SLEEP DISTURBANCES AMONG FIREFIGHTERS: THE IMPACT OF SHIFT WORK ON SLEEP AND COGNITION

by

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ABSTRACT

A comprehensive sleep assessment of 45 firefighters was conducted over 9- days in an effort to determine the impact of their 24 hour work and 48 hour off work schedule on their sleep duration, sleep quality, processing speed, sustained attention, vigilance, and mental health. Chronic patterns of poor sleep are associated with an increased likelihood of performing poorly on tasks that require processing speed and sustained attention/vigilance which could lead to firefighters' suboptimal work performance or an increased risk of injury. Firefighters completed sleep actigraphy, self- report measures, as well as neuropsychological sub-tests at their beginning of their shift and immediately at the end of their work shift. As measured by actigraphy, firefighters in this sample slept an average of 5 hours and 20.99 minutes at work, which was significantly less than was found in a large sample of U.S. working adults. Firefighters endorsed poor sleep efficiency and poor sleep quality as assessed by self-report and objective actigraphy. One limitation is that only 12 of the 45 firefighters endorsed responding to a nighttime call during the work night that occurred between the two neuropsychological assessments. Comparing changes in neuropsychological performance between firefighters who had disrupted sleep compared to firefighters who did not, significant performances decrements were evident only for the psychomotor vigilance test (PVT) reaction time. If confirmed with a larger sample, the results suggest that reaction time may be a sensitive indicator of decreasing cognitive performance because of sleep loss. Limitations, future study directions, and recommendations are discussed.

Keywords: firefighters, sleep, actigraphy, processing speed, psychomotor vigilance task

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CHAPTER ONE: INTRODUCTION

First responders (i.e., police officers, firefighters, paramedics, emergency medical technicians, dispatchers, and any other employee of an emergency service) report disrupted sleep patterns as a result of long, variable and inconsistent work- shifts (Vila & Samuels, 2010). Chronic sleep disruption can lead to fatigued first responders who, in turn, could suffer from a decrease in overall performance, and decision-making deficits (Banks & Daniels, 2007). The work schedules of one group of first responders, namely firefighters, typically consists of 24 hours on shift and 48 hours off shift (or 48 and 72 hours, respectively) and this type of work schedule may also contribute to sleep problems. Numerous studies confirm that shift work disrupts workers' natural sleep process (Drake, Roehrs, Richardson, Walsh & Roth, 2004; Ohayon, Lemoine, Arnaud-Briant & Dreyfus, 2002), and in some cases, leads to the development of shift work disorder (SWD; Wright, Bogan & Wyatt, 2012). Shift work disorder (5th ed.; DSM–5; American Psychiatric Association, 2013) is, "a circadian rhythm sleep disorder" that includes a pattern of disrupted sleep related to circadian disruption and circadian misalignment resulting in insomnia and/or excessive daytime sleepiness, and the sleep disturbance results in significant impairment in their lives (Wright, Bogan & Wyatt, 2012, p. 41).

Several factors influence sleep, but one of the main processes is the circadian system, which promotes brain arousal during the day and, at night, promotes sleep (Wright, Bogan & Wyatt, 2012). The circadian system, the "brain's master clock," is regulated by the suprachiasmatic nuclei (SCN; Wright, Bogan & Wyatt, 2012). The SCN

is, “primarily synchronized by the daily light/dark cycle”, and maintains a 24-hour cycle of, “wakefulness and sleepiness, organ function, and cognition” (Duffy & Czeisler, 2009; Wright, Bogan & Wyatt, 2012). Regulated by the SCN, the pineal gland typically releases melatonin 2 hours before one’s habitual bed time. Melatonin serves to reduce SCN neuronal firing, and may serve to initiate a homeostatic sleep drive known as sleep inertia. In other words, melatonin release initiates a chain reaction that leads to sleepiness. Therefore, when work activity takes place during what should be the normal, circadian rhythm driven rest period, shift workers experience sleep disruption that negatively impacts their mental and physical health. Specifically, sleep restriction is known to negatively impact mood and is, “associated with adverse health outcomes, including total mortality, cardiovascular disease, type 2 diabetes, hypertension and respiratory disorders, obesity in both children and adults, and poor self-rated health” (Cappuccio, D'Elia, Strazzullo & Miller, 2010, p. 586).

Firefighters’ “shift work schedules may negatively influence [their] physiology, health, and safety” because it “disrupts their circadian sleep and alerting cycles, resulting in disturbed daytime sleep and excessive sleepiness during the work shift” (Wright, Bogan & Wyatt, 2012, p. 41). Firefighters are abruptly awakened by fire alarms at intermittent times at night, and these prolonged periods of sleep disruption may put them at higher risk of developing a wide variety of physical and mental health problems (Carey, Al-Zaiti, Dean, Sessanna & Fennell, 2011; de Barros, Martins, Saitz, Bastos & Ronzani, 2012; Waters & Bucks, 2011; Wright, Bogan & Wyatt, 2012).

People under prolonged shift work conditions are at higher risk of occupational or motor vehicle accidents (Roth, 2012). Feeling sleepy can, "lead to rapid and frequent uncontrolled sleep or micro sleeps, frequent prolonged eye-lid closures, and inattention in the form of behavioral lapses that involve a failure to detect a monitored stimulus or a failure to respond in a normal timely manner" (Kloss, Szuba & Dinges, 2002, p. 1898). Daytime performance can be affected by hours slept, time awake, disrupted sleep, and sleep inertia or impairment in alertness level (Elliott & Kuehl, 2007). These same authors noted that a general grogginess feeling most often occurs when one wakes up from a deep stage of NREM sleep, and that this grogginess can take as long as two hours before the individual becomes fully alert. Within one sample of firefighters, screening positively for a sleep disorder was associated with a motor vehicle crash and self-reports of falling asleep while driving (Barger et al., 2015).

In addition to physical impairment, sleep deprivation in firefighters may be associated with mental health impairment such as binge drinking, poor mental well-being and depression (Carey, Al-Zaiti, Dean, Sessanna & Fennell, 2011; de Barros, Martins, Saitz, Bastos & Ronzani, 2012; Hom, Stanley, Rogers, Tzoneva, Bernert & Joiner, 2016). Finally, although not specifically limited to firefighters, a recent meta-analysis found that chronic sleep disruption can have, "a substantial impact on health and mortality, and also cognition and mood," and these authors of this meta-analysis concluded that, "Sleep loss reliably produces reductions in speed of processing and attention" (Waters & Bucks, 2011, p. 571). Therefore, losses of attention/vigilance and processing speed due to sleep deprivation could produce significant functional impairment in firefighter performance.

Attention is the ability to, "maintain focus over extended periods", and vigilance is the ability to maintain close, continuous attention to specific stimuli (Warm & Parasuraman, 2008). According to Lim and Dinges (2010), "impairment of the [Pre-Frontal Cortex; PFC] following a period of [sleep deprivation; SD] may underlie changes in both executive functioning and attention" (Lim & Dinges, 2010, p. 376). Meta-analytic evidence also suggests that simple attention and vigilance showed the greatest decline under sleep deprivation conditions; however, "the average effect size of the change in accuracy measures for tests of processing speed" was not statistically significant (p =.06; Lim & Dinges, 2010, p. 376).

Processing speed, clinically defined as the rate at which one takes in information, makes sense of it, and executes some form of cognitive operation, is typically interpreted as, "the faster the processing can be performed, the better the resulting level of cognitive performance" (Kail & Salthouse, 1994, p. 201). Some of the primary domains of processing speed include reaction time, general speed of processing, speed of short-term memory processing, speed of long term memory retrieval, and inspection time (Sheppard & Vernon, 2008). One meta-analysis (Lim & Dinges, 2012) failed to find a statistically significant accuracy decline in processing speed after 24-48 hour sleep deprivation. However, individual studies have found decrements in speed on both simple response time tasks and reductions on tasks of both processing speed and executive functions such as the Trail Making Test (Waters & Bucks, 2011; Martin, Engleman, Deary & Douglas, 1996).

Although no existing studies of sleep and cognition conducted on firefighters during their actual shift days are known to the author, researchers in one study (Christoforou, Cvirn, Ferguson, Armstong & Smith, 2013) created a simulated "work day" experience and examined the reaction time performance of 24 Australian firefighters. The research design utilized a controlled environment where, on the first night, firefighters slept 8 hours followed by 2 nights of 4- hours of sleep, followed by a "recovery" night where they had the opportunity to sleep 8- hours. The results indicated significantly lower reciprocal reaction times on day 2 compared to day 1, as assessed by the Psychomotor Vigilance Test (PVT). This suggests that, after one night of sleep deprivation, firefighters are susceptible to decreased reaction time performance. After the second night of sleep restriction, deficits in performance were amplified, but after 8 hours of sleep on the fourth night, their performance was significantly improved. They recommended that fire departments, "acknowledge that even one night of little sleep may lead to a decline in their ability to remain vigilant and respond rapidly to threatening situations" (Christoforou, Cvirn, Ferguson, Armstong & Smith, 2013).

In summary, because of their unique work schedules, firefighters may undergo prolonged periods of chronic sleep disruption. As a result of this chronic pattern of poor sleep, firefighters may have an increased likelihood of performing poorly on tasks that require processing speed and sustained attention/vigilance (Waters & Bucks, 2011). In turn, these impairments may put them at greater risk for suboptimal performance or accidents at work. Despite these concerns, to our knowledge, no study has looked at how mental health, processing speed, and sustained attention/vigilance are influenced by

firefighters' actual shift schedule. Given the need for firefighters to respond rapidly in life and death situations, assessing how sleep deprivation may impact cognitive processes such as attention, vigilance, and processing speed of first responders is needed.

This study has 3 specific aims/hypotheses:

Hypothesis 1: As assessed by sleep actigraphy and self-report, firefighters will endorse sleep difficulties as they cycle through a 24 hour on/48 hour off work rotation.

Hypothesis 2: Firefighters who get less sleep on an "on shift" night will demonstrate decreased processing speed scores at end of shift (as assessed by The Trail Making A and B and subsequent alternate versions, and RBANS Coding) in comparison to firefighters who did not lose sleep responding to emergency calls.

Hypothesis 3: Firefighters who get less sleep on an "on shift" night will demonstrate decreased sustained vigilance and auditory attention scores at the end of shift [as assessed by the psychomotor vigilance task (PVT) and the Woodcock Johnson Auditory Attention, (WJAA) tasks] in comparison to firefighters who did not lose sleep responding to emergency calls.

Exploratory Analyses: Because of their shift work and their frequent exposure to traumatic events, the severity of mental health symptoms in this group of firefighters was compared to the general population. Finally, the relationships between licit drugs (caffeine and alcohol) and sleep disturbance variables will be assessed.

CHAPTER TWO: METHOD

Participants

This study was approved by the University of Central Florida's Institutional Review Board**,** and all firefighters provided written consent to participate. Firefighters worked full time and participants were excluded if they reported taking medications specifically to promote sleep or linked to excessive drowsiness (Ambien, Prazosin, and Trazodone). Other exclusionary criteria included substance abuse disorders, and/or major sleep disorders (sleep apnea, periodic limb movement).

Fifty-four firefighters were screened for participation; six (6) firefighters endorsed sleep apnea and 3 firefighters did not want to discontinue sleep medication. Therefore, 45 firefighters participated in the study. Four of the 45 firefighters did not wear the sleep watch, and not all the 45 firefighters completed all the assessment materials. Only one of the 45 firefighters in this study was a female; however, none of her results were found to be an outlier from the other 44 firefighters. Therefore, the decision was made to keep her data in the study. Demographic data are listed in Table 1.

Measures

Sleep measures.

The Pittsburgh Sleep Quality Index (PSQI) is a self-report measure that assesses sleep quality and disturbances over a one-month time interval. It allows the rater to describe the total sleep time compared to the total awake time, the overall sleep quality and/or efficiency, sleep

latency and sleep disruption (Buysse et al., 1989). It has good internal consistency and convergent validity with sleep quality, and good internal consistency and convergent validity with trauma exposure, PTSD symptoms, depression, and anxiety (Insana, 2013). A score of 5 or more on this scale is considered indicative of poor sleep quality.

Micro Sleep Watch actigraphs (Ambulatory Monitoring, Inc.) were used to objectively measure sleep. The device is worn on the wrist and continually records movement. Data are then downloaded and analyzed using a validated computer-generated algorithm for detecting sleep versus wake periods. Actigraphy shows high correlation (0.97) with polysomnography (Jean-Louis, VonGizycki, & Zizi, 1996), and are considered, “valid and reliable devices for detecting sleep/wake diurnal patterns” (Cellini, Buman, Mcdevitt, Ricker, & Mednick, 2011, p. 691). Variables analyzed from actigraphy recordings included: (a) total sleep minutes (amount of actual sleep time during the time in bed), (b) wake after sleep onset (WASO; total wake minutes from sleep onset to final morning awakening), (c) sleep efficiency (total sleep minutes divided by total time in bed), (d) sleep onset latency (time period from "lights out," or bedtime as indicated by event markers to sleep onset), and (e) time in bed (minutes from bedtime to final morning awakening).

Participants completed a paper and pencil sleep log (recording total sleep time in hours and minutes) and an activity log for nine days (three 24 hours on/48 hours off shifts for a total of three days on shift and six days off shift). Participants recorded their daily sleep quality (separately from the PSQI) on a 0-4 Likert scale as well as their alertness level throughout the day on a 0-4 Likert scale (where 0 for both scales equates to poor or least and 4 equates to best or most). Participants recorded frequency of symptoms associated with trauma and emotional

arousal such as the number of nightmares, flashbacks, verbal rage episodes, and physical rage episodes. These emotional arousal symptoms may interfere with sleep (Stout et al., 2017). The form also included global rating scales for anxiety and anger, which were rated on a 10- point scale ranging from 0 = no anxiety/anger; 5 = moderate anxiety/anger; 10 = Most anxious/angry. The frequency of caffeinated drinks and alcohol beverages was also assessed via the activity log.

Processing speed measures.

The Trail Making A and B and subsequent alternate versions, "provides information on visual search, scanning, speed of processing, mental flexibility, and executive functioning" and has excellent test and retest reliability (Tombaugh, 2004, p. 203). This task required the participant to quickly draw lines to connect numbers from lowest to highest. Next, on a separate page, the participant was required to quickly draw lines from a number to a letter back to a number, in alpha numeric order, starting with the lowest number followed by the letter a (Baron, 2004). In order to guard against the negative consequences of practice effects (e.g., Beglinger et al., 2005), the standard version will be given at Time 1, and the alternate version will be given at Time 2.

Two alternate versions of the RBANS Coding sub test (Randolph, Tierney, Mohr & Chase (1998) were used to measure processing speed at Time 1 and Time 2. Coding measures processing speed, short-term visual memory, psychomotor speed, and visual-motor coordination (Randolph, Tierney, Mohr & Chase (1998) by requiring the participant to copy symbols that are paired with numbers within a specified time limit.

Sustained attention and vigilance measures.

The psychomotor vigilance task (PVT) is a sustained-attention, reaction-timed task that measures the speed with which subjects respond to a visual stimulus. (Dinges & Powell, 1985; Blatter et al., 2006). It is one of the most common tests used to measure alert levels, and numerous studies have found it to be a sensitive measure to sleep loss (Lim & Dinges, 2008; Dorrian, Dinges & Kushida, 2005).

On the Woodcock Johnson Auditory Attention, (WJAA) the participant tries to recognize words dictated against increasingly loud background noise measured an aspect of speech-sound discrimination, and it measures the participants' ability to overcome the effects of auditory distractions (Woodcock, McGrew, Mather & Schrank, 2003). This is an auditory processing ability requiring selective attention, and it has been shown to have high reliability and validity (Schrank & McGrew, 2001; Woodcock, McGrew, Mather & Schrank, 2003), and, with regards to firefighters, it has excellent ecological validity because this task can be compared to when firefighters arrive to a call and is forced to attempt to listen to orders over the radio while attending to external stimuli associated with a typical call.

Mental health measures.

As noted above, prolonged periods of disrupted sleep can lead to a wide variety of mental health symptoms; therefore, this study administered diagnostic interviews and various mental health self-report measures. The Mini International Neuropsychiatric Interview (MINI) module for DSM-5 With Mixed Features specifier (MINI, Tolin et al., 2016; Sheehan et al., 1998) is a structured diagnostic interview for psychiatric disorders that has good inter-rater and test retest

reliability (Sheehan et al., 1997; Lecrubier et al., 1997). The interview was administered by 6 clinicians supervised by a licensed psychologist and nine (20%) of the interviews were coded by a second individual for inter-rater reliability, with a Kappa coefficient of 1.00.

The PTSD symptom severity was assessed with the PTSD Checklist (PCL-5; Weathers, et al., 2013), a 20-item self-report inventory. Symptoms are rated using a five-point Likert-scale ranging from 1 (not at all) to 5 (extremely). The PCL-5 has excellent internal consistency, test-retest reliability, and convergent and discriminant validity (Bovin et al., 2015). In addition, a score of 33 on the PCL-5 is considered indicative of a diagnosis of PTSD (Bovin et al., 2015). Previous versions of the new PCL are highly correlated with the Clinician Administered PTSD Scale (CAPS-5; 0.93; Blanchard, Jones-Alexander, Buckley, Forneris, 1996).

Depressive symptoms were assessed by the Beck Depressive Inventory version II (BDI-II; Beck, Steer & Brown, 1996). The BDI-II is a 21- item self-report measure that has demonstrated excellent internal validity (Dozois, David, Dobson, Keith, Ahnberg & Jamie, 1998).

Anxiety symptoms were assessed by the Global Anxiety Disorder self-report measure (GAD-7; Spitzer, Kroenke, Williams & Löwe, 2006). The GAD-7 is a 7- item anxiety scale with good reliability, sensitivity (89%), and specificity (82%). It is a moderately good screener for other common anxiety disorders such as PTSD, social anxiety disorder, and panic disorder (Kroenke, Spitzer, Williams, Monahan & Löwe, 2007).

A Quality of Life Inventory (QOLI; Frisch, Cornell Villanueva & Retzlaff, 1992) was given to assess firefighters' perception of their overall quality of life across 15 domains. It is a 32

item self-report, and it assesses dimensions of interpersonal relationships (marital, parent-child, extended family, extramarital, and occupational) and social activities (altruistic behavior, political behavior, creative-aesthetic behavior, sports activity, and vacation behavior). These domains are broken into subscales which have been shown to have good internal consistency and test-retest reliability (QOLI; Frisch, Cornell Villanueva & Retzlaff, 1992).

Procedure

Participants were recruited through flyers, websites, in person at fire stations, and at outreach events and screened in person or by telephone. After determining eligibility, participants were administered the MINI to confirm the presence or absence of DSM-5 disorders, and completed the BDI-II, PCL-5, QOLI, and PSQI. They were also instructed on the use of the actigraph and the self-report sleep and activity log; specifically, to wear the sleep actigraph each night and to fill out the activity logs for 9 consecutive days. Nine consecutive days of actigraph sleep data allowed for the assessment of 3 nights while working at the fire station (on shift) and for 6 nights while not working (off shift). Overall, 32 of the firefighters wore the watch for 9-nights, 6 firefighters wore the watch for 8 nights, 1 firefighter wore the watch for 7 nights, 2 firefighters wore the watch for 6 nights, and 2 firefighters wore the watch for 4 nights. The average nights worn for all participants was 8.38 nights. All the firefighters included in the analyses wore the watch for at least two days while they were on shift and at least two days while they were off shift.

Processing speed and sustained attention/vigilance was assessed at two time points: when they first started their shift (Time 1; after 48 hours of off duty), and at the end of their work shift (Time 2, same work day as Time 1).

CHAPTER THREE: RESULTS

Sleep Dysfunction

Sleep dysfunction could be lack of sleep (sleep duration) or problems with the quality of sleep, thus these characteristics were analyzed separately.

Sleep duration.

As measured by actigraphy, firefighters in this sample slept significantly less than the U.S. general population on work day and non-work days combined (i.e., weekly average; 6 hours and 6.2 minutes vs 7 hours and 6 minutes respectively - one sample t test; M =366.20, SD=50.16 vs. M =426); t (40) = -7.633, $p < .001$). Compared to the normative sample, 90.2% (n= 37) of firefighters slept less than the 7- hours and 6- minute average, and 39% (n=16) slept less than 6 hours per night, on average.

Based on actigraphy, the average workday sleep duration was 5 hours and 20.99 minutes, which was significantly less than the average off-day sleep duration of 6 hours and 30.26 minutes (M =320.99, SD=73.59 vs. M =390.26, SD = 53.46; t (40) = -5.78, $p <$ .001).

Since the study analyzed neuropsychological functioning at the start and end of a 24 hour work shift, further analyses explored firefighters' first night sleep duration. Average on shift sleep duration was 5 hours 28.93 minutes (M= 328.93, SD=101.91).

Sleep quality.

With respect to overall sleep quality, mean PSQI score was 6.84, which is above the suggestive cut off score of 5 and is indicative of poor perceived sleep quality. Only 11 firefighters reported a PSQI total score of 4 or less, indicative of perceived good sleep quality. There were no significant differences on actigraph sleep duration (overall, on shift, and off shift) between firefighters who endorsed good sleep quality (4 or less on the PSQI) and firefighters that endorsed poor quality of sleep (5 or more on the PSQI). These data suggest that sleep duration was not a good predictor of sleep quality, and that firefighters, regardless of how long they reported sleeping, reported overall poor sleep quality.

On the nightly sleep record, firefighters rated their overall sleep quality on a 0 to 4 scale as 2.19, which is indicative of "fair sleep". A paired samples *t* test revealed that firefighter's sleep quality on shift was perceived as significantly poorer than firefighter's sleep quality off shift (M =1.72 vs. M =2.44; see Table 2).

Consistent with self-report, actigraphy data revealed overall sleep efficiency was 83.95%, which is indicative of spending approximately 16% of time awake in bed. Thirty-seven (37) out of 41 (90.2%) firefighters had sleep efficiency scores of less than 90%, which is indicative of poor sleep efficiency, and 9 of the 41 firefighters had sleep efficiency scores of 80% or less, which is indicative of very poor sleep efficiency. Comparing on shift vs. off-shift, actigraph sleep efficiency on work days was significantly less than on non-work days (M =78.41 vs. M =87.04; see Table 2); average sleep efficiency on shift was 8.63% less than average sleep efficiency off shift, indicating

firefighters spent more time awake while in bed when they were at work compared to when at home (see Table 2).

Average sleep latency, as assessed by actigraphy, was zero, indicating no problem with initial ability to go to sleep. The overall Wake After Sleep Onset (WASO) mean score was 69.90 minutes, which means that, on average, firefighters lost about 70 minutes of sleep from when they intended to go to bed and from when they intended to wake up. Similarly, the WASO on shift and off shift scores were significantly different (M = 86.84 vs. M = 57.67; see Table 2); the WASO on shift mean was 29.17 minutes greater than the WASO off shift average, indicating more time spent awake during on shift nights.

With respect to the first work night, firefighters' average self-report sleep quality was 1.90 (SD = .88), which is slightly below a "fair" sleep quality rating, and the sleep efficiency was 78.45% (SD = .89).

Impact of Sleep on Neuropsychological Subtests from Start of Shift (Time 1) to End of Shift (Time 2)

The intent of Hypotheses 2 and 3 was to determine how sleep disruption might affect neuropsychological functioning. However, only a subset of firefighters actually experienced significant sleep disruption during their "on call" night (11:00pm to 7:00am), meaning that analyses of the entire sample would not provide an adequate test of the hypotheses (because the majority of the sample did not have disturbed sleep). Thus, the sample was split into two groups: Group 1 (n = 33) or the "low disruption sleepers" had < 60 minutes of sleep interruption and Group 2 (n =12) or the "disturbed sleepers" (n = 12)

was greater or equal than 60 minutes spend on call during the 11:00 pm until 7:00 am time period. Change scores were calculated (pre – post) and between group analyses were conducted on the change score values.

Impact of Sleep on Processing Speed

See Table 3 for Time 1 to Time 2 processing speed scores. There were no significant differences between the two groups (non-disturbed sleepers versus disturbed sleepers) on the Trails A (*M* = -.59, *SD* = 2.15 vs. *M* = -.17, *SD* = 2.66; *t* (42) = -.550, *p* =.586) and Trails B scores (*M* = -1.78, *SD* = 2.87 vs. *M* = -.17, *SD*=2.17; *t* (42) = -1.76, *p* =.085). Additionally, there were no significant group differences between the groups on the Trails A Errors (*M* = 0.00, *SD* = .72 vs. *M* = .17, *SD* = .58; *t* (42) = -.720, *p* =.476) and Trails B Errors scores (*M* = -.09, *SD* = .82 vs. *M* = -.17, *SD* =.83; *t* (42) = -1.76, *p* =.085). There were no significant group differences on Coding (Time 1 vs. Time 2) change scores (*M* = -.18, *SD* = 1.84 vs. *M* = -.58, *SD* = 1.56; *t* (42) = .670, *p* =.506).

Impact of Sleep on Sustained Vigilance and Auditory Attention PVT and WJCAA Time 1 compared to Time 2

See Table 4 for Time 1 to Time 2 auditory attention and vigilance scores. There was a significant group difference on PVT reaction time change scores (*M* = 1.05, SD = 27.54 vs. *M* = -18.61, *SD* = 28.22; *t* (42) = 2.095, *p* =.04). The results indicated that the disturbed sleepers group had significantly larger (and more negative) change scores compared to non-disturbed sleepers group, indicating slower reaction times as a result of less sleep.

There were no significant group difference on the PVT average false start change score (*M* = -.13, *SD* = 1.70 vs. *M* = -.17, *SD* = 3.24; *t* (42) = .056, *p* = .956 or on the WJCAA change score (*M* = -.82, *SD* = 12.46 vs. *M* = 4.17, *SD*= 13.38; *t* (43) = -1.16, *p* =.251).

Exploratory Analyses

Because of their shift work and frequent exposure to traumatic events, mental health was examined. Additionally, the relationship between illicit drugs (caffeine and alcohol) and sleep disturbance variables was assessed.

Firefighter mental health.

Six out of the 45 firefighters (13.3%) met DSM-5 criteria for a mental health diagnosis. Three firefighters met criteria for major depressive disorder, 1 firefighter had an existing diagnosis of shift work disorder, and 2 of the firefighters met criteria for PTSD. Two of the 6 firefighters with a primary mental health diagnosis met criteria for a secondary diagnosis: Attention-deficit hyperactivity disorder (ADHD), predominantly inattentive type and Persistent Depressive Disorder.

On self-report measures of psychopathology, results indicated that firefighters endorsed few symptoms of anxiety or depression. Mean score on the Beck Depression Inventory (BDI-II) was 6.63, (*SD* = 5.85), which is indicative of minimum depression. The average PCL-5 score was 9.4 (*SD* = 9.32), well below the suggested cutoff score of 33, indicative of a diagnosis of PTSD. The average General Anxiety Disorder Scale (GADS-7) score was 6.84 (SD = 3.4), and their GADS-7 Impairment score was 0.32 (*SD* = 0.47), which is indicative of mild anxiety.

Finally, on the Quality of Life Inventory (QOLI), the firefighters reported an average *t* score of 52.11, *SD* = 15.11, which is indicative of an average quality of life satisfaction.

On the daily diary measure of emotional distress, firefighters (*n* =35) reported very mild overall anxiety (*M* = .90, SD = 1.27) and overall anger (*M* = .90, *SD* = .22. Similarly, they reported few nightmares per night (*M* = .03, SD = .09).

Use of licit drugs.

Overall use of caffeine and alcohol, two licit drugs well known to interfere with sleep, were assessed, and correlational analyses examined the relationships between use of these substances and the actigraphy data collected over the 9 days of the study. Firefighters' average total number of caffeine beverages over the 9 days was 17.53 (*SD* = 11.90), and their total number of alcohol beverages was, on average, 6.81 (*SD* = 9.29). There were no significant correlations between the total alcohol and caffeine variables and actigraphy measures of sleep duration, sleep efficiency, or wake after sleep onset.

CHAPTER FOUR: DISCUSSION

The primary purpose of this study was to determine if firefighters, as a result of their 24- hour on shift/48- hour off shift work schedule endorse sleep difficulties, and how that sleep disruption might affect cognitive functioning such as processing speed, attention, and vigilance. Additional analyses explored the relationship between the firefighters' work schedule and mental health symptoms, and the relationship between caffeine and alcohol consumption on their sleep. The results indicated that firefighters endorsed sleep difficulties, in terms of fewer hours of sleep when compared to the National Sleep Foundation's normative sample. Additionally, the firefighters in this investigation endorsed poor sleep efficiency and poor sleep quality as assessed by self-report and objective actigraphy. These results are consistent with other investigations reporting that first responders working a night shift suffer from poor sleep duration and poor sleep quality (Carey, Al-Zaiti, Dean, Sessanna & Fennell, 2011; Christoforou, Cvirn, Ferguson, Armstong & Smith, 2013; de Barros, Martins, Saitz, Bastos & Ronzani, 2012; Waters & Bucks, 2011; Wright, Bogan & Wyatt, 2012). In contrast to previous investigations, this sample of firefighters did not report a significant volume of nighttime calls. Surprisingly, only 12 of the 45 firefighters endorsed responding to a nighttime call during the 24 hour shift that occurred between the two neuropsychological assessments. Although we feared that for some reason, the shift selected may have constituted an aberrant work night, a post-hoc analysis of the other two on call nights that occurred across the 9 day assessment period, revealed that emergency night calls were uncommon. Only one firefighter reported spending more than an hour on call on the second night of

work and only three firefighters reported spending more than 60 minutes on call on the third night of work. These data suggest that a clearer examination of the impact of sleep disruption upon the neuropsychological functioning of firefighters will have to use samples that are specifically selected for having a high volume of nighttime calls.

Despite the minimal disruption of sleep as a result of emergency calls, the other sleep data suggest that firefighters report poor sleep quality. Furthermore, their complaints are supported by actigraphy data that indicate that, on work nights firefighters only slept an average of 5 hours and 20.99 minutes and had very low sleep efficiency score of 78.41. These findings suggest that, in comparison to individuals who work a more typical 9am to 5pm shift (and probably sleep in the same bed/environment every night), there may be something about the sleep schedules of firefighters that leads to poorer sleep quality and duration. One hypothesis is that sleeping in a different environment (firehouse vs home) could affect sleep in subtle, yet important ways. For example: noise, ambient temperature, light, and air quality are all factors known to impact sleep, and firefighters may have less control over these factors at the fire station compared to their home environment (Caddick, Arsintescu & Flynn-Evans, 2018).

With respect to the second and third hypotheses, the results suggest that, when comparing tests that assessed processing speed, sustained vigilance, and auditory attention, only the psychomotor vigilance test (PVT) reaction time was negatively impacted by night time emergency calls. Specifically, firefighters whose sleep was disrupted by nighttime calls had significantly larger and negative change scores when compared to firefighters who did not go on calls at night. This significant decrease in

PVT reaction time after a night of sleep disruption is consistent with the simulated work day firefighter study conducted by Christoforou and colleagues (2013). This investigation extends those findings in several important ways: a) the firefighters were in their natural work environment and b) the firefighters' sleep duration average on work night 1 was 5 hours and 28.93 minutes, which was about 90 minutes longer than Christoforou et al.'s 4-hours. Therefore, it appears that even small decrements in sleep can lead to statistically significant decreases in reaction times.

One explanation why reaction time was the only neuropsychological subtest to display a significant decrease in cognitive performance after the firefighter's shift was because the PVT is an extremely sensitive test that captures the number of lapses, or responses greater than 500 milliseconds (Lim & Dinges, 2008). Reaction time tests are designed to detect acute lapses, also known as "brief periods of half a second to many seconds of no response" (Goel, Rao, Durmer & Dinges, 2009, p. 3), in attention. The results of this study suggest that the PVT is a more sensitive test than the other tests used in this sample because it is better equipped to detect possible impairment as a result of firefighters' disrupted sleep patterns, and this study's results suggest calls at night may be a factor in a decrease in performance on the PVT immediately after a firefighter's 24-hour shift is over. However, research on ecological validity of neuropsychological measures is notoriously scarce, and further exploration on which neuropsychological measures best capture impairment as a result of sleep disruption and poor sleep quality is warranted.

This study's findings are consistent with the Lim and Dinges meta-analysis finding that simple attention and vigilance showed the greatest decline under sleep deprivation conditions; however, "the average effect size of the change in accuracy measures for tests of processing speed" was not statistically significant (2010, p. 376). Several studies suggest that greater amounts of sleep disruption can lead to an increase in frequency and duration of time lapses, which, in turn, could lead to an increase in cognitive errors that could lead to an increase in "risks to safe operation in all modes of transportation and to performance in other safety-sensitive activities" (Goel, Rao, Durmer & Dinges, 2009, p. 2). Future investigations conducted with samples of firefighters who had more extensive sleep disruption (greater number of calls, more time spent awake on a call) could reveal a linear relationship between extent of sleep disruption and impaired functioning on these tasks. Critically, with a broad range of sleep disruption (going from none to complete disruption during the 8 hour nighttime period), there could be an opportunity to develop guidelines that could indicate at what point sleep deprivation results in critical impairment in neuropsychological functioning in this high risk occupation. Further exploratory analyses in this sample revealed extensive variability between fire stations and the number of minutes of sleep disruption the firefighters experienced due to responding to nighttime emergency calls. Specifically, only 2 of the 8 fire stations in this sample had a mean sleep disruption of 60 minutes or more due to emergency calls at night. Therefore, future studies could possibly find firefighters that experience a higher volume of calls at night at fire stations that historically respond to

more calls, and call records are recorded by fire stations in monthly and annual detailed reports.

Given the relatively high correlation between sleep problems and mental health problems (Carey, Al-Zaiti, Dean, Sessanna & Fennell, 2011; de Barros, Martins, Saitz, Bastos & Ronzani, 2012; Hom, Stanley, Rogers, Tzoneva, Bernert & Joiner, 2016), it was interesting to find that this sample of firefighters did not endorse any significant symptoms of anxiety or depression, and total caffeine and alcohol consumption was not a significant predictor of sleep difficulties. One possible explanation is that, for this sample, lack of calls at night leads to relatively low sleep disturbance which, in turn, might account for the lack of significant mental health problems endorsed. Again, the low sample size and scarce inclusion of firefighters that responded to at least 60 minutes out on call from 11:00 pm until 7:00 am may not be the best representation of how a firefighter's 24/48 hour shift schedule impacts their mental health. A greater inclusion of firefighters that more consistently respond to a large volume of calls late at night is required before one can determine the relationship between sleep, number of calls, and mental health problems. Post hoc analyses revealed that the firefighter diagnosed with ADHD, inattentive type improved on his before shift to after shift scores on all neuropsychological assessments with the exception of the PVT False Starts (PVT FS) variable (M = 2.00 vs M = 6.00). Of note, this particular firefighter's increased in false starts was more than the average found in the rest of the sample. With this finding in mind, future studies could specifically look at how firefighters with various mental health diagnoses known to be correlated with impaired concentration such as ADHD, PTSD, and MDD perform on neuropsychological assessments before and after shift

while also controlling for minutes of sleep disruption due to responding to emergency calls at night.

CHAPTER FIVE: LIMITATIONS

The major limitation to this investigation was the small number of firefighters who had to respond to nighttime calls during the 24 shift allocated for pre and post neuropsychological testing. Given the random nature of "emergencies" it would be difficult to identify a priori whether a given participant would have an active or restful night. A larger, more diverse sample with varying amounts of time spent on call at night would better address the hypothesis that sleep disruption leads to poorer performance on processing speed, sustained vigilance, and auditory attention. Alternatively, limiting study recruitment to only those stations that historically had a high volume of nighttime calls may have resulted in a larger sample with the necessary sleep deprivation to more fully test the study's hypotheses.

Another limitation is that this study analyzed performance on neuropsychological subtests on the first day, before and after shift, of sleep recorded via actigraphy, followed by about 8- nights of recorded sleep. It did not assess firefighters' sleep prior to the initial neuropsychological testing. A future study should consider analyzing several nights of sleep on shift and off shift before the neuropsychological subtests are administered to better understand how several nights of the firefighter's sleep prior to the testing impacts their performance on the various tests. In addition, it is still unclear whether these firefighters' sleep complaints are associated with significant job impairment because this study did not assess firefighters' job performance, perception of their job performance, or history of occupational or motor vehicle accidents. Since firefighters endorsed sleep complaints regardless of how many minutes of sleep disruption at night due to calls they

responded to, it is important to explore what other potential environmental conditions and behavioral activities they engage in that might interfere with sleep in in an effort to better understand what else might contribute to their sleep complaints. By identifying these environmental and behavioral variables that may interfere with sleep, researchers may be able to a CBTI compliant intervention that is more applicable to firefighters and their unique working conditions.

Furthermore, although firefighters' mental health was assessed via the MINI and filled out various self-report mental health measures, what would appear to be a common result of shift work, shift work sleep disorder was not conducted, as it was not included in the structured diagnostic interview. Sleep watch actigraphs are subject to user error, and a firefighter that lies awake without moving could falsely be recorded as sleeping on the sleep watch actigraphy. Gender differences could also not be assessed as this study only had one female firefighter, and, given one recent meta-analysis' confirmation that a gender difference exists among rates of insomnia, future studies should explore if differences exist between male and female firefighters in terms of sleep, processing speed, sustained attention and vigilance (Zhang & Wing, 2006). Finally, since firefighters were assessed at the beginning of their shift and, only 24- hours later, at the end of their shift, such close, repeated testing raises the risk of practice effects, the magnitude of which "varies as a function of type of measure, test–retest interval, age, and overall competency level of the participant." (Dikmen, Heaton, Grant & Temkin, 1999). To mitigate this concern, this study utilized alternate neuropsychological test forms. A perusal of the mean group scores for both groups at each time, did not show any overall

pattern of practice effects and indeed, demonstrated a significant decrease in PVT performance in this study.

CHAPTER SIX: CONCLUSION

This is the first study to explore how firefighters' 24- hour on/ 48- hour off work shift schedule impacts their sleep duration, sleep quality, mental health, and performance on neuropsychological measures that assess one's performance on processing speed, sustained vigilance, and auditory attention. A strength of this study was that it was an ecologically valid study in that the data was collected in the firefighters' natural work environment. Although extraneous factors were not controlled for (i.e., sleep duration, duration and/or type of calls), it is important to attempt to assess how firefighters work environment impacts their overall health. This study found that firefighters in this sample sleep significantly less and report significantly poorer sleep quality than other working adults that work exclusively on day shift. However, due to a limited sample size, the possibility of practice effects, and an inability to control for whether a firefighter receives a call at night, this study's findings that the only neuropsychological test that indicated a decrement in functioning because of less sleep was the psychomotor vigilance task reaction time. These results suggest that reaction time may be the most efficient neuropsychological subtest at detecting lapses in attention, and could potentially serve as signal that a firefighter could be at risk for suboptimal performance or work accidents because of insufficient vigilance, should these results be replicated in a larger investigation. A larger sample size and an exploration of other neuropsychological and/or job performance measures may help better address this study's research questions. Additionally, separately analyzing the impact of calls of varying call duration (i.e., Group 1 is 1 hour on call, Group 2 is 2 hours on call, etc.,) one may help determine at which time length calls at night significantly impact sleep and/or reduce performance on various tasks that measure processing speed, attention, and vigilance.

Despite its limitations, the results of this investigation suggest that firefighters experience poor quality of sleep, even poorer quality of sleep when “on the job” vs “of the job”, and that even an hour of sleep loss significant affects reaction time, an important neuropsychological function given the work requirements of first responders. In fact, given the life and death decisions firefighters and other first responders face every day the results of this investigation point to the need to continue research in this area, to further understand how their work shift schedules may affect their optimal cognitive and physiological functioning.

CHAPTER SEVEN: RECOMMENDATIONS

Anecdotally, firefighters in this sample reported concerns about their sleep, mental health, and fire house environment. Many firefighters felt that several changes around the fire house could be made. For example: many firefighters felt their stations' alarms were too loud, and they were quick to point out that some fire stations in the U.S. have alarms that progressively get louder, which they felt would be less "anxiety provoking." In addition, other firefighters voiced frustration at waking up to alarms only to learn that the particular alarm did not apply to their unit/job specification. Therefore, it may benefit firefighters to be placed in sound proof rooms with their respective units, and to design an alarm system that only goes off in the rooms of the relevant unit. Thus, firefighters that do not need to be awakened will get to continue sleeping. In addition, some firefighters pointed out that certain stations receive, on average, many more calls at night than other stations. Therefore, it may be helpful to rotate firefighters in and out of "busier stations that receive more calls at night." Also, given this sample's findings of firefighters endorsing sleep complaints, firefighters may benefit from receiving a psychoeducation on sleep hygiene. For example, the firefighters' low sleep efficiency average could possibly be improved through a psychotherapy intervention such as cognitive behavior therapy for insomnia (CBTI) that focuses, among other things, on improving one's sleep duration and time in bed ratio, improving work environment conditions such as low amounts of light and sound, maintaining optimal temperatures, and reducing behavioral activities that are known to disrupt sleep. One study has looked at the effectiveness of CBTI on shift workers involved in the media (Järnefelt et al.,

2012), but these researchers are not aware of any studies to date that have specifically looked at CBTI related interventions with firefighters in their natural environment. Again, further research is recommended to better determine if firefighters' shift schedules lead to chronic sleep disruption, and, if they do suffer from chronic sleep disruption, what impact does chronic sleep disruption have on firefighters' health, cognitive performance, and mental health. More research could help lead to improved working conditions and implementation of evidenced based psychotherapies, which, in turn, could lead to healthier, more effective, and more alert firefighters that voluntarily put their lives at risk in service to others.

APPENDIX A: TABLES

Table 1. Demographics

Variable	Mean (sd)	Range or Percentage
Age	37.4 (7.22)	21-51
Sex		
Male	44	
Female	1	
Race/Ethnicity		
African American	4	8.7%
Asian	1	2.2%
Caucasian	33	73.3%
Hispanic	7	
Education (Years)	14.6 (1.2)	12-19
Marital Status		
Single	11	23.9%
Married	33	73.3%
Divorced	1	2.2%
Months as a Firefighter	155.9 (66.0)	36-288
Job Title		
Lieutenant	7	15.6%
Paramedic	17	37.8%
Engine	13	28.9%
Tower	6	13.3%
Heavy Rescue	2	4.4%

Table 2. Comparison of Sleep Quality Variables On and Off Shift

Variable	On Shift M (sd)	Off Shift M (sd)	N	t test
Sleep Quality	1.72 (.73)	2.44 (.55)	36	5.84***
Sleep Efficiency	78.41 (9.84)	87.04 (6.77)	40	7.22***
WASO	86.84 (39.10)	57.67 (29.25)	41	5.17***

WASO (Wake After Sleep Onset)

** p<.05; **p<.01; ***p<.001*

Table 3. Processing Speed Time 1 Compared to Time 2 by group

Variable	Low disruption sleepers	Low disruption sleepers	Disturbed Sleepers	Disturbed Sleepers
	Time 1	Time 2	Time 1	Time 2
	M (sd)	M (sd)	M (sd)	M (sd)
	n = 26	n = 26	n = 12	n = 12
Trail Making A	12.38 (1.94)	13.2 (1.61)	12.17 (2.37)	12.33 (2.02)
Trail Making B	10.48 (3.62)	12.58 (3.07)	11.58 (4.27)	11.75 (4.67)
Trail Making A Errors	0.23 (.43)	0.28 (.54)	.33 (.49)	.08 (.29)
Trail Making B Errors	0.28 (.54)	0.31 (.74)	.17 (.39)	.33 (.65)
Coding	9.88 (3.51)	10.12 (3.61)	10.42 (3.45)	11.00 (3.62)

Table 4. Auditory Attention and Vigilance Time 1 Compared to Time 2 by Group

Variable	Low disruption sleepers	Low disruption sleepers	Disturbed Sleepers	Disturbed Sleepers
	Time 1	Time 2	Time 1	Time 2
	M (sd)	M (sd)	M (sd)	M (sd)
	n = 26	n = 26	n = 12	n = 12
PVT Reaction Time	309.88 (32.94)	310.15 (29.59)	310.36 (29.93)	328.97 (31.01)
PVT False Starts	1.96 (2.03)	2.04 (2.78)	2.00 (1.86)	2.17 (2.98)
WJCAA	86.73 (10.58)	88.85 (11.65)	91.33 (8.38)	87.17 (9.35)

APPENDIX B: IRB APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Jeremy W. Stout**

Date: **January 08, 2018**

Dear Researcher:

On 01/08/2018 the IRB approved the following human participant research until 01/07/2019 inclusive:

Type of Review:	IRB Continuing Review Application Form Expedited Review Category #1B, 6, & 7
Project Title:	Sleep Disturbances Among Firefighters: An Exploration Of How Shift Work Impacts Sleep And Cognition
Investigator:	Jeremy W. Stout
IRB Number:	SBE-16-12763
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 01/07/2019, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

This letter is signed by:

Kamille Chap

Signature applied by Kamille Chaparro on 01/08/2018 02:03:17 PM EST

Designated Reviewer

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