run;

title "Boxplot: Steering Wheel Angle";
proc boxplot data=drive;
  plot AggSTDSteer*Condition /
     boxstyle=schematicid
     cboxes=black
     cboxfill=empty
     idsymbol=plus
     idcolor=black
     caxis=black
     cframe=empty;
  id Subject;
  label AggSTDSteer='Steering Wheel Angle Variation' Condition='Condition';
```

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run;

title "Boxplot: Fuel Usage";
proc boxplot data=drive;
   plot AggFuelUseage*Condition / 
      boxstyle=schematicid
      cboxes=black
      cboxfill=empty
      idsymbol=plus
      idcolor=black
      caxis=black
      cframe=empty;
   id Subject;
   label AggFuelUseage='Fuel Usage (?)' Condition='Condition';
run;

*generates boxplots for PVT data variables;

title "Boxplot: PVT Mean RT";
proc boxplot data=PVT;
   plot MeanRT*Condition / 
      boxstyle=schematicid
      cboxes=black
      cboxfill=empty
      idsymbol=plus
      idcolor=black
      caxis=black
      cframe=empty;
   id Subject;
   label MeanRT='Mean Reaction Time (ms)' Condition='Condition';
run;

title "Boxplot: PVT - Total Lapses of Attention";
proc boxplot data=PVT;
   plot TotalLapses*Condition / 
      boxstyle=schematicid
      cboxes=black
      cboxfill=empty
      idsymbol=plus
      idcolor=black
      caxis=black
      cframe=empty;
   id Subject;
   label TotalLapses='Total Lapses of Attention' Condition='Condition';
title "Boxplot: PVT 1/RT";
proc boxplot data=PVT;
  plot ReciproicalRT*Condition /
    boxstyle=schematicid
    cboxes=black
cbboxfill=empty
    idsymbol=plus
    idcolor=black
    caxis=black
cframe=empty;
  id Subject;
  label ReciproicalRT='1/RT (ms)' Condition='Condition';
run;
*generates boxplots for KSS data variables;

title "Boxplot: Subjective Sleepiness";
proc boxplot data=KSSRaw;
  plot KarolinskaValue*Condition /
    boxstyle=schematicid
    cboxes=black
cbboxfill=empty
    idsymbol=plus
    idcolor=black
    caxis=black
cframe=empty;
  id Subject;
  label KarolinskaValue='Subjective Sleepiness (KSS)' Condition='Condition';
run;
*generates boxplots for DFDM data variables;

title "Boxplot: Hit Rate";
proc boxplot data=prob;
  plot HR*Condition /
    boxstyle=schematicid
    cboxes=black
cbboxfill=empty
    idsymbol=plus
    idcolor=black
    caxis=black
    cframe=empty;
run;
cframe=empty;
    id Subject;
    label HR='Hit Rate (HR)' Condition='Condition';
run;

title "Boxplot: False Alarm Rate";
proc boxplot data=prob;
    plot FAR*Condition /
        boxstyle=schematicid
cboxes=black
cboxfill=empty
idsymbol=plus
idcolor=black
caxis=black
cframe=empty;
    id Subject;
    label HR='False Alarm Rate (FAR)' Condition='Condition';
run;

title "Boxplot: Adjusted Hit Rate";
proc boxplot data=prob;
    plot aHR*Condition /
        boxstyle=schematicid
cboxes=black
cboxfill=empty
idsymbol=plus
idcolor=black
caxis=black
cframe=empty;
    id Subject;
    label aHR='Adjusted Hit Rate (aHR)' Condition='Condition';
run;

title "Boxplot: Adjusted False Alarm Rate";
proc boxplot data=prob;
    plot aFAR*Condition /
        boxstyle=schematicid
cboxes=black
cboxfill=empty
idsymbol=plus
idcolor=black
caxis=black
cframe=empty;
    id Subject;
label aFAR='Adjusted False Alarm Rate (aFAR)' Condition='Condition';
run;

title "Boxplot: Sensitivity (D-Prime)";
proc boxplot data=prob;
   plot dprime*Condition /
      boxstyle=schematicid
cboxes=black
cboxfill=empty
idsymbol=plus
idcolor=black
caxis=black
cframe=empty;
   id Subject;
   label dprime='Sensitivity (D-Prime)' Condition='Condition';
run;

title "Boxplot: Response Bias (beta)";
proc boxplot data=prob;
   plot beta*Condition /
      boxstyle=schematicid
cboxes=black
cboxfill=empty
idsymbol=plus
idcolor=black
caxis=black
cframe=empty;
   id Subject;
   label beta='Response Bias (beta)' Condition='Condition';
run;

title "Boxplot: Response Bias (c)";
proc boxplot data=prob;
   plot c*Condition /
      boxstyle=schematicid
cboxes=black
cboxfill=empty
idsymbol=plus
idcolor=black
caxis=black
cframe=empty;
   id Subject;
   label c='Response Bias (c)' Condition='Condition';
run;
**B.5: Driving Performance Code**

*Importing driving spreadsheet;*

```plaintext
class import out=drive
  datafile="C:\Lauren\PhD\Dissertation\Analysis\DriveStraight.xlsx"
  dbms=xlsx replace; getnames=yes;
run;
```

*Means for aggregated lane deviation, speed variability, steering wheel angle, and fuel usage;*

```plaintext
title "Aggregated Means (all variables)";
proc sort data=drive;
  by Condition session;
proc means data=drive;
  var AggSTDLane AggSTDSpeed AggSTDSteer AggFuelUseage;
  by condition;
run;
```

*Mixed-effects ANOVA's (condition-by-session) for aggregated lane deviation, speed variability, steering wheel angle, and fuel usage;*

```plaintext
proc sort data=drive;
  by Subject;
run;
```

*Aggregated lane deviation (AggSTDLane);*

```plaintext
proc mixed data=drive covtest;
  class Subject Condition Session;
  model AggSTDLane=Condition|Session ConditionFirst Simulator /solution;
  random intercept /subject=Subject solution;
  lsmeans Condition Session Condition*Session;
run;
```

*Aggregated speed variability (AggSTDSpeed);*

```plaintext
proc mixed data=drive covtest;
  class Subject Condition Session;
  model AggSTDSpeed=Condition|Session ConditionFirst Simulator /solution;
  random intercept /subject=Subject solution;
  lsmeans Condition Session Condition*Session;
run;
```

*Aggregated steering wheel angle (AggSTDSteer);*
proc mixed data=drive covtest;
   class Subject Condition Session;
   model AdjSTDSteer=Condition|Session ConditionFirst Simulator /solution;
   random intercept /subject=Subject solution;
   lsmeans Condition Session Condition*Session;
run;

*Aggregated fuel usage (AggFuelUsage);
proc mixed data=drive covtest;
   class Subject Condition Session;
   model AdjFuelUsage=Condition|Session ConditionFirst Simulator/solution;
   random intercept /subject=Subject solution;
   lsmeans Condition Session Condition*Session;
run;

B.6: PVT Performance Code

*Import the PVT spreadsheet;
proc import out=PVT
   datafile="C:\Lauren\PhD\Dissertation\Analysis\PVT.xlsx"
   dbms=xlsx replace; getnames=yes;
run;

*Means for PVT data;
proc sort data=PVT;
   by condition session;
proc means data=PVT;
   var MeanRT TotalAnticipations MajorLapses MinorLapses TotalLapses PMedianRTsGr2 ReciprocalRT;
   by condition;
run;

*Mixed-effects ANOVA's
proc sort data=PVT;
   by Subject;
run;

*Mean Reaction Time (MeanRT);
proc mixed data=PVT covtest;
   class Subject Condition Session;
   model MeanRT=Condition|Session ConditionFirst /solution;
random intercept /subject=Subject solution;
lsmeans Condition Session Condition*Session;
run;

*Total lapses of attention (TotalLapses);
proc mixed data=PVT covtest;
class Subject Condition Session;
model TotalLapses=Condition|Session ConditionFirst /solution;
random intercept /subject=Subject solution;
lsmeans Condition Session Condition*Session;
run;

*1/Reaction Time (ReciporicalRT);
proc mixed data=PVT covtest;
class Subject Condition Session;
model AdjRecRT=Condition|Session ConditionFirst /solution;
random intercept /subject=Subject solution;
lsmeans Condition Session Condition*Session;
run;

B.7: Subjective Sleepiness Code

*Import the KSS spreadsheet;
proc import out=KSSRaw
datafile="C:\Lauren\PhD\Dissertation\Analysis\KSSRaw.xlsx" dbms=xlsx replace; getnames=yes;
run;

*Means for Subjective Sleepiness;
title "Overall Means";*means for subjective sleepiness (KSS value);
proc sort data=KSSRaw;
by condition session;
proc means data=KSSRaw;
var KarolinskaValue;
by condition;
run;

*Mixed-effects ANOVA's
proc sort data=KSSRaw;
by Subject;
run;
*Subjective sleepiness (KSS value);
  proc mixed data=KSSRaw covtest;
    class Subject Condition Session;
    model KarolinskaValue = Condition|Session ConditionFirst /solution;
    random intercept /subject=Subject solution;
    lsmeans Condition Session Condition*Session;
  run;

B.8: Deadly Force Decision Making Performance Code

*Import spreadsheet;
  proc import out=DFDM
datafile="C:\Lauren\PhD\Dissertation\Analysis\DFDM.xlsx" dbms=xlsx replace; getnames=yes;
  run;

*ANOVAS;
  proc sort data=dfdm;
    by Subject;
  run;

  proc mixed data=dfdm covtest;
    class Subject Condition;
    model HR=Condition ConditionFirst /solution;
    random intercept;
    repeated Condition /subject=subject;
    lsmeans Condition;
  run;

title

  proc mixed data=dfdm covtest;
    class Subject Condition;
    model FAR=Condition ConditionFirst /solution;
    random intercept;
    repeated Condition /subject=subject;
    lsmeans Condition;
  run;

  proc mixed data=dfdm covtest;
    class Subject Condition;
    model aHR=Condition ConditionFirst /solution;
    random intercept;
repeated Condition /subject=subject;
lsmeans Condition;
run;

proc mixed data=dfdm covtest;
class Subject Condition;
model aFAR=Condition ConditionFirst /solution;
random intercept;
repeated Condition /subject=subject;
lsmeans Condition;
run;

proc mixed data=dfdm covtest;
class Subject Condition;
model dprime=Condition ConditionFirst /solution;
random intercept;
repeated Condition /subject=subject;
lsmeans Condition;
run;

proc mixed data=dfdm covtest;
class Subject Condition;
model c=Condition ConditionFirst /solution;
random intercept;
repeated Condition /subject=subject;
lsmeans Condition;
run;

B.9: Secondary Analysis Code

*Import Spreadsheet;

proc import out=drivecv
datafile="C:\Lauren\PhD\Dissertation\Analysis\DrivingCovariateSheet.xl"
dbms=xlsx replace; getnames=yes;
run;

*Mixed model ANOVA;

proc mixed data=drivecv covtest;
class Subject Condition DriveSession;
model AggSTDlane=Condition|DriveSession ConditionFirst Simulator
*Import spreadsheet;

proc import out=pvtcv
datafile="C:\Lauren\PhD\Dissertation\Analysis\PVT_Covariates.xlsx"
dbms=xlsx replace; getnames=yes;
run;

proc mixed data=pvtcv covtest;
class Subject Condition Session;
run;
model TotalLapses = Condition|Session ConditionFirst KarolinskaValue;
random intercept /subject=Subject;
lsmeans Condition Session Condition*Session;
run;

proc mixed data=pvtcv covtest;
class Subject Condition Session;
model TotalLapses=Condition|Session ConditionFirst MAPSPrediction;
random intercept /subject=Subject;
lsmeans Condition Session Condition*Session;
run;

proc mixed data=pvtcv covtest;
class Subject Condition Session;
model TotalLapses=Condition|Session ConditionFirst PSQI;
random intercept /subject=Subject;
lsmeans Condition Session Condition*Session;
run;

*Import spreadsheet;

proc import out=ksscv
datafile="C:\Lauren\PhD\Dissertation\Analysis\KSSCovariates.xlsx"
dbms=xlsx replace;
  getnames=yes;
run;

proc mixed data=ksscv covtest;
class Subject Condition Session;
model KarolinskaValue=Condition|Session ConditionFirst MAPS_Prediction;
random intercept /subject=Subject;
lsmeans Condition Session Condition*Session;
run;

proc mixed data=ksscv covtest;
class Subject Condition Session;
model KarolinskaValue=Condition|Session ConditionFirst PSQI;
random intercept /subject=Subject;
lsmeans Condition Session Condition*Session;
run;
Appendix C: Additional Plots from Statistical Analysis

C.1: Distribution Box Plots for Dependent Variables

Figure 16: Lane Deviation Box Plot
Figure 17: Steering Wheel Angle Box Plot

Figure 18: Fuel Usage Box Plot
Figure 19: Speed Variability Box Plot

Figure 20: Total Lapses Box Plot
Figure 21: Mean Reaction Time Box Plot

Figure 22: 1/RT Box Plot
Figure 23: Subjective Sleepiness Box Plot

Figure 24: Hit Rate Box Plot
Figure 25: False Alarm Box Plot

Figure 26: Sensitivity Box Plot
Figure 27: Response Bias Box Plot
C.2: Additional Plots from Primary Analysis

Figure 28: Lane Deviation by Condition

Figure 29: Lane Deviation by Testing Session
Figure 30: Steering Wheel Angle by Condition

Figure 31: Steering Wheel Angle by Testing Session
Figure 32: Fuel Usage by Condition

Figure 33: Fuel Usage by Testing Session
Figure 34: Speed Variability by Condition

Figure 35: Speed Variability by Testing Session
Figure 36: Speed Variability by Condition and Testing Session

Figure 37: Total Lapses by Condition
Figure 38: Total Lapses by Testing Session

Figure 39: Mean Reaction Time by Condition
Figure 40: Mean Reaction Time by Testing Session

Figure 41: 1/RT by Condition
Figure 42: 1/RT by Testing Session

Figure 43: Subjective Sleepiness by Condition
Figure 44: Subjective Sleepiness by Testing Session

Figure 45: Distribution of mean false alarm rate by mean hit rate
Figure 46: Hit Rate by Condition

Figure 47: Response Bias by Condition
C.3: Additional Plots from Secondary Analysis

Figure 48: Lane Deviation by Subjective Sleepiness

Figure 49: Lane Deviation by MAPS
Figure 50: Lane Deviation by PSQI

Figure 51: Total Lapses by Subjective Sleepiness
Figure 52: Total Lapses by MAPS

Figure 53: Total Lapses by PSQI
Figure 54: Subjective Sleepiness by MAPS

Figure 55: Subjective Sleepiness by PSQI