Investigation of the Effects of Split Sleep Schedules on Commercial Vehicle Driver Safety and Health

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

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FOREWORD

As part of the Federal Motor Carrier Safety Administration (FMCSA) mandated "Investigation into Motor Carrier Practices to Achieve Optimal Commercial Motor Vehicle (CMV) Driver Performance" Indefinite Date/Indefinite Quantity (IDIQ) Research and Technology Program, a laboratory study was conducted between February 2010 and April 2011 to examine the effect of split sleep versus consolidated sleep on human performance and long-term health-related parameters. This technical report presents the design, methods, research findings, and conclusions of this study.

The study compares the effects of consolidated nighttime sleep, split sleep, and consolidated daytime sleep on total sleep time, performance, participant subjective state, and biomedical parameters. It appears that if consolidated nighttime sleep is not possible, then split sleep is preferable to consolidated daytime sleep. This conclusion is based on the findings of relatively less total sleep time and greater subjective sleepiness in the daytime sleep condition compared to the split sleep and consolidated nighttime sleep conditions. Performance was equivalent across all three of the sleep conditions in the present study. Further, there were some changes in biomedical parameters associated with the different sleep conditions.

This technical report may be of value to anyone interested in fatigue and its management in CMV operations and other modes of transportation.

NOTICE

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16. Abstract

The objective of this study was to evaluate the consequences for safety and health of split sleep versus consolidated sleep by comparing the effects of consolidated nighttime sleep, split sleep, and consolidated daytime sleep on total sleep time, performance, subjective state, and biomedical measures that correlate with health outcomes over the long term. An in-residence laboratory study was conducted on 53 healthy participants making a between-group comparison of nighttime, split, or daytime sleep across a 5-day simulated workweek. The effect of the three sleep conditions was measured on sleep by polysomnography (PSG), performance by the psychomotor vigilance task (PVT), high fidelity driving simulator, digit-symbol substitution task (DSST), and subjective state, as well as the long-term health-related biomedical measurements of blood glucose, interleukin 6 (IL-6), leptin, testosterone, and blood pressure (BP). In comparison to consolidated nighttime sleep or split sleep, participants in the daytime sleep condition slept less and were subjectively sleepier. While performance, mood, and BP were unaffected by sleep condition, there were elevations in glucose and testosterone in the daytime sleep condition at the end of the workweek. With respect to total sleep time and sleepiness, the findings of the present study suggest that split sleep is preferable to consolidated daytime sleep. This finding has implications for any revision of the Federal Motor Carrier Safety Administration (FMCSA) rules governing sleeper berth use in commercial motor vehicle (CMV) drivers.

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Biomedical parameters, circadian rhythm, commercial motor vehicle, consolidated sleep, daytime sleep, fatigue, hours of service, sleep, split sleep	**No restrictions**

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SI* (MODERN METRIC) CONVERSION FACTORS

TABLE OF APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	inches	25.4	millimeters	mm
Ft	feet	0.305	meters	m
Yd	yards	0.914	meters	m
Mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
Ac	acres	0.405	Hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME	1,000 L shall be shown in m^3	
fl oz	fluid ounces	29.57	milliliters	mL
Gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
Oz	ounces	28.35	grams	g
Lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE	Temperature is in exact degrees	
°F	Fahrenheit	5 × (F-32) ÷ 9 or (F-32) ÷ 1.8	Celsius	°C
		ILLUMINATION		
Fc	foot-candles	10.76	lux	lx
Fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
Lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

TABLE OF APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
Mm	millimeters	0.039	inches	in
M	meters	3.28	feet	ft
M	meters	1.09	yards	yd
Km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
G	grams	0.035	ounces	oz
Kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2,000 lb)	T
		TEMPERATURE	Temperature is in exact degrees	
°C	Celsius	1.8C + 32	Fahrenheit	°F
		ILLUMINATION		
Lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		Force & Pressure Or Stress		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003, Section 508-accessible version September 2009)

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LIST OF ABBREVIATIONS AND ACRONYMS

Acronym	Definition
AETR	European Agreement Concerning the Work of Crews of Vehicles Engaged in International Road Transport
ANOVA	analysis of variance
BL1	baseline sleep period one
BL2	baseline sleep period two
BMI	body mass index
BP	blood pressure
cc	cubic centimeter
CMV	commercial motor vehicle
D	driving simulator
DSST	digit-symbol substitution task
EEG	Electroencephalogram
EFFR	effort rating scale
EMG	Electromyogram
EOG	Electrooculogram
EU	European Union
FAA	Federal Aviation Administration
FMCSA	Federal Motor Carrier Safety Administration
G-G	Greenhouse-Geisser
HOS	hours of service
IDIQ	indefinite date/indefinite quantity
IL-6	Interleukin 6

IRB	Institutional Review Board
IV	intravenous
KSS	Karolinska Sleepiness Scale
kcal	kilocalorie
MAP	mean arterial pressure
min	minute(s)
ms	millisecond
N1	non-REM sleep stage one
N2	non-REM sleep stage two
N3	slow-wave sleep (non-REM sleep stage three)
NATCA	National Air Traffic Controllers Association
NREM	non-rapid eye movement (sleep)
p	p value (ps is plural of p)
PANAS	Positive Affect Negative Affect Schedule
PERF	performance rating scale
PSG	polysomnography
PVT	psychomotor vigilance task
REM	rapid eye movement (sleep)
rpm	revolutions per minute
s.d.	standard deviation
sem	standard error of the mean
SL	sleep latency
SWS	slow-wave sleep
SWSL	slow-wave sleep latency

TIB	time in bed
TST	total sleep time (per 24 hours)
VASM	visual analog scale of mood
W1	workweek one
W2	workweek two

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EXECUTIVE SUMMARY

PURPOSE

The question posed by the Federal Motor Carrier Safety Administration (FMCSA) and that the present study was designed to answer is the following: Is split sleep as effective as consolidated sleep with respect to sustaining commercial motor vehicle (CMV) driver safety and, over the long term, sustaining driver health?

PROCESS

To evaluate whether a split sleep opportunity is as beneficial as consolidated sleep with respect to sustaining driver sleep, driver performance, driver subjective state, and biomedical parameters (blood chemistries and blood pressure [BP]) associated with long-term driver health, a three-sleep-condition study design was developed. The three sleep conditions were consolidated nighttime sleep opportunity, split sleep opportunity, and consolidated daytime sleep opportunity.

The core of the study was a 5-day simulated workweek spent in one of the three conditions. The design held constant at 10 hours the total daily amount of time available for sleep for all three conditions—consolidated nighttime sleep opportunity (2200–0800 hours), split sleep opportunity (0300–0800 and 1500–2000 hours), and consolidated daytime sleep opportunity (1000–2000 hours). To assess effects on safety and health, measurements of total sleep time, performance, subjective state, and biomedical parameters (blood chemistries and BP) were made. Sleep was measured with polysomnographic (PSG) recordings before, during, and after the workweek. Performance was measured by the psychomotor vigilance task (PVT), a high-fidelity driving simulator, and by digit-symbol substitution task (DSST) multiple times per day throughout the study. Subjective state was assessed multiple times per day throughout the study using a neurobehavioral test battery in which participants rated their sleepiness, mood, positive and negative emotion, as well as performance and effort. Blood chemistries—glucose, interleukin-6 (IL-6), leptin, and testosterone—were measured multiple times per day on two blood draw days, one before and one after the 5-day workweek. BP was measured once a day in the evening throughout the study.

The study was an in-residence laboratory study conducted from January 10, 2010, to May 5, 2011. Fifty-three participants, divided among the three conditions, were studied in the laboratory for 9 days. These 9 days included two baseline days, the 5-day simulated workweek, and a 2-day recovery period. The recovery period allowed the participants in the split sleep and consolidated daytime sleep conditions to transition back to nighttime sleep before leaving the laboratory.

During the study, participants slept, ate, took performance tests, and had blood draws within the confines of the sleep laboratory. Participants had no contact with the outside world (no cell phones, email, visitors, live television, radio, or Internet). All three sleep conditions had the same total sleep opportunity of 10 hours per day. The effect of each condition on sleep, performance, subjective state, and biomedical measures related to long-term health outcomes was assessed.

RATIONALE AND BACKGROUND

The intent was to develop evidence bearing on the utility of the current sleeper berth rule for sustaining commercial motor vehicle (CMV) driver safety and health. Current hours-of-service (HOS) rules for CMV drivers allow 14 hours on duty and 10 hours off duty. With respect to sleeper berth use, the current rule, on the one hand, limits the splitting of the 10 hours off duty into two blocks—one of 8 hours and one of 2 hours (an 8/2 split)—and, on the other hand, allows complete flexibility in the placement of the sleep opportunities relative to time of day, and therefore relative to the circadian cycle of body temperature, sleep propensity, and performance. The timing of a sleep opportunity relative to time of day and circadian cycle modulates the quantity of sleep obtained during that opportunity. As is documented in studies of shift work, workers working at night and sleeping during the day are chronically sleep restricted, as their sleep is truncated by the increasing circadian drive for wakefulness in the afternoon and evening. An alternative to the current regulations would be to allow CMV drivers more flexibility in splitting their sleeper berth time than the currently allowed 8/2 split by allowing splits ranging from 10/0 through 5/5. In such an alternative the driver on any given day could choose, for example, a 6/4 split, or, as in the present study, a 5/5 split. In this alternative, the driver would choose not only when to place but also how to split the available 10-hour sleep opportunity.

STUDY FINDINGS

With respect to objectively measured sleep, during the 5-day simulated workweek, participants in the nighttime sleep condition slept the most (total sleep time per day 8.4 hours ± 13.4 minutes standard error of the mean [min sem]). Participants in the daytime sleep condition slept the least (total sleep time per day 6.4 hours ± 15.3 min sem). Participants in the split sleep condition were intermediate in how much they slept (total sleep time per day 7.16 hours ± 14.2 min sem). The findings suggest that, with respect to total sleep time, consolidated sleep is better than split sleep if the consolidated sleep opportunity is placed at night, but that split sleep is better than consolidated sleep if the consolidated sleep opportunity is placed during the day (see Table 1). These findings are in accord with human circadian physiology, which has sleep propensity high at night when the circadian drive for wakefulness is falling or low, and sleep propensity low during the day when the circadian drive for wakefulness is rising or high.

With respect to objectively measured cognitive performance, during the 5-day simulated workweek there were no significant differences in performance among the three sleep conditions on the PVT, on high-fidelity driving simulator performance, or on the DSST. Though even mild sleep restriction can degrade performance over time, the sleep in all three conditions in the present study appears to have been adequate to sustain performance as tested at least for the duration of the 5-day simulated workweek.

With respect to subjective measures, during the 5-day simulated workweek, subjective sleepiness, as measured on the Karolinska Sleepiness Scale (KSS), was increased in the daytime sleep condition compared to the split sleep and nighttime sleep conditions. Other subjective measures did not differ by condition.

With respect to biomedical parameters, from the first to the second blood draw, spanning the workweek, there were no condition-specific changes in blood in IL-6 or leptin levels. From the first to the second blood draw, spanning the workweek, glucose and testosterone appeared to increase in the daytime sleep condition. There were no changes in systolic BP, diastolic BP, or mean arterial pressure (MAP) over the simulated 5-day workweek in participants in the daytime sleep condition.

Table 1. Summary of Key Findings

Condition	Sleep Measures (On Recorded Workweek Nights)	Performance Measures (Across the Workweek)	Neurobehavioral Test Battery (Across the Workweek)	Blood Chemistries (On Blood Draw Days)
Consolidated Nighttime Sleep	Average total sleep time: 8.4 hours +/- 13.4 (min sem).	No difference.	Average KSS* = 3.5 +/- 0.2 (sem)	See below.
Split Sleep	Average total sleep time: 7.2 hours +/- 14.2 (min sem).	No difference.	Average KSS* = 3.5 +/- 0.2 (sem)	See below.
Consolidated Daytime Sleep	Average total sleep time: 6.4 hours +/- 15.3 (min sem).	No difference.	Average KSS* = 4.3 +/- 0.2 (sem) Participants in the DAY sleep condition reporting significantly more sleepiness (KSS) than participants in the NIGHT or SPLIT sleep conditions.	Just past the end of the workweek, participants in the DAY sleep condition had significantly higher blood glucose than those in the SPLIT sleep condition. Leptin levels were higher in the DAY sleep condition than in the SPLIT sleep condition at 0900 hours and 2000 hours. Testosterone levels were higher in the DAY sleep condition after the workweek compared to NIGHT sleep and SPLIT sleep conditions.

*The higher the KSS score, the greater degree of participant sleepiness.

CONCLUSIONS

Compared to consolidated sleep opportunities placed at night or split sleep, placement of a consolidated sleep opportunity during the day yielded truncated sleep and increased sleepiness. In the present study, the sleep opportunity was 10 hours per day in each condition. Sleep in the nighttime and split sleep conditions was in the normal range, and sleep in the daytime condition was mildly restricted. Performance was not significantly affected by sleep opportunity placement. The study looked for, but did not find, perturbations in IL-6 and leptin associated with the three sleep conditions, which, if persistent, are associated with adverse effects on long-term health-related outcomes. Glucose and testosterone did increase in the daytime sleep condition from before to after the workweek, suggesting metabolic perturbation in this condition. There were limitations to the study, which are discussed later in the report.

If consolidated nighttime sleep is not possible, a split sleep opportunity appears to be a better choice with respect to effects on sleep than a consolidated daytime sleep opportunity. While any single study is not definitive, the present study is congruent with the literature on shift work and provides support for allowing greater flexibility in the sleeper berth rule for CMV drivers, including permitting CMV drivers to split their sleep more evenly than the currently permitted 8/2 split of off-duty time.

To demonstrate the effect of split versus consolidated sleep on objective performance, subjective status, and chronic-illness related biomedical parameters, young (age range 22–40 years), healthy, non-obese (BMI < 30) men were studied in a carefully controlled laboratory environment. The homogeneity of the population and the controlled laboratory environment were instituted to reduce the noise relative to the signal in the data increasing the likelihood that a difference between groups would be detected if in fact a difference existed. Thus the study population and the study environment were purposely not representative of the population of CMV drivers and their normal working environment. If a difference was found in the laboratory setting between split and consolidated sleep, as a function of the daytime or nighttime placement of the consolidated sleep, then the expectation was that these findings would be followed up with a field study using drivers in their usual environment driving their usual revenue-producing routes. The study population in such a field study would be chosen to be representative of the industry and would therefore be older, heavier, include women, and generally more heterogeneous, relative to the study population in the present laboratory study. The environment of such a field study would also be more variable than in the laboratory. This progression from homogeneous population under controlled conditions (to demonstrate the existence of a phenomenon) to heterogeneous population under uncontrolled conditions (to demonstrate that this phenomenon makes a difference in real world operations) is natural one in behavioral studies of sleep and performance.

What appears to be a limitation of the study actually is a strength and puts the study in the mainstream of translational research, beginning in the lab and ending in the field. In the laboratory, the research team asks is there a difference? In the field, the research team asks does the difference found in the laboratory make a difference in real world measures of sleep and performance for drivers in their normal environment?

1. INTRODUCTION

1.1 OBJECTIVE

This study was designed to answer the question: Is a split sleep opportunity as beneficial as a consolidated sleep opportunity with respect to sustaining driver safety and operational performance and, over the long term, with respect to sustaining driver health? In other words, is split sleep as recuperative as consolidated sleep? The objective of the present study was to compare daily sleep split into two sleep periods versus sleep consolidated into a single period, and to determine the effects of those sleep patterns on total sleep time (TST), performance, subjective state, and biomedical parameters associated with long-term health.

1.2 BACKGROUND

At the time of the study, the Federal Motor Carrier Safety Administration (FMCSA) hours-of-service (HOS) regulations for property-carrying commercial motor vehicle (CMV) drivers prescribe a maximum of 14 hours on duty (maximum 11 hours driving) and a minimum of 10 consecutive hours off duty in successive 24-hour periods with a maximum cumulative number of 60/70 hours on duty over 7/8 consecutive days. A driver could reach the 8-day limit in 5 consecutive days on duty if he/she were on duty 14 hours in every 24 hours.

For CMV drivers using the sleeper berth, the HOS rule allows only limited flexibility with respect to split sleep, permitting the driver to split the 10-hour off-duty time into two blocks of 8 hours and 2 hours separated by some period of time on duty. The rule specifies that drivers must take at least 8 consecutive hours in the sleeper berth plus a separate 2 consecutive hours off duty or off duty in the sleeper berth. FMCSA has implemented a similar sleeper berth rule for passenger-carrying CMV drivers. FMCSA limited the division of sleeper berth time, requiring at least 8 consecutive hours in the sleeper berth, because of concern that, given the limited data on the effects of split sleep on performance and health, the loss of a daily consolidated sleep opportunity would impair driver performance and degrade driver health over the long term. Of critical importance is that, while requiring at least 8 consecutive hours in the sleeper berth, the current sleeper berth rule does not specify the placement of the sleeper berth time with respect to the 24-hour circadian rhythms of core body temperature, performance, and sleep propensity. Under the current rule, a CMV driver using the sleeper berth is free to place the 8-hour block at any point in the 24-hour circadian cycle. As indicated below, this combination of rigid split and flexible placement of sleep opportunity is likely to yield quite different actual total sleep times given the same total sleep opportunity, depending on placement relative to the time of day and hence to the circadian cycle.

The extensive literature on shift work indicates that, for the same duration of consolidated sleep opportunity, actual sleep obtained is critically dependent on the placement of the sleep opportunity with respect to the circadian rhythm phase.[1,2] Shift workers coming off duty in the morning, with an 8–10 hour consolidated sleep opportunity, are only able to sleep for about 5 hours before their sleep is truncated by the combination of decreasing homeostatic drive for sleep and increasing circadian drive for wake.[3,4] Thus, in answering the question regarding which is

better for safety and health—split sleep or consolidated sleep—one must consider the effect of a split sleep opportunity as compared to the same total duration of sleep opportunity consolidated at night and to the same total duration of sleep opportunity consolidated during the day. Thus, an appropriate study to answer the question would entail an experimental condition (split sleep) and two control conditions, one with sleep consolidated at night and one with sleep consolidated during the day.

As indicated above, the scientific literature most relevant to CMV driver health and fatigue is the literature on night shift work, including night shifts *per se* as well as extended work hours and early starts. The effects of night shift work on sleep, health, and performance are not platform specific (i.e., they are not unique to CMV drivers, air traffic controllers, medical personnel, or any other specific occupational or professional group). They are common across all occupations and professions that involve extended hours, night shift work, and early starts. The literature on shift work is extensive and suggests that extended work hours, night shift work, and early starts are associated with daytime sleepiness and insomnia, reduced alertness and accidents, decreased work productivity and quality of life, and a variety of negative health effects, including increased cardiovascular morbidity and mortality.[2]

With regard to operational needs of the CMV industry with respect to sleeper berth use, extensive conversations with industry representatives have yielded the following succinct conclusion as to how industry frames its interests in this regard. Within the HOS framework of 14 hours on duty and 10 hours off duty, drivers using the sleeper berth should be allowed more flexibility with regard to the timing and duration of their sleep periods than the currently required 8/2 split. They should be permitted, again within the limits of the 14 hours on duty, 10 hours off-duty cycle, to split their off-duty time in order to "sleep when sleepy and drive when alert."[5]

Split sleep means two or more sleep periods, ranging from a main sleep and a supplemental nap (e.g., 6 hours and 2 hours), through a main sleep and several naps, to multiple naps with no clear main sleep (also called polyphasic sleep).[5,6,7,8] It appears that any nap longer than 20 minutes has the same full minute-for-minute recuperative value as longer sleep.[9] Highly fragmented sleep has little or no recuperative value (highly fragmented sleep has arousals every 3–5 minutes—not to be confused with split sleep). With respect to cross-cultural comparisons, some cultures, dubbed "siesta cultures," routinely split their sleep with a main sleep period at night and regular napping in the afternoon.[10] Further, physicians working day shifts and sleeping at night, versus working night shifts and having their main sleep during the day supplemented by on-shift nighttime naps, are able to accumulate approximately 7 hours of total sleep time over 24 hours and perform equally well on the psychomotor vigilance task (PVT) in both conditions.[11] Recently, the Federal Aviation Administration (FAA) and the National Air Traffic Controllers Association (NATCA) developed a proposal to sanction scheduled on-shift napping for air traffic controllers as a fatigue countermeasure. On-shift napping sustains performance in night shift work.

Countries and jurisdictions within countries differ in how they regulate sleeper berth use. In Canada, CMV drivers are regulated by Transport Canada.[12] A CMV driver is required to take at least 10 hours off duty each day, divided into a continuous 8-hour block and off-duty periods of no less than 30 minutes each. For a single driver driving a truck equipped with a sleeper berth, he/she may meet the off-duty requirement if he/she accumulates off-duty time in no more than

two periods, neither of which is less than 2 hours, the total of the two periods is at least 8 hours; and the off-duty time is spent resting in the sleeper berth. As in the United States, the rule is silent as to the placement of the off-duty periods with respect to time of day and the 24-hour circadian cycle.

European countries and jurisdictions within countries differ in how they regulate sleeper berth use, reflecting the complex regulatory jurisdictional map of Europe.[13] In the European Union (EU), a solo CMV driver is required to take a consolidated total rest period of 11 hours per day. If he/she splits the sleep, the total rest period is increased to 12 hours/day and the minimum split permitted is 6/3. In marked contrast to the United States, the EU makes no distinction between sleeper berth and fixed rest facilities provided they are both "suitable" and stationary for the period of rest. A rest period is defined as one in which a driver "may freely dispose of his time." Drivers in non-EU countries in Eastern Europe and the former Soviet Union fall under the European Agreement Concerning the Work of Crews of Vehicles Engaged in International Road Transport (AETR). A solo AETR driver is required to have a minimum of 11 hours of daily rest. If he/she splits the rest into 2 or 3 periods, then 12 hours of daily rest is the minimum, with the last rest period being at least 8 continuous hours, and all rest periods must be at least an hour. Again, as in the EU rules, there are no rules specific to sleeper berth use. Sleeper berths are covered under the regular daily rest provision. Drivers in the United Kingdom (England, Scotland, Wales, and Northern Ireland) are mostly bound by EU rules, but parts of Great Britain (England, Scotland, and Wales) have separate domestic rules which specify daily driving (10 hour) and daily duty (11 hour) limits for a solo driver and are silent on the issue of rest, sleeper berth use, and circadian placement of sleep opportunity.

In Australia, CMV regulations for the solo driver require 7 hours of continuous (stationary) rest time, either in an approved sleeper berth or out of the vehicle.[14]

Thus, in the United States, Canada, and Europe, allowable splitting of off-duty time and/or sleeper berth time is typically limited by regulation. However, regulation is generally silent as to the placement of off-duty rest opportunity by time of day and relationship to circadian cycle. Therefore, the present report is of relevance not only in the United States but in Canada and Europe as well.

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2. METHODS

2.1 EXPERIMENTAL DESIGN

To evaluate whether a split sleep opportunity is as beneficial as a consolidated sleep opportunity with respect to sustaining driver total sleep time (TST), driver safety, driver operational performance, and driver health over the long term, a three-condition design was developed—one experimental condition (split sleep opportunity) and two control conditions (consolidated nighttime sleep opportunity, consolidated daytime sleep opportunity).

The study began with 2 baseline days with nighttime sleep, followed by a 5-day simulated workweek in one of the three sleep opportunity conditions, and ended with 2 recovery days, again with nighttime sleep. The consolidated nighttime control sleep condition was implemented as a 10-hour daily nighttime sleep opportunity from 2200 to 0800 hours. This placed the sleep opportunity at times when it is likely that homeostatic drive for sleep was high (early in the night of sleep) and the circadian drive for wakefulness was low (late in the night of sleep), promoting sustained, consolidated sleep.[3] Such a consolidated nighttime sleep opportunity would be typically associated with day shift work.

The split sleep experimental condition was implemented as two 5-hour daily sleep opportunities, one from 0300 to 0800 and the other from 1500 to 2000. This placed the sleep opportunity in the first instance at a time when sleep propensity is high and in the second instance at a time when sleep propensity, at least later in the interval, is low. This is a plausible split sleep schedule, as the first 5-hour sleep opportunity brackets the early morning circadian low and the second 5-hour sleep opportunity begins in the temporal vicinity of the late afternoon "mini" circadian low, both of which are associated with an increase in sleep propensity.[3]

The consolidated daytime control sleep condition was implemented as a 10-hour daytime sleep opportunity from 1000 to 2000. This placed the sleep opportunity initially at a time when sleep propensity is high due to high homeostatic drive and subsequently at a time when sleep propensity is generally low due to the increasing circadian drive for wakefulness.[3]

To approximate a CMV driver working under current HOS rules (14 hours on duty/10 hours off duty) and ramping up as rapidly as possible to the limit of 70 hours in 8 days, all three conditions were continued for a simulated workweek of 5 consecutive days. All three conditions had the same 90-hour total sleep opportunity (10 hours per day) across the consecutive 9 (rounding to 10) days of the study. The basic design (2 days baseline, 5 days experimental or control conditions, 2 days recovery) with associated sleep and wake times is depicted in Figure 1. For the nighttime sleep condition, no adjustment in sleep time was necessary at the beginning or end of the workweek. This is not the case for the split sleep or daytime sleep conditions. Hence, transition naps were implemented for both split sleep and daytime sleep conditions to aid in the transition to the workweek schedule at the beginning of the 5-day workweek and to aid the switch back to nighttime sleep at the end of the workweek (see Figure 1).

Consolidated Nighttime Sleep Condition

Hour of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Day 1										Orientation/Practice Sessions														
Day 2									Off Duty/Neurobehavioral Testing															
Day 3									Off Duty/Neurobehavioral Testing															
Day 4									Workday															
Day 5	Daily 10-Hour Sleep Opportunities								Workday															
Day 6									Workday															
Day 7									Workday															
Day 8									Workday															
Day 9									Off Duty/Neurobehavioral Testing															
Day 10									Wrap-Up															

Split Sleep Condition

Hour of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Day 1										Orientation/Practice Sessions														
Day 2	Baseline Sleep								Off Duty/Neurobehavioral Testing															
Day 3	Baseline Sleep								Off Duty/Testing							Transition Sleep					Off/Testing			
Day 4	Off/Testing	Split Sleep							Workday							Split Sleep					Workday			
Day 5	Workday	Split Sleep							Workday							Split Sleep					Workday			
Day 6	Workday	Split Sleep							Workday							Split Sleep					Workday			
Day 7	Workday	Split Sleep							Workday							Split Sleep					Workday			
Day 8	Workday	Split Sleep							Workday							Split Sleep					Workday			
Day 9	Workday	Recovery Sleep							Off Duty/Neurobehavioral Testing															
Day 10	Recovery Sleep								Wrap-Up															

Consolidated Daytime Sleep Condition

Hour of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Day 1										Orientation/Practice Sessions														
Day 2	Baseline Sleep								Off Duty/Neurobehavioral Testing															
Day 3	Baseline Sleep															Transition Sleep					Workday			
Day 4	Workday									Consolidated Daytime Sleep											Workday			
Day 5	Workday									Consolidated Daytime Sleep											Workday			
Day 6	Workday									Consolidated Daytime Sleep											Workday			
Day 7	Workday									Consolidated Daytime Sleep											Workday			
Day 8	Workday									Transition Sleep														
Day 9	Recovery Sleep								Off Duty/Neurobehavioral Testing															
Day 10	Recovery Sleep								Wrap-Up															

Figure 1. Chart. Sleep/Wake Schedule for the Three Sleep Opportunity Conditions

2.2 DESIGN LIMITATIONS

For the present study, data were collected from participants in the three sleep opportunity conditions—nighttime sleep, split sleep, and daytime sleep. Including baseline, workweek, and recovery, the data collection used for the study analysis lasted 10 days for all three groups.

However, the daytime consolidated sleep condition was part of another study,[4] which was 16 days long and involved two 5-day workweeks separated by a recovery period. The first 5-day workweek, including baseline and recovery, was used in the present study. For participants in the nighttime consolidated sleep condition and the split sleep condition, the stay in laboratory ended on Day 10. For the participants in the daytime sleep condition, the stay in the laboratory ended on Day 16. All groups knew how long they would be in the laboratory and knew in which sleep condition they were participating. However, in contrast to participants in the nighttime and split sleep conditions, participants in the daytime sleep condition were anticipating 6 more days in the laboratory than the participants in the nighttime sleep and split sleep conditions. During the additional 6 days, the participants in the daytime sleep conditions knew that they would transition back to working another workweek in which they slept during the day and worked during the night and then transition back to sleeping nights and working days with the completion of the second 5-day workweek. Thus, the three groups differed in experimental condition, and, in addition, the daytime sleep condition differed from the nighttime sleep and split sleep conditions in having to spend an additional 6 days in the laboratory undergoing a repeat of the 5-day workweek. This difference between the participants in the daytime sleep condition and those in the other two conditions (nighttime sleep and split sleep) is important to bear in mind when interpreting the findings with respect to the present split sleep study.

2.3 LABORATORY CONTROL

During their days in-residence at the sleep and performance research laboratory, participants had no contact with the outside world. They slept, ate, took performance tests, and had blood draws within the confines of the sleep laboratory. There was no cell phone contact, no email, no visitors, and no live television, radio, or internet. Participants arrived in the laboratory at 0900 on Day 1 and completed data collection for the present study at 1400 on Day 10. As indicated in Section 2.2, the participants in the daytime sleep condition continued in the sleep laboratory for an additional 6 days.

2.4 PARTICIPANT RECRUITMENT AND SCREENING

Participants in the study were recruited from the population of healthy young men ranging in age from 22 to 40. This population was selected because of its relative homogeneity and normality in sleep/wake and circadian physiology (e.g., minimal aging effects and low prevalence of sleep disorders). This homogeneity improves statistical power. Women and obese men were not included in the study. Participants were needed in whom intravenous (IV) catheters could be easily placed and from whom blood samples could be easily and reliably drawn repeatedly over time.

Prospective participants were identified through their responding to our advertisements in local newspapers and on the internet. The several hundred people who responded were interviewed by telephone. Those who met key selection criteria—i.e., age and body mass index (BMI)—were screened during two laboratory-based screening sessions), beginning with an informed consent procedure. Screening procedures included a physical exam, blood and urine samples, supervised

test-driving of the driving simulator, and a variety of questionnaires to assess suitability for participation.

The list of inclusion/exclusion criteria are as follows:

- Physically and psychologically healthy (i.e., no clinical disorders and/or illnesses), as determined by physical exam, history, and questionnaires.
- No current medical or drug treatment, as determined by history and questionnaire.
- No clinically significant abnormalities in blood and urine, and free of traces of drugs, as determined by blood chemistry and urinalysis, as well as a urine drug test upon entering the study.
- Free of traces of alcohol, as verified with a breathalyzer during screening and upon entering the study.
- No history of psychiatric illness, as determined by history and questionnaire.
- No history of drug or alcohol abuse in the past year, and no history of methamphetamine abuse, as determined by history and questionnaire.
- Not a current smoker, as determined by questionnaire.
- No history of moderate to severe brain injury, as determined by history and questionnaire.
- No history of a learning disability, as determined by questionnaire.
- Not susceptible to simulator adaptation syndrome, as determined by supervised test-driving of the simulator followed by questionnaire and interview.
- No previous adverse reaction to sleep deprivation, as determined by history and questionnaire.
- Not vision-impaired (unless corrected to normal), as determined by questionnaire.
- No sleep or circadian disorder, as determined by history, suite of questionnaires, and baseline polysomnography (PSG).
- Good habitual sleep, between 6 and 10 hours in duration, as determined by questionnaire and verified with wrist actigraphy and diary in the week before the study.
- Regular bedtimes, habitually getting up between 0600 hours and 0900 hours, as determined by questionnaire and verified with actigraphy and diary in the week before the study.
- Neither an extreme morning-type nor an extreme evening-type, as determined by questionnaire.
- No travel across time zones within 1 month of entering the study, as determined by questionnaire.
- No shift work within 1 month of entering the study, as determined by questionnaire.

- Native English speaker, as determined by questionnaire.
- Proficient driver, as determined by valid driver's license and supervised test driving of the simulator.
- Age from 22 to 40 years, as verified by date of birth on driver's license.
- Male gender.
- Veins suitable for IV catheter insertion.
- No history of problems having blood drawn from a vein or donating blood.
- Not donated blood within 2 months of entering the study, and not planning to donate blood within 2 months after the study.
- BMI less than 30.
- Not a participant in previous FMCSA restart studies.

2.5 MEASURES

2.5.1 Sleep

Sleep was measured by PSG, based on the continuous, parallel recording of electroencephalogram (EEG) (brain electrical activity), electrooculogram (EOG) (electrical activity generated by eye movements), and electromyogram (EMG), which is electrical activity generated by muscle activity. From these variables, one can score whether a person is awake or asleep and, if asleep, in what stage of sleep they are. Sleep is divided into non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep. NREM sleep is divided into stages of progressively deeper sleep: NREM sleep stage 1 (N1), NREM sleep stage 2 (N2), and NREM sleep stage 3 (N3). N3 sleep is also called slow-wave sleep (SWS) because of the high amplitude, low-frequency waves in the EEG that characterize this state. REM sleep alternates with NREM sleep with a 90–120-minute periodicity. REM sleep is associated with dreaming. NREM sleep episodes become shorter and less intense as the night of sleep progresses. REM sleep episodes become longer and more intense as the night of sleep progresses. Time in bed is total time in bed including wake time, NREM sleep time, and REM sleep time. Total sleep time is the sum of NREM and REM sleep time. It is total sleep time that correlates best with recuperation during sleep and with next day performance. Sleep latency is the time from lights out to the first episode of stage 1 sleep. Across the three conditions, the following PSG/Sleep variables were compared between conditions:

- Time in bed.
- Total sleep time.
- N3 sleep time.
- REM sleep time.
- N2 sleep time.

- N1 sleep time.
- Sleep latency.
- Latency to N3 sleep.
- Latency to REM sleep.

Polysomnographs were recorded digitally and total sleep time and sleep stages were scored by a Registered PSG Technologist using the standard technical specifications and rules recommended by the American Academy of Sleep Medicine.[15] Scalp and skin electrodes were used to record brain waves (bipolar EEG), eye movement (EOG), muscle activity (submental [chin] EMG), and heart beat (electrocardiogram). The EEG electrodes were placed at frontal (F3, F4), central (C3, C4), and occipital (O1, O2) locations, referenced against the mastoids (M1, M2). Every third or fourth day, electrodes were removed to give participants an opportunity to take a shower and to heal any skin irritation caused by the electrodes. The sleep periods that were recorded and the comparisons made across conditions are shown in Figure 2 and Table 2.

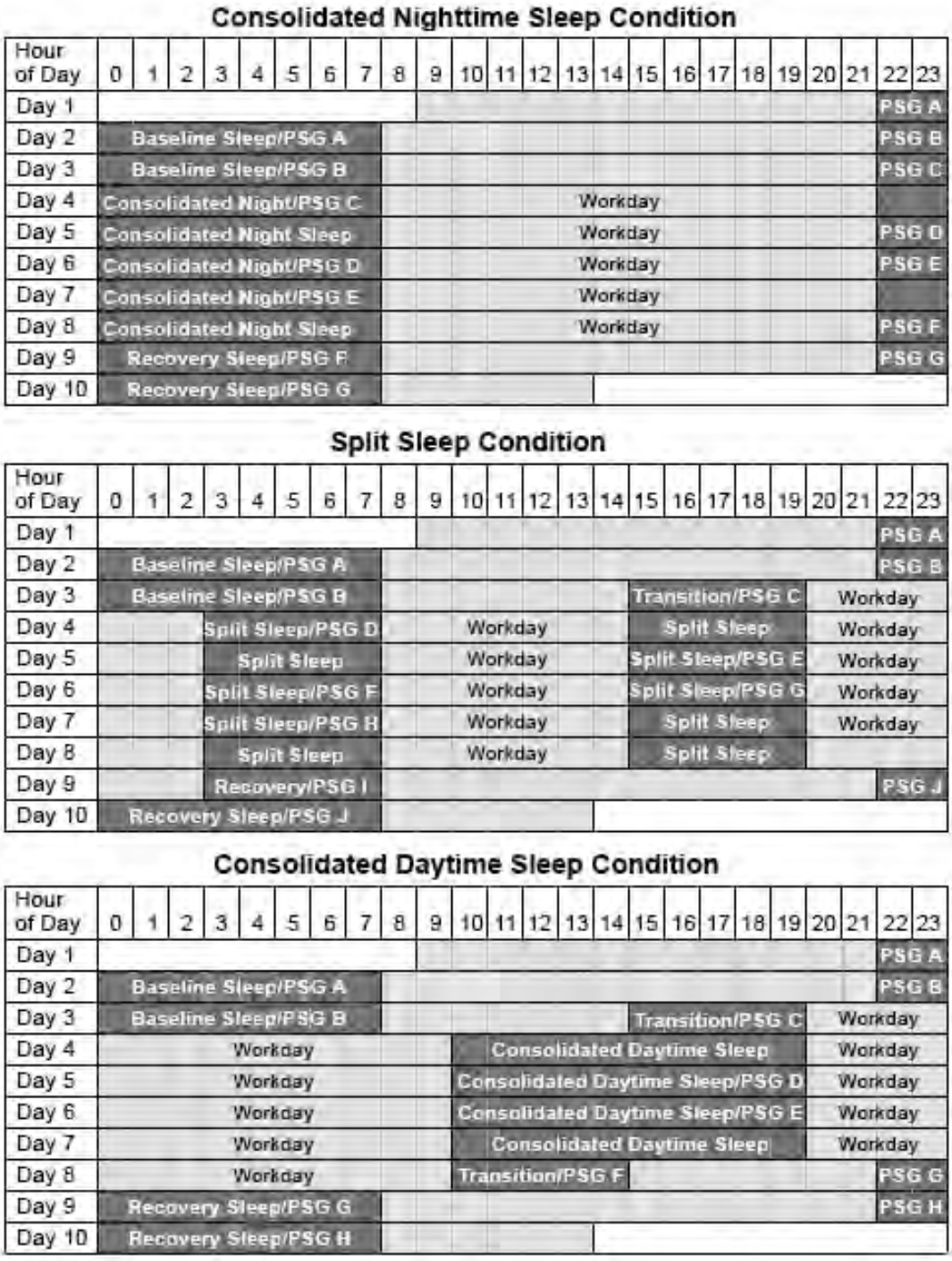

Figure 2. Chart. PSG Recording Schedule for the Three Sleep Conditions

Table 2. Comparison of PSG Across Three Conditions

	Nighttime Sleep Control Condition	Split Sleep Experimental Condition	Daytime Sleep Control Condition
Baseline (BL1)	PSG A	PSG A	PSG A
Baseline (BL2)	PSG B	PSG B	PSG B
Workweek (W1)	PSG D	PSG E + F	PSG D
Workweek (W2)	PSG E	PSG G + H	PSG E
Recovery (R)	PSG G	PSG J	PSG H

2.5.2 Performance

Description of the performance tasks is outlined below. Figure 3 shows the timing of the 1-hour blocks, consisting of a 10-minute psychomotor vigilance task (PVT), 40-minute simulator driving, and 10-minute PVT (PDP). Figure 3 also shows the timing of the brief neurobehavioral test bouts (S). On off-duty days, no driving occurred, but the neurobehavioral test battery was administered several times, augmented with a 10-minute PVT (SP). This off-duty performance monitoring served to gauge fatigue levels during the baseline and recovery periods bracketing the 5-day work period; they were not used for the present analyses. Driving simulator and performance testing practice occurred on the first day; these practice sessions also were not used for analysis.

Figure 3. Chart. Schedule for the Three Sleep Conditions for PVT Testing (P), Neurobehavioral Test Battery (S), and Driving Simulator (D) Performance

2.5.2.1 Psychomotor Vigilance Task

Vigilance performance, the primary performance metric, was assessed using a 10-minute PVT, a simple reaction time test with a high stimulus density. The following PVT-derived metrics were compared across the three sleep opportunity conditions:

- Lapses (reaction times greater than 500 milliseconds [ms]) across days, collapsed over time of day, and across time of day, collapsed over days.
- Median reaction time (across days, collapsed over time of day and across time of day, collapsed over days).
- Fastest 10 percent of reaction times across days, collapsed over time of day.
- Reciprocal (1/RT) of the slowest 10 percent of reaction times across days, collapsed over time of day.

The PVT is a standard assay of vigilance used to assess fatigue.[16] As in previous studies,[17,18,19] the number of performance lapses was extracted, with performance lapses being defined as reaction times greater than 500 ms. The PVT has high sensitivity to fatigue and favorable statistical properties.[20] The 10-minute PVT was administered alone (P) or in combination with the subjective state measures and the neurobehavioral test battery (S) or before and after the driving simulator (D) for the three conditions as indicated in Figure 3. With respect to the driving simulator, a 10-minute PVT was done before and after each driving simulator run as indicated by the "PDP." For all conditions across the workweek, there were eight PVTs in every 24-hour period.

2.5.2.2 Driving Simulator

For the driving simulator testing, the participants drove a 40-minute route in a high-fidelity driving simulator used for professional driver training. Hardware and software were developed enabling the capture of the performance metrics outlined below, thereby converting a training device into a research tool. A standard driving scenario was used—driving on a rural highway with five to seven randomly distributed pedestrians or dogs crossing the road providing the events to test reaction time in emergency braking. In addition, 10 straight, uneventful road segments in the scenario (straightaways) were used to extract non-confounded data on lane deviation and other performance measures potentially indicative of fatigued driving. The speed limit in the scenario was 55 miles per hour. Participants drove the driving simulator for 40 minutes four times during each workday.

Specific driving simulator metrics are below:

- Average speed in the straightaways (across days, collapsed over time of day).
- Speed variability (standard deviation) in the straightaways (across days, collapsed over time of day).
- Lane deviation (standard deviation of lane position) in the straightaways (across days, collapsed over time of day).
- Emergency braking (reaction time for braking for pedestrian/dog crossing road) (across days, collapsed over time of day).
- Performance on the driving simulator is as sensitive as performance on the PVT to degrees of sleep restriction.[21]

Two driving simulators were available in the laboratory, and up to four participants could be participating in the study at a given time. Therefore, participants were randomly assigned consistently either to do the PVT/driving/PVT block first and undergo the neurobehavioral testing second, or the other way around. Figure 3 illustrates the simulator driving and performance testing schedule for the participants who underwent the PVT/driving/PVT block first and the neurobehavioral testing second.

2.5.2.3 Neurobehavioral test battery

Other assessments of cognitive function were performed during the study. The neurobehavioral test battery (~12 minutes) was administered either alone (S) or in combination with a PVT (SP) as indicated in Figure 3. The battery consisted of the digit-symbol substitution test[22] (DSST); computerized versions of the Karolinska Sleepiness Scale[23] (KSS); a visual analog scale of mood[18] (VASM); the Positive Affect Negative Affect Schedule[24] (PANAS), which is a measure of positive and negative emotion; and performance and effort rating scales[25] (PERF/EFFR).

The DSST is a performance test involving matching numbers to symbols. The computer screen showed a key with a set of nine symbols, each with a corresponding digit (1–9). When given a symbol in another, fixed location on the screen, participants were required to type its corresponding number. After the response, a new symbol was immediately presented. The number of correct responses in the 3-minute task duration was extracted, yielding a measure of cognitive throughput. The DSST is sensitive to acute total sleep deprivation and chronic sleep restriction.[17]

The KSS, VASM, PANAS, PERF, and EFFR yielded subjective assessments of sleepiness, mood, and effort. For each, an overall score was extracted, except for the PANAS, for which both positive and negative affect scores were determined. Thus, the subjective state measures were:

- KSS—a 9-point scale ranging from 1 = “very alert” to 9 = “very sleepy—great effort to keep awake, fighting sleep.”
- VASM—a single-item visual analog scale rating mood from “elated” to “depressed.”
- PANAS—participants were asked to rate on a 5-point scale how strongly they felt 10 positive emotions (attentive, interested, alert, excited, enthusiastic, inspired, proud, determined, strong, and active) and 10 negative emotions (distressed, upset, hostile, irritable, scared, afraid, ashamed, guilty, nervous, and jittery).
- PERF/EFFR—participants were asked to rate their performance (PERF) on a scale of 1–7 and the effort needed to sustain that performance (EFFR) on a scale of 1–4.

2.5.3 Biomedical Metrics

2.5.3.1 Blood Chemistries

The blood chemistries are the following:

- Glucose.
- Interleukin-6 (IL-6).
- Leptin.
- Testosterone.

Blood glucose reflects glucose regulation and is related to overweight, obesity, type 2 diabetes, metabolic syndrome, and cardiovascular disease;[26] IL-6, a representative cytokine and marker for the pro-inflammatory cytokine, IL-1, reflects immune response and inflammation;[27] leptin plays a role in appetite regulation, in particular satiety;[28] and testosterone plays a role in metabolism, particularly anabolic metabolism.[29]

Blood draws for chemistries were done for the three conditions every 2 hours while awake on Day 2, the first baseline day and before the 5-day workweek, and approximately every 2 hours while awake on Day 9, the first recovery day after the 5-day workweek. On blood draw days, participants were instrumented with indwelling intravenous catheters between 0800 and 0830 hours. Blood was then drawn from this catheter every 2 hours over the course of the day, eliminating the need for repeated needle sticks. The first blood draw was a half an hour after IV catheter insertion to dissipate any reaction to the catheter insertion. A supplementary blood draw was done at 0830 on Day 3 and Day 10, using direct venipuncture with a needle. These blood draws were not used in the analysis due to the potential effect of the different techniques used to obtain the sample on the results. The tubes for IL-6, leptin, and testosterone were placed on dry ice prior to use. For the actual draw, the catheter was flushed with 10 cubic centimeters (cc) of normal saline, 2 cc of blood was drawn and discarded, the samples were drawn, and the line was flushed again with 10 cc of normal saline. Once drawn, tubes were spun at 1,000 rpm for 15 minutes in a refrigerated (4 degrees centigrade) centrifuge. Plasma was aliquoted and frozen at -80 centigrade. The schedule for blood draws and BP measurements is given in Figure 4.

With respect to glucose measurements, the participants were instrumented at 2015 the evening before each blood draw day with continuous glucose monitors. These devices were removed 24 hours later at the end of the blood draw day. The every-2-hour glucose draws from the IV catheter during the blood draw days were for the purpose of calibrating the continuous glucose monitors.

For all participants in all conditions, caloric intake was limited to 2,400 kilocalories (kcal) per day. On the blood draw days, meals were at 0900, 1300, and 1900. Meal timing was strictly adhered to, and the only between-meal snacking allowed was a non-caloric snack once per 24 hours (carrot or celery stick). To control both number and source of calories, each participant was given exactly the same meal (amount and menu items) on the post-workweek blood draw day (Day 9) as on the baseline blood draw day (Day 2).

Consolidated Nighttime Sleep Condition

Hour of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Day 1																					BP			
Day 2	Baseline Sleep									C	C		C		C		C		C		C	BP		
Day 3	Baseline Sleep								C												BP			
Day 4	Consolidated Night Sleep														Workday						BP			
Day 5	Consolidated Night Sleep														Workday						BP			
Day 6	Consolidated Night Sleep														Workday						BP			
Day 7	Consolidated Night Sleep														Workday						BP			
Day 8	Consolidated Night Sleep														Workday						BP			
Day 9	Recovery Sleep									C	C		C		C		C		C		C	BP		
Day 10	Recovery Sleep								C															

Split Sleep Condition

Hour of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Day 1																					BP			
Day 2	Baseline Sleep									C	C		C		C		C		C		C	BP		
Day 3	Baseline Sleep								C							Transition Sleep					BP	Workday		
Day 4				Split Sleep							Workday					Split Sleep					BP	Workday		
Day 5				Split Sleep							Workday					Split Sleep					BP	Workday		
Day 6				Split Sleep							Workday					Split Sleep					BP	Workday		
Day 7				Split Sleep							Workday					Split Sleep					BP	Workday		
Day 8				Split Sleep							Workday					Split Sleep					BP			
Day 9				Recovery Sleep						C	C		C		C		C		C		C	BP		
Day 10	Recovery Sleep								C															

Consolidated Daytime Sleep Condition

Hour of Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Day 1																					BP			
Day 2	Baseline Sleep									C	C		C		C		C		C		C	BP		
Day 3	Baseline Sleep								C								Transition Sleep				BP	Workday		
Day 4					Workday							Consolidated Daytime Sleep									BP	Workday		
Day 5					Workday							Consolidated Daytime Sleep									BP	Workday		
Day 6					Workday							Consolidated Daytime Sleep									BP	Workday		
Day 7					Workday							Consolidated Daytime Sleep									BP	Workday		
Day 8					Workday						Transition Sleep										BP			
Day 9	Recovery Sleep/PSG G									C	C		C		C		C		C		C	BP		
Day 10	Recovery Sleep/PSG H								C															

Figure 4. Chart. Blood Chemistries (C) and BP Schedule for the Three Sleep Conditions

2.5.3.2 Blood Pressure

BP was taken daily at 2045 for each participant. Four measurements were made over 10 minutes by a programmable automatic BP device. The five daily BP averages during the workweek were used in the analysis. These measurements were expressed as the daily average for each

participant. Chronically and episodically elevated BP, particularly diastolic pressure and mean arterial pressure (MAP), are risk factors for cardiovascular disease.

The panel of blood chemistries plus the measures of BP discussed above yield a means of detecting sleep condition-dependent perturbation of biomedical markers associated with increased risk for developing overweight, obesity, metabolic syndrome, type 2 diabetes, cardiovascular disease, renal failure, and stroke.

2.6 STATISTICAL METHODS AND POWER CALCULATIONS

The primary statistical design involved a between-groups comparison of the effects of three sleep opportunity Conditions (between-groups factor: nighttime sleep, split sleep, and daytime sleep) on physiological and behavioral parameters. For the sleep variables, the primary statistical analyses involved a two-way Condition by Sleep Period (repeated-measures factor: baseline sleep period 1 [BL1], baseline sleep period 2 [BL2], work period 1 [WP1], work period 2 [WP2], recovery) repeated-measures analysis of variance (ANOVA).

For PVT lapses, the primary statistical analysis involved a three-way Condition by Workday (repeated-measures factor: Workday 1–5) by Session (repeated-measures factor: Session 1–8) repeated-measures ANOVA.

For the driving simulator variables, a three-way Condition by Workday (repeated-measures factor: Workday 1–5) by Session (repeated-measures factor: Session 1–4) repeated-measures ANOVA, accounting for participants' assignment to either simulator #1 or #2.

For the behavioral measures, the primary statistical analysis involved a three-way Condition by Workday (repeated-measures factor: Workday 1-5) by Session (repeated-measures factor: Session 1–4) repeated-measures ANOVA.

For biomedical metrics, the primary analysis involved a three-way Condition by Week (repeated-measures factor: pre-workweek, post-workweek) by Time (repeated-measures factor: blood draw 1–7) mixed-effects ANOVA. This approach was taken to account for both within-subject and between-subject variability in blood results.

Because this study is the first of its kind, a more liberal approach was taken with post-hoc analyses of significant interactions: that is, independent (between-groups factors) or dependent (repeated-measures factors) post-hoc comparisons were used to compare all possible combinations of conditions and time points. Specific details regarding statistical analyses for each dependent measure are found in the appendixes.

Results of power calculations showed that 12 participants per condition was sufficient to detect differences in PVT lapses (considered the primary outcome metric) and that 16 participants per condition were needed in order to detect a change in IL-6 (a secondary outcome metric). The study met both requirements (Section 3.1 Participants).

3. RESULTS

3.1 PARTICIPANTS

Fifty-three participants completed the study (53 men; mean age 26.51 years ± 4.07 years standard deviation); by condition: consolidated nighttime sleep condition (19 participants), split sleep condition (17 participants), and consolidated daytime sleep condition (17 participants). There was no significant difference in age between the conditions ($F_{2,48} = 0.74$; $p = 0.48$). The study was approved by the Washington State University Institutional Review Board (IRB) and all participants gave informed consent.

3.2 SLEEP

The polysomnographically recorded sleep periods for the three sleep conditions—nighttime sleep, the split sleep, and the daytime sleep for baseline (two recordings; BL1, BL2), workweek (two recordings; W1, W2), and recovery (one recording)—were compared (see Figure 2 for the PSG recoded sleep periods for each condition and Table 2 for the PSG comparisons).

One participant in the nighttime sleep condition was excluded from the sleep analysis due to a suspected sleep disorder. Two participants in the daytime sleep condition were also excluded from the sleep analysis—one due to poor sleep efficiency throughout the study (due to flu-like symptoms) and one due to light exposure during the sleep periods. This left 15 participants in the daytime sleep condition, 18 participants in the nighttime sleep condition, and 17 participants in the split sleep condition for the PSG analysis.

Time in bed was equivalent for the three conditions (nighttime sleep, split sleep, and daytime sleep) across the baseline, workweek, and recovery periods. For the PSG recordings, total time in bed (TIB) was 20 hours for the two baseline recordings, 20 hours for the 2 workweek recordings, and 10 hours for the single recovery recording.

For all sleep parameter analyses reported below, complete ANOVA and post-hoc test results tables are provided in Appendix A.

3.2.1 Total Sleep Time

Figure 5 illustrates minutes of total sleep time (TST—sum of stages N1, N2, SWS, and REM) for nighttime sleep (NIGHT), split sleep (SPLIT), and daytime sleep (DAY) conditions across the five polysomnographically recorded sleep periods.

During W1, TST differences among all three groups (NIGHT, SPLIT, and DAY) were significant, with NIGHT sleep obtaining the most TST, followed by SPLIT and DAY sleep (Condition × Sleep Period interaction $p < 0.001$; post-hoc ps < 0.05). During W2, participants in NIGHT condition obtained significantly more TST than participants in the SPLIT and DAY conditions (ps < 0.05). During REM, participants in SPLIT sleep condition obtained significantly more TST than participants in DAY sleep condition ($p < 0.05$).

Within a given condition, participants in the NIGHT sleep condition obtained significantly more TST during BL2 than during REM ($p < 0.05$). Participants in the DAY sleep condition obtained significantly more TST during BL1 and BL2 than during W1 and W2 (ps < 0.05). Participants in the SPLIT sleep condition obtained significantly more TST during BL1 and BL2 than during W1 and W2, and more TST during REM than during W2 (all ps < 0.05).

Overall, participants in the NIGHT and SPLIT conditions obtained significantly more TST than participants in the DAY condition (condition main effect and contrasts, ps < 0.05). Across sleep periods, participants obtained significantly more TST during BL1 and BL2 than during W1, W2, and recovery (sleep period main effect and contrasts, ps < 0.05). Although it appeared that participants obtained more TST during recovery than during either W1 or W2, these differences were not significant (ps > 0.05).

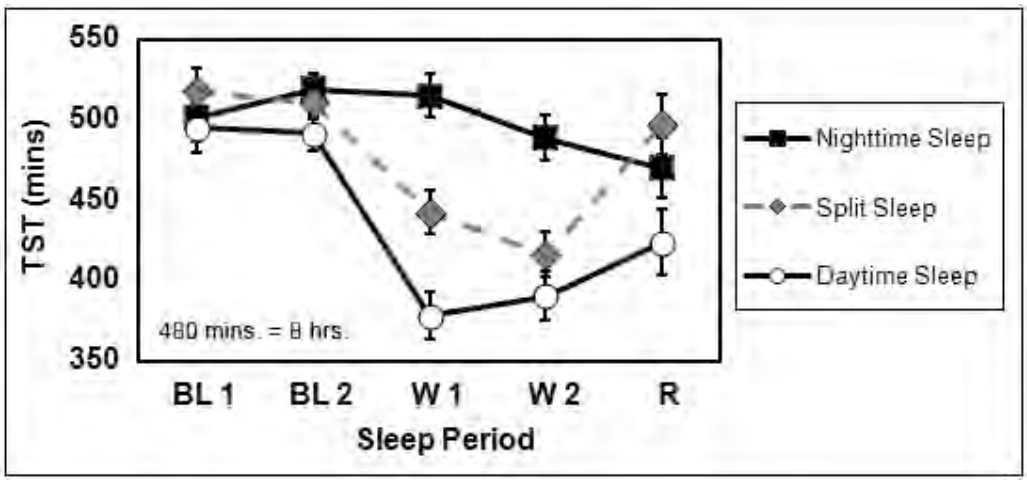

Figure 5. Feverline chart. Total sleep time (TST) across two baseline sleep periods (BL1, BL2), two sleep periods during the workweek (W1, W2), and one recovery sleep period (R) for the nighttime sleep, split sleep, and daytime sleep conditions

3.2.2 Stage N3 Sleep

No significant effects were found for slow-wave sleep (stage N3 sleep) (all ps > 0.05).

3.2.3 Stage REM Sleep

Figure 6 illustrates minutes of REM sleep for NIGHT, SPLIT, and DAY conditions across the five polysomnographically recorded sleep periods.

During BL2, participants in the DAY sleep condition obtained significantly less REM than participants in the NIGHT sleep conditions (Condition × Sleep Period interaction and post-hoc, $p < .0.05$). During W1 and W2, participants in the NIGHT sleep condition obtained significantly more REM sleep than the SPLIT and DAY sleep conditions (ps < 0.05). During recovery, participants in the DAY sleep condition obtained significantly less REM than participants in the NIGHT sleep condition ($p < 0.05$).

Within a given condition, participants in the NIGHT sleep condition obtained significantly more REM during BL2 and W1 compared to BL1 (ps < 0.05). Participants in the SPLIT condition obtained significantly more REM sleep in BL1 and BL2 than in W2 (ps < 0.05).

Overall, REM sleep differed significantly among all three conditions, with participants in the NIGHT condition obtaining the most REM sleep and participants in the DAY condition obtaining the least (condition main effect and contrasts, ps < 0.05). Across sleep periods, more REM sleep was obtained during BL2 versus BL1, W1, and W2 (sleep period main effect and contrasts, ps < 0.05).

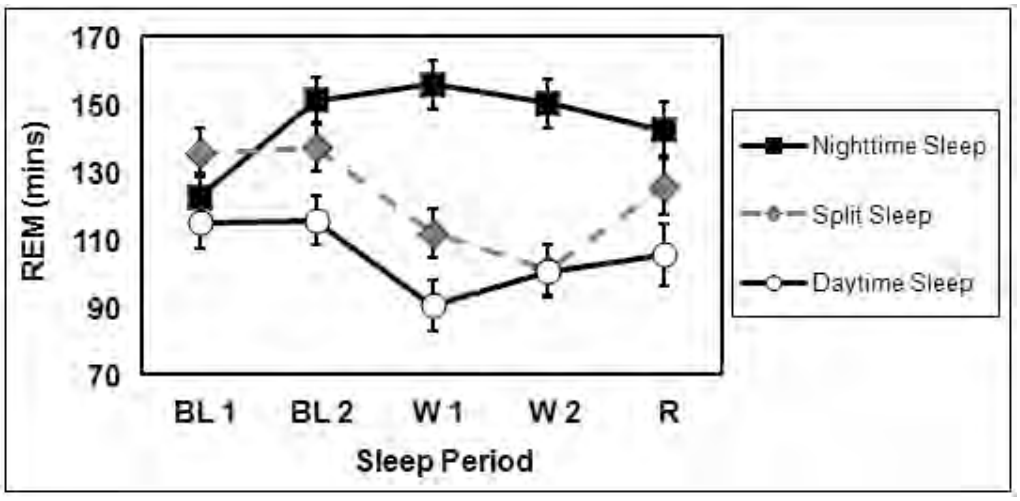

Figure 6. Feverline chart. REM sleep across two baseline sleep periods (BL1, BL2), two sleep periods during the workweek (W1, W2), and one recovery sleep period (R) for the nighttime sleep, split sleep, and daytime sleep conditions

3.2.4 Stage N2 Sleep

Figure 7 illustrates minutes of stage N2 sleep for NIGHT, SPLIT, and DAY conditions across the five polysomnographically recorded sleep periods. ANOVA and post-hoc results are presented in Appendix A.

During W1 and W2, participants in the DAY sleep condition obtained significantly less N2 than participants in the NIGHT sleep condition (Condition × Sleep Period interaction and post-hoc *t* test, p < 0.05). Within a given condition, participants in the NIGHT sleep condition obtained significantly more N2 sleep during BL1 than during W2 and recovery (ps < 0.05). Participants in the NIGHT sleep condition obtained significantly more N2 during BL1 than during recovery (ps < 0.05). Participants in the DAY sleep condition obtained significantly more N2 during BL1 and BL2 than during W1 and W2, and significantly less N2 during W1 and W2 than during recovery (ps < 0.05). Participants in the SPLIT sleep condition obtained significantly more N2 during BL1 and BL2 than during W1 and W2 (ps < 0.05) and tended to have less N2 during W1 and W2 than during recovery (ps = 0.05).

Overall, there were no significant differences in minutes of N2 among conditions (condition main effect, p > 0.05). Across sleep periods, significantly more N2 sleep was obtained during

BL1 and BL2 than during W1, W2, and recovery, and significantly less N2 was obtained during W1 and W2 than during recovery (ps < 0.05).

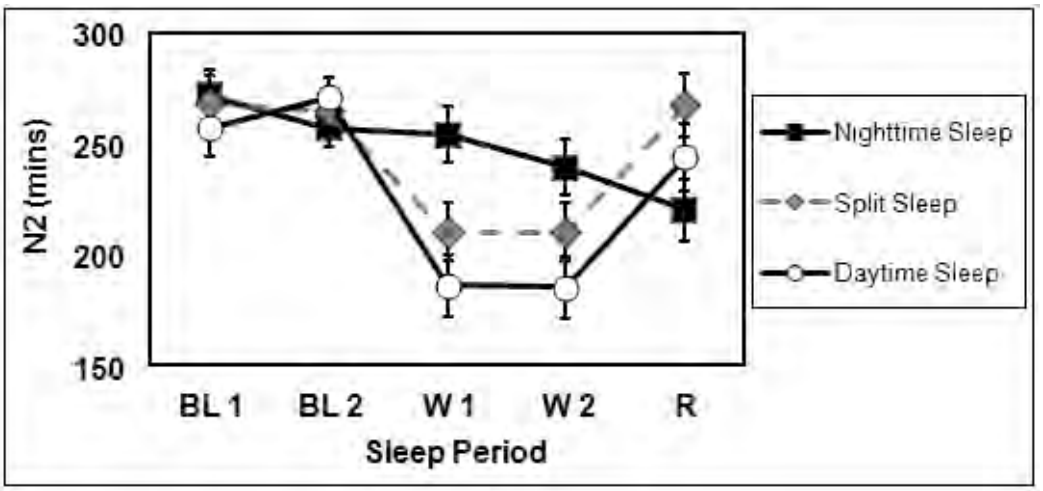

Figure 7. Feverline chart. N2 sleep across two baseline sleep periods (BL1, BL2), two workweek sleep periods during the workweek (W1, W2), and one recovery sleep period (R) for the nighttime sleep, split sleep, and daytime sleep conditions

3.2.5 Stage N1 Sleep

No significant effects were found for stage N1 sleep (all ps > 0.05).

3.2.6 Latency To Sleep

Figure 8 illustrates latency to sleep (in minutes) for NIGHT, SPLIT, and DAY sleep conditions across the five polysomnographically recorded sleep periods.

During W1 and W2, participants in the DAY sleep condition displayed significantly shorter sleep latencies than participants in the NIGHT sleep condition (Condition × Sleep period interaction and post-hoc *t* test, ps < 0.05). During recovery, participants in the NIGHT sleep condition displayed significantly longer sleep latencies than participants in the SPLIT sleep condition (p < 0.05).

Within a given condition, participants in the NIGHT sleep condition displayed significantly shorter sleep latency on BL1 and BL2 compared to recovery (ps < 0.05). Participants in the DAY sleep condition displayed significantly longer sleep latency during BL2 compared to W1 and W2 (ps < 0.05).

Overall, there were no significant differences in latency to sleep among conditions (condition main effect, p > 0.05). Across sleep periods, sleep latency was significantly shorter on W1 compared to BL2, W2, and recovery (sleep period main effect and post-hoc *t* tests, ps < 0.05).

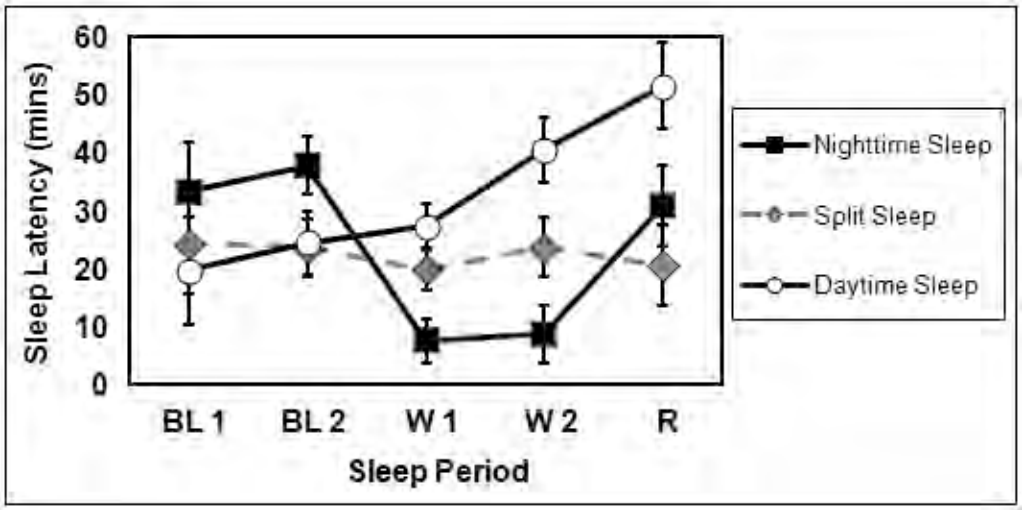

Figure 8. Feverline chart. Latency to sleep (SL) in minutes across two baseline sleep periods (BL1, BL2), two sleep periods during the workweek (W1, W2), and one recovery sleep period (R) for the nighttime sleep, split sleep, and daytime sleep conditions

3.2.7 Latency To Stage N3 Sleep

Figure 9 illustrates latency (in minutes) to stage N3 among NIGHT, SPLIT, and DAY sleep conditions across the five polysomnographically recorded sleep periods.

During W1, participants in the SPLIT sleep condition displayed significantly longer latency to stage N3 than participants in the NIGHT sleep condition (Condition × Sleep period interaction and post-hoc *t* test, ps < 0.05). During recovery, participants in the DAY condition displayed significantly longer latency to stage N3 than participants in the NIGHT and SPLIT sleep conditions (ps < 0.05). Within a given condition, participants in the DAY condition displayed significantly shorter stage N3 latency during BL1, BL2, and W1 compared to recovery (all ps < 0.05). Participants in the SPLIT sleep condition displayed significantly shorter stage N3 latency during BL1, BL2 and recovery compared to W2 (ps < 0.05).

Overall, there were no significant differences in latency to stage N3 among conditions (condition main effect, p > 0.05). Across sleep periods, participants displayed significantly shorter stage N3 latency during BL1 compared to W2 and during BL2 compared to W1 and W2 (p < 0.05).

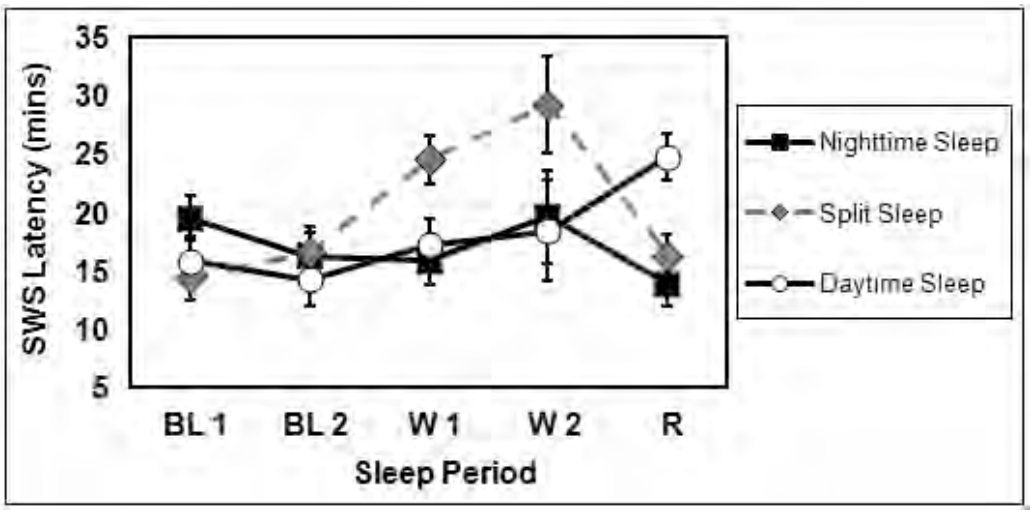

Figure 9. Feverline chart. Average slow-wave sleep latency (SWSL) across two baseline sleep periods (BL1, BL2), two sleep periods during the workweek (W1, W2), and one recovery sleep period (R) for the nighttime sleep, split sleep, and daytime sleep conditions

3.2.8 Latency to Stage REM Sleep

For latency to REM sleep, the interaction between condition and sleep period was not significant ($p > 0.05$).

Overall, there were no significant differences among conditions (condition main effect, $p > 0.05$). Across sleep periods, latency to stage REM sleep was longer during BL1 compared to W1, W2, and recovery (sleep period main effect and post-hoc *t* tests, $ps < 0.05$). Latency to stage REM sleep also was longer during BL2 compared to W2 and recovery ($ps < 0.05$).

3.2.9 Nap Data in the Split Sleep Condition

A subanalysis was performed on the split sleep condition data, comparing the Afternoon naps and Morning naps.

There was a significant effect of nap for total sleep time, as shown in Figure 10, with significantly more sleep being obtained in the morning sleep opportunity (260.2 ± 7.56 sem) than in the afternoon sleep opportunity (154.3 ± 6.63 sem) ($p < 0.001$). Sleep efficiency was also significantly higher in the morning nap compared to the afternoon nap ($p < 0.001$). Participants obtained significantly more slow-wave sleep and REM sleep during the morning nap relative to the afternoon nap ($ps < 0.001$).

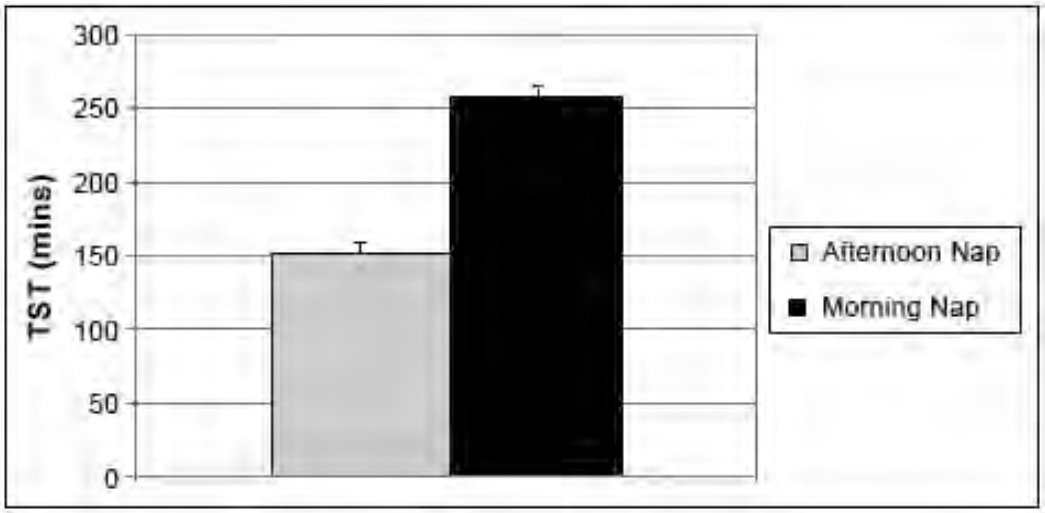

Figure 10. Column chart. Average total sleep time (TST) during the afternoon naps (1500–2000) and morning naps (0300–0800) in the split sleep condition

3.3 PERFORMANCE

The participant in the nighttime sleep condition who had a suspected sleep disorder was excluded from all behavioral analyses, leaving 18 participants in the consolidated nighttime sleep condition, 17 in the split sleep condition, and 17 in the consolidated daytime sleep condition.

3.3.1 Psychomotor Vigilance Task

The primary performance outcome measure for the study was the number of lapses on the psychomotor vigilance test (PVT). Two participants in the nighttime sleep condition and two participants in the split sleep condition were excluded from the PVT analysis as they were found to be noncompliant on this task. These participants exhibited a grand average of 8.82 (standard deviation [s.d.] 4.87) lapses on the PVT, whereas the other participants had a grand average of only 1.99 (s.d. 1.56). This left 16 participants in the nighttime sleep condition and 15 in the split sleep condition for the PVT analysis. Two of the runs in the nighttime sleep condition were affected by external noise from construction that was occurring outside the lab. A separate analysis of the participants in these runs compared to the other participants in the nighttime sleep condition was conducted to examine whether there was an effect of the construction noise on PVT performance. This was found to be significant. After running the full analysis with these participants excluded, there was very little difference in the final results, and therefore these participants were left in the analysis.

Figure 11 illustrates mean number of PVT lapses for NIGHT, SPLIT, and DAY conditions as a function of session (time of day) within the work period. ANOVA and post-hoc results are presented in Appendix B.

In sessions 1 and 2, participants in the DAY sleep condition had significantly fewer lapses compared to the NIGHT sleep condition (Condition × Time interaction, post-hoc ps < 0.05). In session 3, participants in the DAY sleep condition had significantly fewer lapses compared to the SPLIT sleep condition (post-hoc $p < 0.05$). In sessions 4 and 5, participants in the SPLIT sleep

condition had more lapses than the other conditions (post-hoc ps < 0.05). In session 6, participants in the SPLIT sleep condition had more lapses than participants in the DAY sleep condition (post-hoc p < 0.05). In session 7, participants in the SPLIT sleep condition had more lapses than the NIGHT sleep condition (post-hoc p < 0.05). In session 8, participants in the NIGHT sleep condition had more lapses than the DAY sleep condition (post-hoc p < 0.05).

Within a given condition, for the NIGHT sleep condition, PVT lapses did not increase across sessions; in contrast, in the DAY condition, number of lapses increased significantly across sessions (p < 0.05). For the latter condition, there were significantly more lapses in sessions 7 and 8 compared to sessions 1, 2, and 3 (post-hoc ps < 0.05). There were also more lapses in session 8 compared to sessions 4, 5, 6, and 7 (post-hoc ps < 0.05). For the SPLIT condition, significantly more lapses were seen during sessions 4–8 compared to session 1, and more lapses in session 4, 6, and 8 compared to session 2 (post-hoc ps < 0.05).

Overall, lapses increased significantly from sessions 3 to 8 compared to session 1 (time main effect, p < 0.05; post-hoc ps < 0.05). Lapses increased significantly from session 2 compared to sessions 4, 6, 7, and 8 (post-hoc ps < 0.05), and from session 3 compared to sessions 4–8 (post-hoc ps < 0.05). Lapses also increased significantly from session 4, 5, 6, and 7 compared to session 8 (post-hoc ps < 0.05).

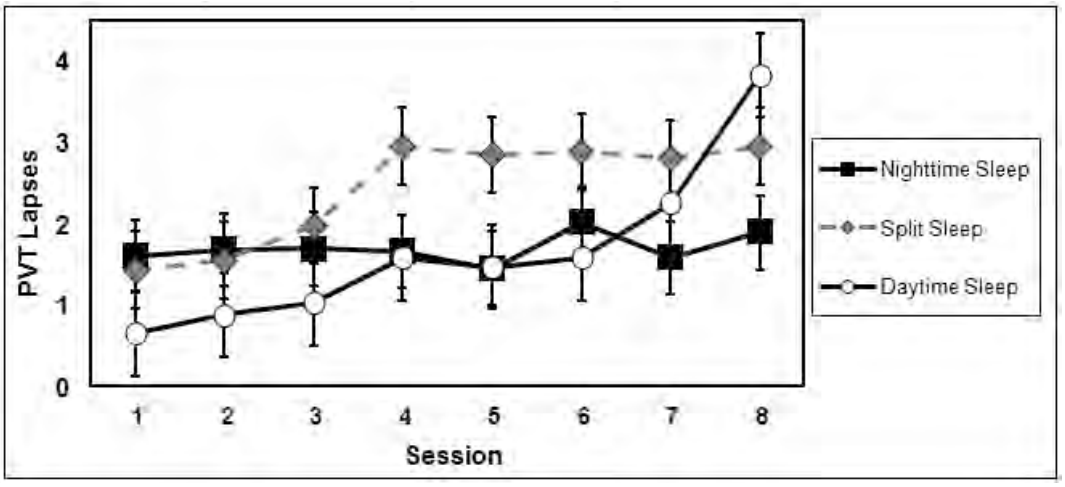

Figure 11. Feverline chart. Lapses on the eight sessions per workday 10-minute PVT, collapsed over the 5-day work period for each condition

Notes: For the nighttime sleep condition, testing was at 0900, 0930, 1200, 1230, 1500, 1530, 1800, and 1830. For the split sleep condition, testing was at 2100, 2130, 0000, 0030, 0900, 0930, 1200, and 1230. For the daytime sleep condition, testing was at 2100, 2130, 0000, 0030, 0300, 0330, 0600, and 0630. The higher the number of lapses, the greater the degree of performance impairment. Error bars indicate standard error.

Figure 12 illustrates mean number of lapses across workdays collapsed across sessions within work period. Lapses differed significantly across workdays (workday main effect, p < 0.05). Compared to workday 1, significantly more lapses were seen on workdays 3 and 5 (p < 0.05). Compared to workday 2, significantly more lapses were seen during workday 3 (p < 0.05) and marginally more lapses were seen during workday 5 (p = 0.060). Compared to workday 4, marginally more lapses were seen during workday 5 (p = 0.053).

No other main effects or interactions were significant for PVT lapses.

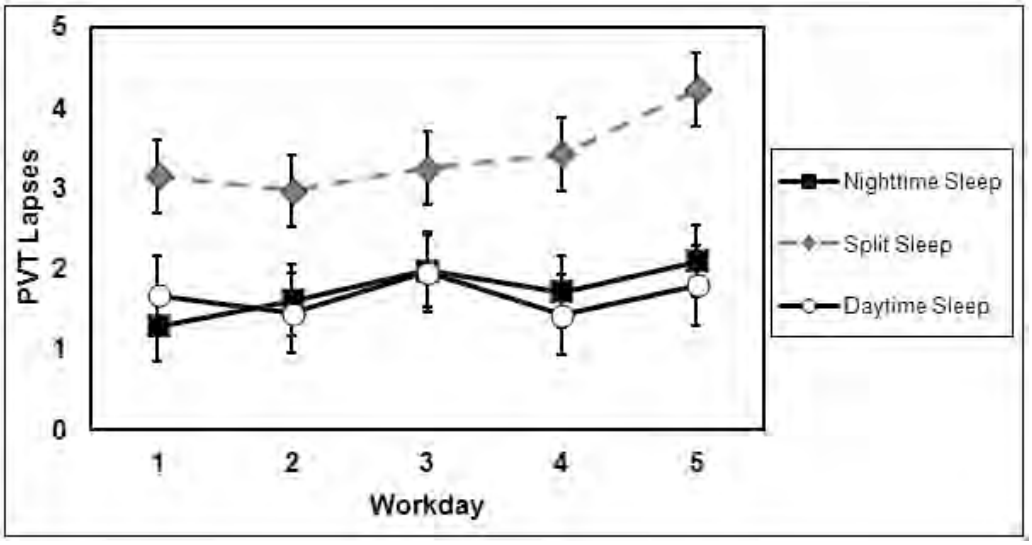

Figure 12. Feverline chart. Lapses on the 10-minute PVT as a function of days in the 5-day work period in the nighttime sleep, split sleep, and daytime sleep conditions

Notes: The higher the number, the greater the degree of performance impairment. Error bars indicate standard error.

3.3.2 Driving Simulator

Driving simulator outcome variables were subjected to the same analyses as were the cognitive performance outcomes described above, but participants' assignment to simulator number 1 or number 2 was added as a covariate to account for possible simulator hardware differences.

Average driving speed in the straightaways by day for NIGHT, SPLIT, and DAY conditions is displayed in Figure 13. ANOVA and post-hoc test results are presented in Appendix C.

During workdays 4 and 5, participants in the DAY sleep condition drove significantly faster than participants in the NIGHT sleep condition (Condition × Day interaction and post-hoc *t* tests, ps < 0.05).

Within a given condition, for the NIGHT sleep condition, there was a tendency for average speed to vary across the workweek (post-hoc test $p = 0.052$). Average speed was higher on workday 3 compared to workday 1 ($p < 0.05$).

No other main effects or interactions were significant for average driving speed.

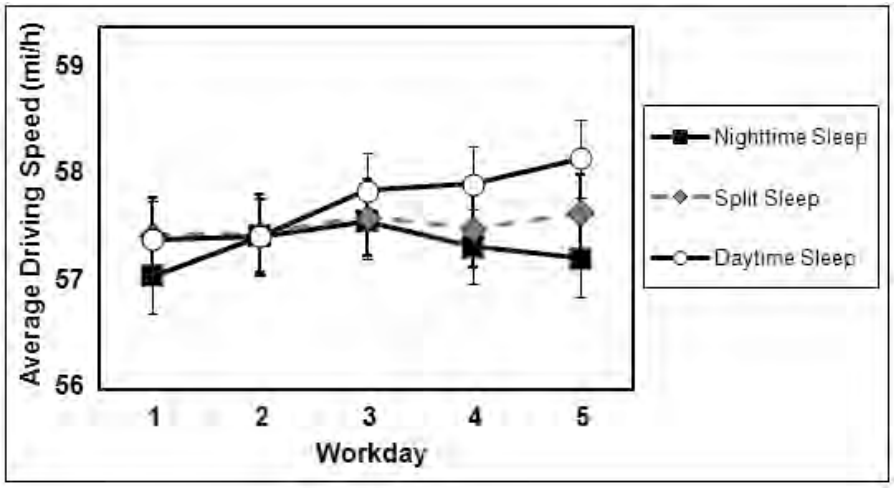

Figure 13. Feverline chart. Average simulator driving speed in the 5-day work period for the nighttime sleep, split sleep, and daytime sleep conditions

Figure 14 displays standard deviation of lane position in the straightaways by session (time of day) within each work period for the NIGHT, SPLIT, and DAY conditions. ANOVA and post-hoc test results are presented in Appendix C.

During session 3, participants in the SPLIT sleep condition displayed significantly more lane deviation than participants in the DAY sleep condition (Condition × Time interaction, ps < 0.05; post-hoc *t* tests, ps < 0.05). During session 4, participants in the DAY sleep condition had significantly higher lane deviation than participants in the NIGHT sleep condition (ps < 0.05).

Within a given condition, for the DAY sleep condition, lane deviation increased from sessions 1, 2, and 3 to session 4 (post-hoc ps < 0.05).

Lane deviation differed significantly across sessions (within each workday) (time main effect, $p < 0.001$). Compared to sessions 1 and 2, lane deviation was significantly greater during sessions 3 and 4 (ps < 0.05). Compared to session 3, lane deviation was marginally lower during session 4 ($p = 0.054$).

No other main effects or interactions were significant for lane deviation.

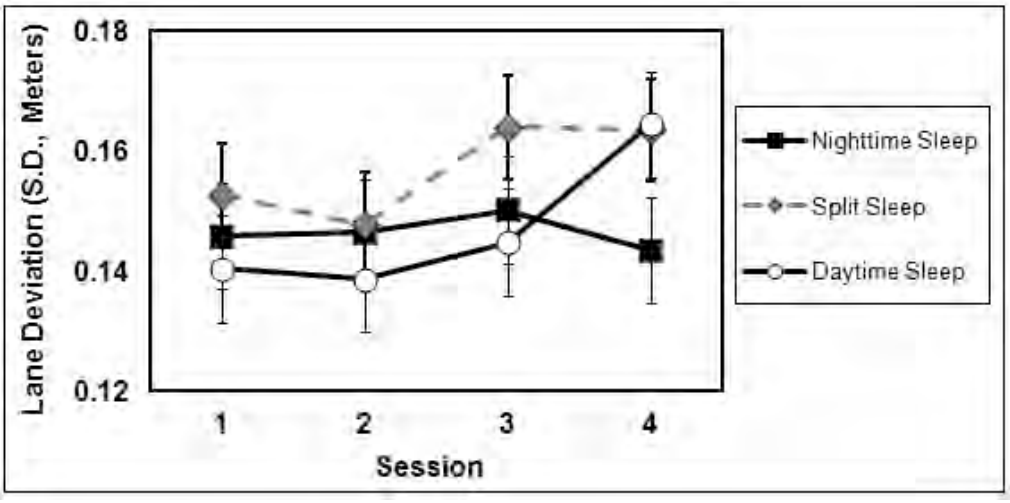

Figure 14. Feverline chart. Lane deviation (standard deviation of lane position) on the driving simulator during each session of the day, collapsed over work period for the nighttime sleep, split sleep, and daytime sleep conditions

ANOVA and post-hoc test results for braking reaction time are presented in Appendix C.

Braking reaction times differed significantly across sessions (within each workday) (time main effect, $p < 0.05$). Compared to session 2, braking reaction time was significantly slower during session 4 ($ps < 0.05$). No other main effects or interactions were significant for braking reaction times.

3.4 NEUROBEHAVIORAL TEST BATTERY

Secondary performance outcomes were derived from a computerized neurobehavioral test battery, which included, in order of presentation, the KSS, VASM, PANAS (both subscales were analyzed), PERF, EFFR, and DSST. Results for these outcome measures are presented here in that order.

3.4.1 Karolinska Sleepiness Scale (KSS)

Figure 15 displays the KSS scores by workday for the NIGHT, SPLIT, and DAY conditions. ANOVA and post-hoc *t* test results are presented in Appendix D.

During workdays 1, 2, and 3, participants in the DAY sleep condition had significantly higher KSS scores than participants in the NIGHT and SPLIT sleep conditions (Condition × Day interaction and post-hoc tests, $ps < 0.05$). During workday 4, KSS scores were significantly higher in the DAY sleep condition compared to participants in the NIGHT sleep condition ($p < 0.05$).

Within a given condition, for the NIGHT sleep condition, KSS scores were higher on workday 5 compared to workdays 1 and 4 ($ps < 0.05$).

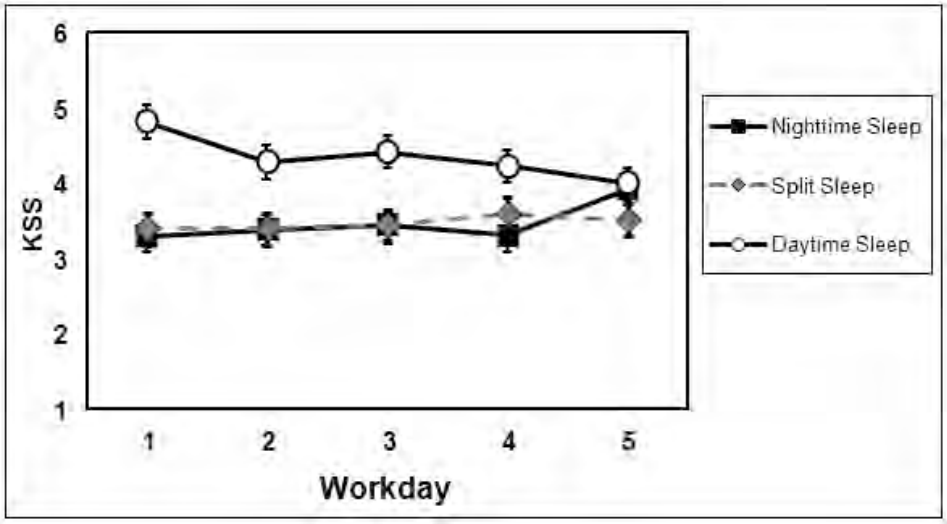

Figure 15. Feverline chart. Participant sleepiness on the KSS as a function of days in the 5-day work period in the nighttime sleep, split sleep, and daytime sleep conditions

Notes: The higher the number, the greater the degree of participant sleepiness. Error bars indicate standard error.

Figure 16 displays the KSS scores by session (within workdays) for the NIGHT, SPLIT, and DAY conditions. During session 1, participants in the SPLIT sleep condition had significantly lower KSS scores than participants in the NIGHT sleep condition (Condition × Time interaction; post-hoc test, ps < 0.05). During session 2, participants in the NIGHT sleep condition had significantly lower KSS scores than participants in the SPLIT sleep condition ($p < 0.05$). During sessions 3 and 4, participants in the DAY sleep condition had significantly higher KSS scores than participants in the NIGHT and SPLIT sleep conditions (ps < 0.05).

Within a given condition, for the DAY sleep condition, KSS scores increased in sessions 3 and 4 relative to sessions 1 and 2 (ps < 0.05). KSS scores also increased significantly from session 3 to session 4 ($p < 0.05$). For the SPLIT condition, KSS scores increased significantly in session 2 compared to session 1, and in sessions 3 and 4 compared to session 2 ($p < 0.05$).

Overall, KSS scores differed significantly across the three conditions (condition main effect, $p < 0.001$). Participants in the DAY sleep condition had significantly higher KSS scores than both NIGHT and SPLIT sleep conditions (ps < 0.05).

Comparing sessions collapsed across conditions, KSS scores also differed significantly across sessions (within each workday) (time main effect, $p < 0.001$). Compared to session 1, KSS scores were significantly higher in sessions 2, 3, and 4 (ps < 0.05). Compared to session 2 and 3, KSS scores were significantly higher in session 4 (ps < 0.05).

No other main effects or interactions were significant for KSS.

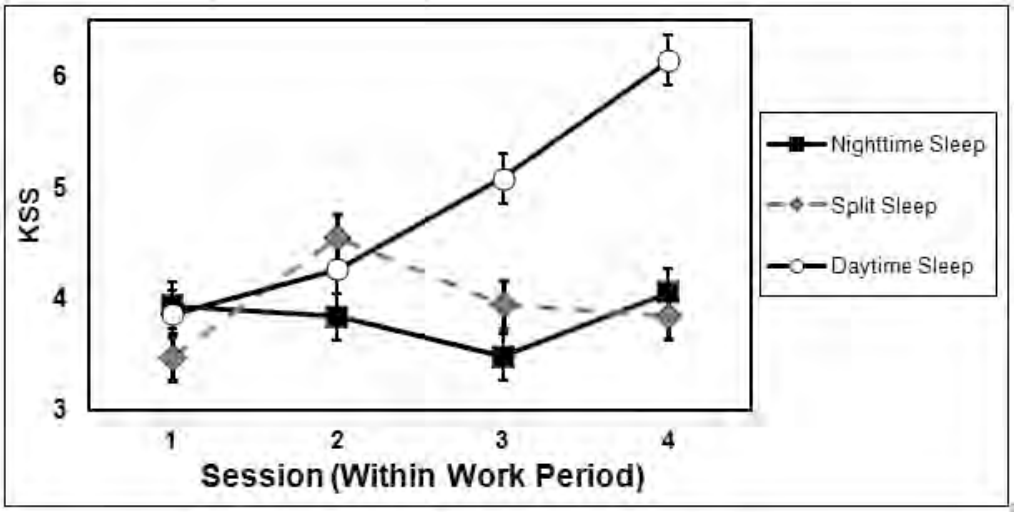

Figure 16. Feverline chart. Subjective sleepiness on the KSS as a function of time of day, collapsed over days

Notes: The horizontal axis shows the four sessions across the workday, for the nighttime sleep, split sleep, and daytime sleep conditions. For the nighttime sleep condition, testing was at 0900, 1200, 1500, and 1800. For the split sleep condition, testing was at 2100, 0000, 0900, and 1200. For the daytime sleep condition, testing was at 2100, 0000, 0300 and 0600. The higher the number, the greater the degree of subjective sleepiness. Error bars indicate standard errors.

3.4.2 Visual Analog Scale of Mood (VASM)

ANOVA and post-hoc *t* test results for VASM are presented in Appendix D.

VASM scores differed significantly across sessions (within each workday) (time main effect, $p < 0.001$). Compared to session 1, VASM scores were significantly higher in sessions 2, 3, and 4 (ps < 0.05).

No other main effects or interactions were significant for VASM.

3.4.3 Positive and Negative Affect Scale (PANAS)

Figure 17 displays the Positive Affect scores by session (within workdays) for the NIGHT, SPLIT, and DAY conditions. ANOVA and post-hoc *t* test results are presented in Appendix D.

During session 1, participants in the SPLIT sleep condition had significantly higher positive affect scores than participants in the NIGHT sleep condition (Condition × Time interaction; post-hoc *t* tests, ps < 0.05). During session 2, participants in the NIGHT sleep condition had significantly lower positive affect scores than participants in the SPLIT and DAY sleep conditions (ps < 0.05). During sessions 3 and 4, participants in the SPLIT sleep condition had significantly higher positive affect cores than participants in the NIGHT and DAY sleep conditions (ps < 0.05).

Positive affect scores differed significantly across sessions (within each workday) (time main effect, $p < 0.001$). Compared to session 1, positive affect scores decreased significantly in sessions 2, 3, and 4 (ps < 0.05). Compared to session 2 and 3, positive affect scores were significantly lower in session 4 (ps < 0.05). Positive affect scores also differed significantly

across the workweek (day main effect, $p < 0.05$). Compared to workday 1, positive affect scores decreased significantly on workdays 3, 4, and 5 ($ps < 0.05$).

No other main effects or interactions were significant for positive affect scores.

No main effects or interactions were significant for negative affect scores ($ps < 0.05$; ANOVA results are presented in Appendix D).

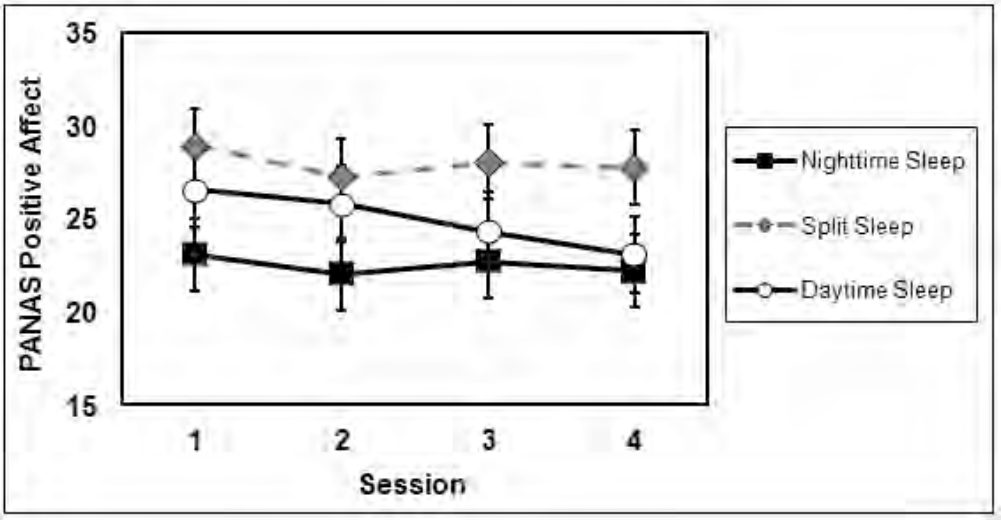

Figure 17. Feverline chart. Positive affect score on the PANAS as a function of time of day (sessions) in the 5-day work period in the nighttime sleep, split sleep, and daytime sleep conditions

Notes: The vertical scale is inverted; the lower numbers correspond to less positive affect. Error bars indicate standard error.

3.4.4 Performance Rating Scale (PERF)

No main effects or interactions were significant for PERF scores ($ps < 0.05$; ANOVA results are presented in Appendix D).

3.4.5 Effort Rating Scale (EFFR)

Figure 18 displays the EFFR scores by day for the NIGHT, SPLIT, and DAY conditions. ANOVA and post-hoc *t* test results can be found in Appendix D.

During workday 1, participants in the NIGHT sleep condition had significantly lower EFFR scores than participants in the DAY sleep condition (Condition × Day interaction and post-hoc tests, $ps < 0.05$). During workday 2, participants in the NIGHT sleep condition had significantly lower EFFR scores than participants in the SPLIT sleep condition ($ps < 0.05$) and marginally lower EFFR scores than participants in the DAY sleep condition ($p = 0.058$).

During session 2, participants in the SPLIT sleep condition had marginally higher EFFR scores than participants in the NIGHT sleep condition (Condition × Time interaction $p < 0.05$; post-hoc test $p = 0.053$). During session 4, participants in the NIGHT sleep condition had significantly

higher EFFR scores than participants in the SPLIT and DAY sleep conditions (post-hoc tests, ps < 0.05).

No other main effects or interactions were significant for EFFR scores.

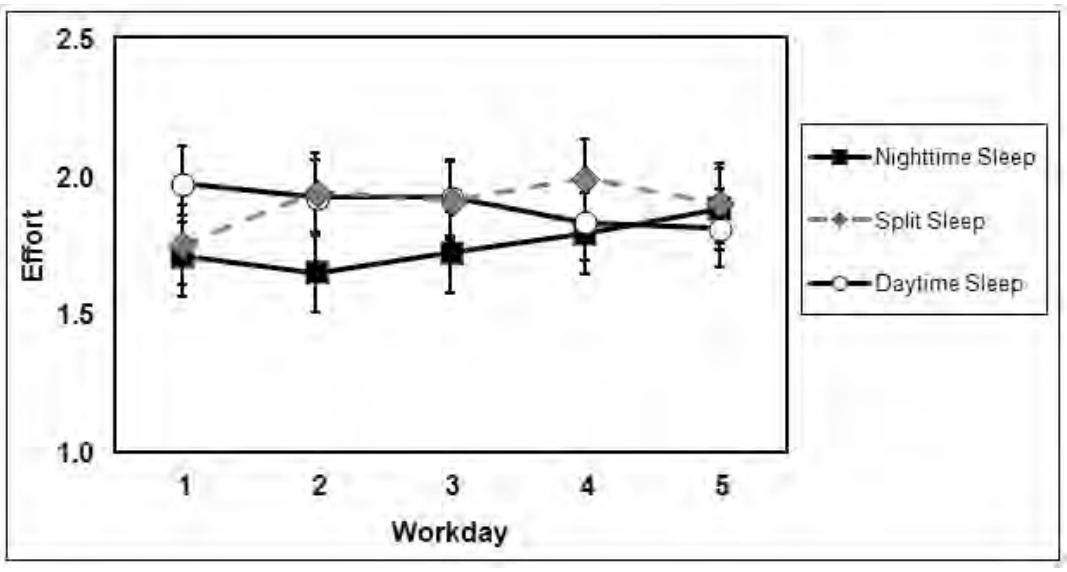

Figure 18. Feverline chart. Subjective effort score on the EFFR as a function of days in the 5-day work period in the nighttime sleep, split sleep, and daytime sleep conditions

Notes: The higher numbers correspond to greater subjective effort. Error bars indicate standard error.

3.4.6 Digit-Symbol Substitution Test (DSST)

Figure 19 displays the DSST scores by day for the NIGHT, SPLIT, and DAY conditions. ANOVA and post-hoc *t* test results are presented in Appendix D.

During session 1, participants in the NIGHT sleep condition had marginally higher DSST scores than participants in the SPLIT sleep condition (Condition × Time interaction; post-hoc *t* tests, ps < 0.05). During sessions 2, 3, and 4, participants in the NIGHT sleep condition had significantly higher DSST scores than participants in the SPLIT and DAY sleep conditions (ps < 0.05).

DSST scores also differed significantly across the workweek (day main effect, p < 0.001). Compared to workday 1, DSST scores decreased significantly across the rest of the workweek (ps < 0.05). Compared to workdays 2 and 3, DSST scores were significantly higher on days 4 and 5 (p < 0.05).

No other main effects or interactions were significant for DSST scores.

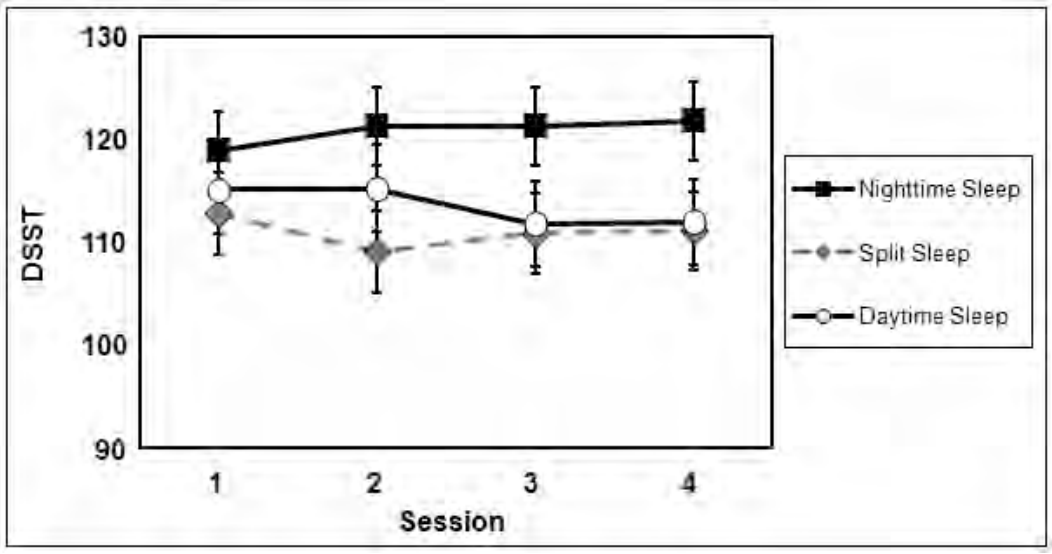

Figure 19. Feverline chart. Number of correct responses on DSST as a function of time of day (session) in the 5-day work period in the nighttime sleep, split sleep, and daytime sleep conditions

Notes: The lower numbers correspond to greater performance impairment. Error bars indicate standard error.

3.5 BIOMEDICAL METRICS

All participants were retained for the blood chemistries and BP analyses. The final numbers were 19 participants in the consolidated nighttime sleep condition, 17 participants in the split sleep condition, and 17 participants in the consolidated daytime sleep condition.

3.5.1 Blood Chemistries

3.5.1.1 Glucose

As indicated in Methods, participants were instrumented with continuous glucose monitors for 24 hours ending with the end of the first blood draw and again with the end of the second blood draw. Thus, the blood draws bookended the workweek during which participants were in one of the three conditions. The blood-glucose measurements drawn every 2 hours were taken to calibrate the continuous glucose monitor. The current calibration algorithm supplied by the manufacturer entails a 12-hour "look back" window, making it unsuitable for our study design. The company had indicated that it was developing a new algorithm that would work with our data and that it would be ready in time for us to use for the current report. Unfortunately, the new algorithm is not yet available. Therefore, the draws taken every 2 hours over 12-hours, originally intended to calibrate the continuous glucose monitors were used as the glucose measurements.

Figure 20 shows the glucose data at each time point before and after the work period for the three conditions. Mixed-model ANOVA and post-hoc results for glucose data are presented in Appendix E.

For glucose levels, the three-way interaction between condition, week, and time was significant ($p < 0.001$). Before the workweek, participants in the NIGHT sleep condition had significantly higher glucose levels compared to the DAY sleep condition (Condition × Week interaction and

post-hoc tests; ps < 0.05). After the workweek, participants in the DAY sleep condition had significantly higher glucose levels compared to the SPLIT sleep condition ($p < 0.05$).

Glucose levels also varied significantly within blood draw days (Condition × Time interaction, post-hoc test; ps < 0.05). At 0900, participants in the SPLIT sleep condition had lower glucose levels than subjects in the NIGHT and DAY sleep conditions (ps < 0.05). At 1000, participants in the SPLIT and NIGHT sleep conditions had lower glucose levels than subjects in the DAY sleep condition (ps < 0.05). At 1400 and 1600, participants in the DAY sleep condition had lower glucose levels than subjects in the NIGHT sleep condition ($p < 0.05$). At 1800, participants in the SPLIT and DAY sleep conditions had lower glucose levels than subjects in the NIGHT sleep condition (ps < 0.05). Within a given condition, participants in the NIGHT sleep condition had higher glucose levels at 1000, 1400, and 2000 compared to 0900; higher glucose levels at 1000 (after the breakfast) compared to 1200, 1600, 1800, and 2000; higher glucose levels at 1400 (after the lunch) compared to 1600, 1800, and 2000; and higher levels at 2000 (after dinner) compared to 1600 and 1800 (post-hoc test ps < 0.05). Participants in the DAY sleep condition had higher glucose levels at 1000 compared to 0900, 1200, 1400, 1600, and 1800; higher glucose levels at 1400 compared to 1600 and 1800; and higher glucose levels at 2000 compared to 0900, 1200, 1600, and 1800 (ps < 0.05). Participants in the SPLIT sleep condition had higher glucose levels at 1000 compared to 0900, 1200, 1600, and 1800; higher glucose levels at 1400 compared to 1200, 1600, and 1800; and higher glucose levels at 2000 compared to 0900, 1200, 1600, and 1800 (ps < 0.05).

Glucose levels were significantly higher at the end of the work period compared to the start of the work period (workweek main effect; $p < 0.001$). Glucose levels also varied across each blood draw day (time of day main effect; $p < 0.001$). Relative to the first draw of the day, glucose levels increased at 1000, 1400, and 2000 (post-hoc ps < 0.05). Glucose levels at 1000 were significantly higher than at any other blood draws except the last draw of the day (2000), and higher at time point 1400 compared to the draws at 1200, 1600, and 1800 (ps < 0.05). Blood glucose levels were highest at 2000 relative to all other time points (ps < 0.05).

No other main effects or interactions were significant for glucose.

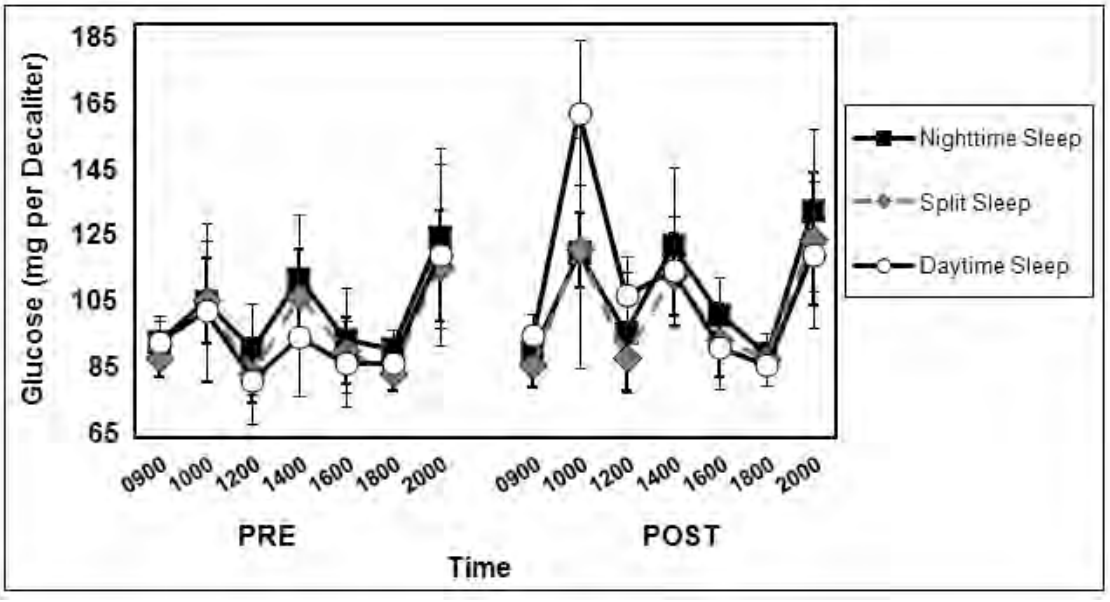

Figure 20. Feverline charts. Glucose levels at each time point at baseline (pre) and after (post) the 5-day work period in the nighttime sleep, split sleep, and daytime sleep conditions

3.5.1.2 Interleukin 6 (IL-6)

Figure 21 shows the IL-6 data at each time point before and after the work period for the three conditions. Mixed-model ANOVA and post-hoc results for IL-6 data are presented in Appendix E.

IL-6 levels increased significantly after the work period compared to before the work period (main effect of week; $p < 0.001$), suggesting an increase in immune response across the simulated work period for all participants across the three conditions.

IL-6 levels were significantly higher at each time point between 1400 and 2000 than at 0900 and 1000 (main effect of time; post-hoc ps < 0.05). IL-6 levels were also significantly higher at time points 1600, 1800, and 2000 compared to 1200; and higher at 1800 compared to 1400 (ps < 0.05).

No other main effects or interactions were significant for IL-6 levels.

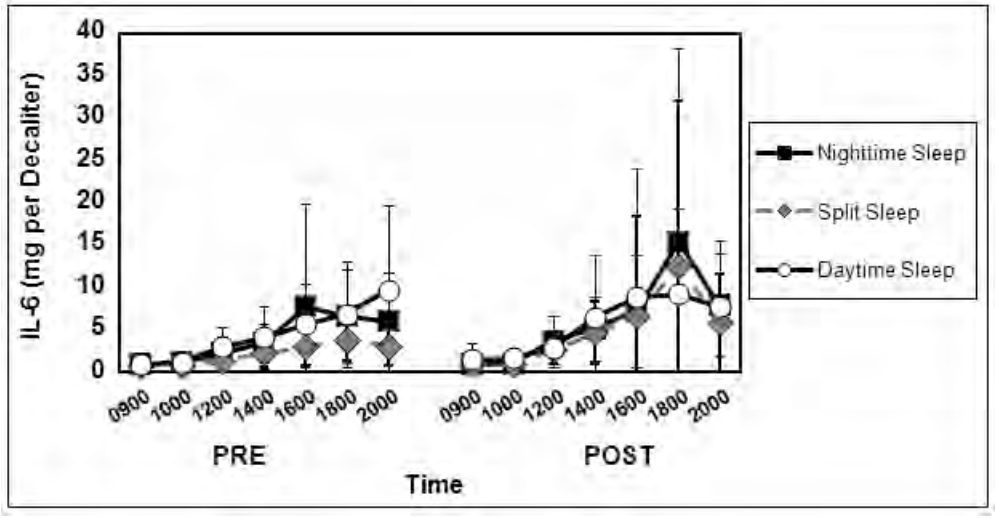

Figure 21. Feverline charts. Interleukin 6 (IL-6) levels at baseline (pre) and after (post) the 5-day work period in the nighttime sleep, split sleep, and daytime sleep conditions

3.5.1.3 Leptin

Figure 22 shows the leptin data at each time point before and after the work period for the three conditions. Mixed-model ANOVA and post-hoc results for leptin data are presented in Appendix E.

For leptin levels, the three-way interaction between condition, week, and time was significant ($p < 0.01$). At 0900 and 2000 hours, leptin levels were higher in the DAY sleep condition compared to the SPLIT sleep condition (Condition × Time interaction; post-hoc ps < 0.05).

Leptin levels were slightly lower after the work period (main effect of week; $p = 0.014$). Leptin levels also varied significantly across each day, with levels increasing significantly at 1400, 1600, 1800, and 2000 compared to 0900 and 1000 (main effect of time; $p < 0.001$). Leptin levels were also higher at 1600, 1800, and 2000 compared to 1200, and they were higher at 1800 compared to 1400 (ps < 0.05).

No other main effects or interactions were significant for leptin.

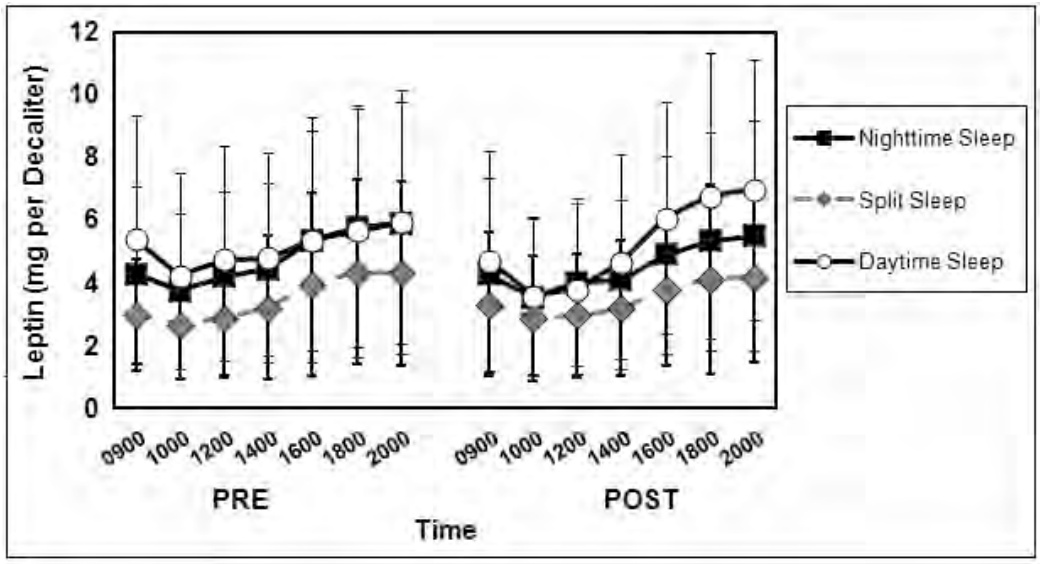

Figure 22. Feverline charts. Leptin levels at baseline (pre) and after (post) the 5-day work period in the nighttime sleep, split sleep, and daytime sleep conditions

3.5.1.4 Testosterone (Quest Diagnostics, Seattle, WA)

Figure 23 shows the testosterone data at each time point before and after the work period for the three conditions. Mixed-effects ANOVA and post-hoc results for testosterone are presented in Appendix E.

For testosterone levels, participants in the DAY sleep condition has significantly higher levels after the work period compared to the other conditions (Condition × Week interaction; $p < 0.001$).

At 1800, testosterone levels were significantly higher in the DAY sleep condition compared to the SPLIT sleep condition (Condition × Time interaction; post-hoc ps < 0.05). Testosterone levels were also marginally higher in the DAY sleep condition compared to the NIGHT sleep condition at 1200 ($p = 0.068$). Within a given condition, participants in the NIGHT sleep condition had higher testosterone levels at 0900 compared to the other time points, and significantly higher levels at 1800 compared to 1400 and 1600 (ps < 0.05). Participants in the DAY sleep condition had higher testosterone levels at 0900 compared to the other time points (except 1800) (ps < 0.05). Participants in the SPLIT sleep condition had higher testosterone levels at the 0900 compared to the other time points (ps < 0.05).

Testosterone levels varied across the blood draw day (main effect of time, $p < 0.001$). Testosterone levels were highest at 0900 compared to the rest of the day; levels were higher at 1000 compared to 1400, 1600, and 2000; and levels were higher at 1200 compared to 1600 and 2000 (ps < 0.05), and marginally higher than at 1400 ($p = 0.055$). Testosterone levels were also higher at 1800 compared to time points between 1200 and 2000 (ps < 0.05).

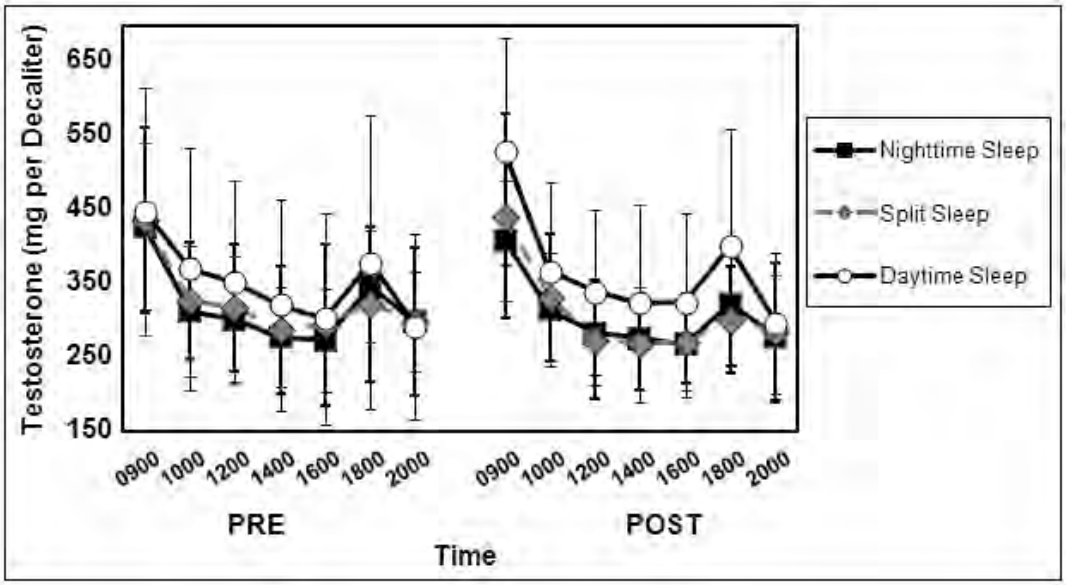

Figure 23. Feverline charts. Testosterone levels at baseline (pre) and after (post) the 5-day work period in the nighttime, split sleep, and daytime sleep conditions

3.5.2 Blood Pressure

Measures of systolic and diastolic BP, MAP, and pulse rate daily at 2045 were analyzed separately. BP, MAP and pulse rate ANOVA results are presented in Appendix E.

No main effects or interactions were significant for systolic BP (ps < 0.05).

For diastolic BP, on workday 4, participants in the NIGHT sleep condition had significantly lower diastolic BP compared to participants in the SPLIT and DAY sleep conditions (Condition × Workday interaction, post-hoc ps < 0.05). Within a given condition, participants in the SPLIT sleep condition had significantly lower diastolic BP on workdays 2, 3, and 5 compared to 4 (ps < 0.05).

Overall, diastolic BP was significantly lower on workdays 1, 2, 3, and 5 compared to 4 (main effect of workday, ps < 0.05).

On workday 1, participants in the NIGHT sleep condition had significantly lower MAP compared to participants in the DAY sleep condition (Condition × Workday interaction, post-hoc ps < 0.05). On workday 4, participants in the NIGHT sleep condition had significantly lower MAP compared to participants in the DAY and SPLIT sleep conditions (ps < 0.05). Within a given condition, participants in the SPLIT sleep condition had significantly lower MAP on workdays 2, 3, and 5 compared to 4 (ps < 0.05).

Overall, MAP was significantly lower on workdays 1, 2, and 5 compared to workdays 3 and 4 (main effect of workday, ps < 0.05). No other main effects or interactions were significant for MAP.

For pulse rate, on workday 1 of the study, participants in the DAY sleep condition had significantly higher pulse rates than participants in the NIGHT and SPLIT sleep conditions

(Condition × Workday interaction and post-hoc *t* tests, ps < 0.05). On workday 4, participants in the DAY sleep condition had significantly higher pulse rates than participants in the NIGHT sleep condition ($p < 0.05$). On workday 5, participants in the NIGHT sleep condition had marginally higher pulse rates than participants in the SPLIT sleep condition ($p = 0.05$).

Within a given condition, participants in the NIGHT sleep condition had marginally lower pulse rates on workdays 1 and 4 compared to workday 5 (ps = 0.058). No other main effects or interactions were significant for pulse rate.

4. CONCLUSIONS

4.1 SUMMARY OF KEY FINDINGS

4.1.1 Sleep

Overall, participants in the NIGHT and SPLIT sleep conditions obtained significantly more TST than participants in the DAY sleep condition. Examining the effects of condition (NIGHT sleep, SPLIT sleep, and DAY sleep) on distribution of sleep stages (N1, N2, N3, and REM), REM sleep differed significantly among the three conditions. Participants in the NIGHT sleep condition obtained the most REM sleep, while participants in the DAY sleep condition obtained the least. There were no significant main effects of condition on other sleep stages (N1, N2, or N3).

Thus, TST, the primary determinant of recuperation,[30] differed across the three conditions in a manner consistent with our knowledge of the human circadian rhythm in sleep propensity.[3] TST for the night sleep and split sleep conditions during the workweek were in the normal range of 7–9 hours. TST in the DAY sleep condition was in the mildly sleep-restricted range of 6–7 hours. In a previous study, similar mild sleep restriction resulted in detectable performance impairment when continued for 7 days.[31, 32]

Of further interest is the comparison of the two sleep opportunities in the split sleep condition. Participants in the split sleep condition obtained substantially more sleep during the morning sleep opportunity (0300–0800 hours) when sleep propensity was presumably high than in the afternoon/evening sleep opportunity (1500–2000) when sleep propensity, especially in the early evening, was presumably low (see Figure 10). This highlights the benefits of placing at least some of the available sleep opportunity during periods of high circadian sleep propensity. Despite the ample daily sleep opportunity of 10 hours, actual sleep time varied by condition. In other words, actual sleep varied by the placement of the sleep opportunity at more or less sleep-conducive times in the circadian cycle.

4.1.2 Performance

As indicated in Section 4.1.1, sleep was in the normal range of 7–9 hours for the NIGHT and SPLIT sleep conditions and in the mildly restricted range of 6–7 hours for the DAY sleep condition. Thus, even for the participants in the DAY sleep condition, performance degradation would be on the edge of detectability. This is effectively what was found.

For performance on the PVT, there was no main effect of condition (NIGHT sleep, SPLIT sleep, and DAY sleep) on attention lapses.

For performance on the driving simulator performance, there was no main effect of condition (NIGHT sleep, SPLIT sleep, and DAY sleep) on lane deviation, speed, or braking performance.

For performance on the DSST, there was no main effect of condition (NIGHT sleep, SPLIT sleep, and DAY sleep) on performance. There was evidence of improvement in performance

across all conditions over the course of the study, representing the effects of learning and practice.

Thus, performance was relatively unaffected by nighttime, split, or daytime sleep placement of what was an ample sleep opportunity, despite the clear sleep placement-dependent effects on actual sleep (see Section 4.1.1). Note that the sleep opportunity was 10 hours per day for all days in all conditions. This lack of effect of condition on performance is probably because, even for the DAY sleep condition, the actual degree of sleep restriction was mild.

4.1.3 Neurobehavioral Test Battery

Subjective sleepiness was measured by the KSS. Sleepiness by the KSS differed significantly among the three conditions (NIGHT sleep, SPLIT sleep, and DAY sleep) with participants in the DAY sleep condition reporting significantly more sleepiness than participants in the NIGHT or SPLIT sleep conditions. Overall KSS scores were in the low to moderate sleepiness range.[23] In contrast to the KSS, there were no main effects of condition on mood, positive or negative effect, or on self-ratings of performance or effort.

4.1.4 Blood Chemistries

4.1.4.1 Glucose

There was no difference among the sleep conditions (NIGHT sleep, SPLIT sleep, and DAY sleep) on blood glucose measured at two-hour intervals on the first (pre-workweek) and second (post-workweek) blood draw days bracketing the 5-day workweek. There was, however, a significant three-way interaction among condition, week, and time. Before the workweek, participants in NIGHT sleep condition had higher blood glucose levels than participants in the DAY sleep condition. Just past the end of the workweek, participants in the DAY sleep condition had significantly higher blood glucose than those in the SPLIT sleep condition. Within conditions, glucose levels were higher after than before the workweek, suggesting an overall decrease in glucose tolerance for all conditions across the workweek. Note that each participant in each condition had identical meals during the before the workweek blood draws and during the after the workweek blood draws, providing a degree of control over caloric intake. Participants could consume no more than 2,400 kcal/day.

4.1.4.2 Interleukin 6 (IL-6)

An overall increase in IL-6 from the first to the second blood draw day bracketing the 5-day workweek across all three conditions was found in the current study. These findings suggest an overall increase in inflammatory response for all conditions across the workweek.

4.1.4.3 Leptin

Leptin levels were higher in the DAY sleep condition than in the SPLIT sleep condition at 0900 hours and 2000 hours. There was an overall decrease in leptin from the first to the second blood draw days bookending the workweek across all three conditions, suggesting a decrease in satiety for all conditions across the workweek.

4.1.4.4 Testosterone

Testosterone levels were higher in the DAY sleep condition after the workweek compared to NIGHT sleep and SPLIT sleep conditions, suggesting a perturbation in testosterone resulting from the interaction of sleep condition and workweek.

4.1.4.5 Blood Pressure and Pulse

For diastolic BP, there was no main effect of condition, but there was a significant interaction between condition and workday, with participants in the NIGHT sleep condition having significantly lower diastolic BP than participants in the SPLIT or DAY sleep conditions on the fourth workday. Thus, diastolic pressure (the pressure to which the heart and vascular tree are exposed two-thirds of the time) was increased in the daytime sleep condition most obviously on the fourth workday. Similarly, there was no main effect of condition for MAP; however, a significant condition by workday interaction indicated that participants in the NIGHT sleep condition had significantly lower MAP compared to participants in the DAY and SPLIT sleep conditions on the fourth workday. There was no main effect of condition or workday on systolic BP or pulse rate.

4.2 INTERPRETATION OF KEY FINDINGS

With respect to the effects of condition, the participants in the daytime sleep condition compared to the nighttime and split sleep conditions slept less and were subjectively sleepier. There were no systematic effects of condition on performance, other subjective measures, BP, or pulse. The increases in blood glucose and testosterone at the end of the workweek in daytime sleep condition suggest perturbations in metabolism that could adversely affect long-term health, increasing the risk of overweight, obesity, metabolic syndrome, type 2 diabetes, obstructive sleep apnea, and cardiovascular disease.

With respect to the lack of effect of condition on performance, both the nighttime sleep and the split sleep condition TSTs were in the normal range, and the daytime sleep condition TST was in the mildly sleep-restricted range. In a study with a similar degree of mild daily sleep restriction over 7 days, a small increase in PVT lapses was seen.[31,32] In the present study, the experimental manipulation lasted 5 days, perhaps not sufficient to create a detectable performance decrement on the PVT.

As described in Section 2.2, the participants in the daytime sleep condition were concurrently participants in a longer study that kept them living in the laboratory for 6 more days beyond the 10 days that were used for the present split sleep study.[4] So, the daytime sleep condition differed from the nighttime sleep condition in two respects: placement of the 10-hour sleep opportunity and spending 16 days as opposed to 10 days in the laboratory, with the additional 6 days involving a second workweek with a return to daytime sleeping during that workweek. The prospect of additional time in the laboratory could have affected the participants in the daytime sleep condition, and perhaps this anticipation accounted for the changes observed. However, the findings with respect to TST fit well with our knowledge of the effect of circadian rhythms on sleep propensity, thus making it less likely that this was an effect of anticipating more time in the laboratory rather than of the sleep condition itself. Further, with the exception of differences in

sleepiness (which were in accord with the differences in TST), there were no differences among the conditions on the subjective measures, one of which (the PANAS) included ratings of anxiety and another (the VASM) assessed depression. Thus, it seems reasonable to take the findings of the present study as a direct effect of the sleep condition manipulation (nighttime sleep, split sleep, or daytime sleep) rather than an effect of the participants in the day sleep condition anticipating additional days in the laboratory.

4.3 RECOMMENDATIONS

Results of the present study suggest that when consolidated night sleep is not possible, split sleep is preferable to consolidated daytime sleep in that split sleep yields more total sleep time and less subjective sleepiness. The study looked for but did not find strong support for differential effects of nighttime versus split versus daytime sleep on performance, mood, and BP. With respect to chronic illness-related blood chemistries, there were increases in blood glucose and testosterone in the daytime sleep condition at the end of the workweek suggesting perturbations in metabolism that if continued could impair health in the long term. There were no condition-related changes in IL-6, a marker of inflammation, or leptin, a marker of satiety. With respect to the FMCSA regulations pertaining to CMV driver use of sleeper berths, the study findings suggest possible benefits—in the form of increased total sleep time and decreased sleepiness—of a more flexible sleeper berth rule, allowing for a greater splitting of sleep opportunity than is currently permitted.

4.4 STUDY LIMITATIONS AND FURTHER RESEARCH DIRECTIONS

To demonstrate the effect of split versus consolidated sleep on objective performance, subjective status, and chronic-illness related biomedical parameters, young (age range 22–40 years), healthy, non-obese (BMI < 30) men were studied in a rigidly controlled laboratory environment. The homogeneity of the population and the controlled laboratory environment were instituted to reduce the noise relative to the signal in the data increasing the likelihood that a difference between groups would be detected if in fact a difference existed. Thus the study population and the study environment were purposely not representative of the population of CMV drivers and their normal working environment. If a difference was found in the laboratory setting between split and consolidated sleep, as a function of the daytime or nighttime placement of the consolidated sleep, then the expectation was that these findings would be followed up in a field study with actual drivers in their usual environment driving their usual routes. The study population in such a field study would be chosen to be representative of the industry and would therefore be older, heavier, include women, and generally more heterogeneous, relative to the study population in the present laboratory study. The environment of such a field study would also be more variable than in the laboratory. This progression from homogeneous population under controlled conditions (to demonstrate the existence of a phenomenon) to heterogeneous population under uncontrolled conditions (to demonstrate that this phenomenon makes a difference in real world operations) is natural one in behavioral studies of sleep and performance.

What appears to be a limitation of the study actually is a strength and puts the study in the mainstream of translational research, beginning in the lab and ending in the field. In the

laboratory, the research team asks is there a difference? In the field, the research team asks does the difference found in the laboratory make a difference in real world measures of sleep and performance for drivers in their normal environment?

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APPENDIX A: ANALYSIS OF VARIANCE TABLES FOR SLEEP VARIABLES

All statistical analysis results shown in tables in Appendix A were derived from a two-way Condition (between-groups factor: Night Sleep, Day Sleep, and Split Sleep) x Sleep Period (repeated-measures factor: BL1, BL2, WP1, WP2, recovery) repeated-measures ANOVA. Greenhouse-Geisser (G-G) correction factor was applied to all repeated-measures factors to reduce the likelihood of detecting false positives ("Type I" errors). Significant interactions were followed by one-way ANOVAs (e.g., one-way ANOVA for Condition at each sleep period) and then further analyzed using post-hoc *t* tests with Bonferroni corrections (corrected for multiple comparisons). Interactions that were not significant were not followed by one-way ANOVAs or post-hoc *t* tests.

Differences in error degrees of freedom across analyses are due to missing data points (resulting from occasional technical difficulties during data collection).

Table 3. Total Sleep Time: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	82,462.66	6,717.91	2, 47	12.28	0.000
Sleep Period	77,504.86	3,959.23	3, 141	19.58	0.000
Sleep Period × Condition	21,867.35	3,959.23	6, 141	5.52	0.000

Table 4. Total Sleep Time: One-Way ANOVAs for Condition, Conducted Separately for Each Sleep Period

Sleep Period	Source	Sum of Squares	*df*	Mean Square	*F*	p value
BL1	Between Groups	4,187.65	2	2,093.83	0.56	0.577
	Within Groups	180,839.86	48	3,767.50	–	–
BL2	Between Groups	7,197.43	2	3598.72	2.03	0.142
	Within Groups	85,038.23	48	1,771.63	–	–
W1	Between Groups	159,752.18	2	79,876.09	24.52	0.000
	Within Groups	156,385.64	48	3,258.03	–	–
W2	Between Groups	97,317.10	2	48,658.55	13.89	0.000
	Within Groups	168,194.14	48	3,504.05	–	–
R	Between Groups	43,607.34	2	21,803.67	3.52	0.038
	Within Groups	291,005.79	47	6,191.61	–	–

Table 5. Total Sleep Time: Post-Hoc Comparisons Among Conditions at Each Sleep Period for Which There Was a Significant Condition Effect (see Table 4)

Sleep Period	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
W1	Night	Day	137.29	19.72	0.000
		Split	73.01	19.06	0.001
	Day	Night	-137.29	19.72	0.000
		Split	-64.28	20.22	0.008
	Split	Night	-73.01	19.06	0.001
		Day	64.28	20.22	0.008
W2	Night	Day	101.54	20.45	0.000
		Split	75.80	19.76	0.001
	Day	Night	-101.54	20.45	0.000
		Split	-25.74	20.97	0.677
	Split	Night	-75.80	19.76	0.001
		Day	25.74	20.97	0.677
R	Night	Day	46.14	27.51	0.300
		Split	-27.34	26.61	0.928
	Day	Night	-46.14	27.51	0.300
		Split	-73.48	27.87	0.034
	Split	Night	27.34	26.61	0.928
		Day	73.48	27.87	0.034

Table 6. Total Sleep Time: One-Way ANOVAs for Sleep Period, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	28,524.18	4	7,131.05	2.79	0.031
	Within Groups	230,440.55	90	2,560.45	–	–
Day	Between Groups	181,596.75	4	45,399.19	8.63	0.000
	Within Groups	368,390.83	70	5,262.73	–	–
Split	Between Groups	136,961.81	4	34,240.45	9.60	0.000
	Within Groups	285,363.62	80	3,567.05	–	–

Table 7. Total Sleep Time: Post-Hoc Comparisons Among Sleep Periods for Each Condition

Condition	(*I*) Period	(*J*) Period	Mean Difference (*I*-*J*)	Std. Error	p value
Night	BL1	BL2	-16.4737	16.417	1.000
		W1	-11.3947	16.417	1.000
		W2	12.2895	16.417	1.000
		R	31.6316	16.417	0.572
	BL2	BL1	16.4737	16.417	1.000
		W1	5.0789	16.417	1.000
		W2	28.7632	16.417	0.832
		R	48.1053*	16.417	0.043
	W1	BL1	11.3947	16.417	1.000
		BL2	-5.0789	16.417	1.000
		W2	23.68	16.417	1.000
		R	43.03	16.417	0.103
	W2	BL1	-12.2895	16.417	1.000
		BL2	-28.76	16.417	0.832
		W1	-23.68	16.417	1.000
		R	19.34	16.417	1.000
	R	BL1	-31.63	16.417	0.572
		BL2	-48.11	16.417	0.043
		W1	-43.03	16.417	0.103
		W2	-19.34	16.417	1.000
Day	BL1	BL2	3.27	26.49	1.000
		W1	116.50	26.49	0.000
		W2	104.43	26.49	0.002
		R	71.20	26.49	0.090
	BL2	BL1	-3.27	26.49	1.000
		W1	113.23	26.49	0.001
		W2	101.17	26.49	0.003
		R	67.93	26.49	0.125
	W1	BL1	-116.50	26.49	0.000
		BL2	-113.23	26.49	0.001
		W2	-12.07	26.49	1.000
		R	-45.30	26.49	0.917
	W2	BL1	-104.433	26.49	0.002
		BL2	-101.17	26.49	0.003
		W1	12.07	26.49	1.000
		R	-33.23	26.49	1.000
	R	BL1	-71.20	26.49	0.090
		BL2	-67.93	26.49	0.125
		W1	45.30	26.49	0.917
		W2	33.23	26.49	1.000
Split	BL1	BL2	7.00	20.49	1.000
		W1	74.91	20.49	0.005
		W2	101.38	20.49	0.000

Condition	(*I*) Period	(*J*) Period	Mean Difference (*I*-*J*)	Std. Error	p value
		R	20.41	20.49	1.000
	BL2	BL1	-7.00	20.49	1.000
		W1	67.91	20.49	0.014
		W2	94.38	20.49	0.000
		R	13.41	20.49	1.000
	W1	BL1	-74.91	20.49	0.005
		BL2	-67.91	20.49	0.014
		W2	26.47	20.49	1.000
		R	-54.50	20.49	0.094
	W2	BL1	-101.38	20.49	0.000
		BL2	-94.38	20.49	0.000
		W1	-26.47	20.49	1.000
		R	-80.97	20.49	0.002
	R	BL1	-20.41	20.49	1.000
		BL2	-13.41	20.49	1.000
		W1	54.50	20.49	0.094
		W2	80.97	20.49	0.002

Table 8. Total Sleep Time: Post-Hoc Comparisons Among Conditions (for Condition Main Effect, Omnibus ANOVA, see Table 3)

(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
Night	Day	63.01	12.82	0.000
	Split	21.98	12.40	0.248
Day	Night	-63.01	12.82	0.000
	Split	-41.03	13.00	0.008
Split	Night	-21.98	12.40	0.248
	Day	41.03	13.00	0.008

Table 9. Total Sleep Time: Post-Hoc Comparisons Among Sleep Periods (for Sleep Period Main Effect, Omnibus ANOVA, see Table 3)

(*I*) Sleep Period	(*J*) Sleep Period	Mean Difference (*I*-*J*)	Std. Error	p value
BL1	BL2	-2.34	7.20	1.000
	W1	59.31	9.07	0.000
	W2	72.86	9.84	0.000
	R	41.12	12.49	0.019
BL2	BL1	2.34	7.20	1.000
	W1	61.65	9.17	0.000
	W2	75.20	8.17	0.000
	R	43.46	12.07	0.008
W1	BL1	-59.31	9.07	0.000
	BL2	-61.65	9.17	0.000
	W2	13.55	11.40	1.000
	R	-18.19	14.20	1.000
W2	BL1	-72.86	9.84	0.000
	BL2	-75.20	8.17	0.000
	W1	-13.55	11.40	1.000
	R	-31.74	13.41	0.221
R	BL1	-41.12	12.49	0.019
	BL2	-43.46	12.07	0.008
	W1	18.19	14.20	1.000
	W2	31.74	13.41	0.221

Table 10. Slow Wave Sleep (N3): Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	9,241.57	6,081.89	2, 47	1.52	0.229
Sleep Period	10,538.62	6,516.07	1.3, 62.6	1.62	0.211
Sleep Period × Condition	9,524.29	6,516.07	2.7, 62.6	1.46	0.236

Table 11. REM Sleep: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	31,687.29	102,527.55	2, 47	14.526	0.000
Sleep Period	2,717.19	788.62	3.3, 154.8	3.445	0.015
Sleep Period × Condition	4,122.16	788.62	6.6, 154.8	5.227	0.000

Table 12. REM Sleep: One-Way ANOVAs For Condition, Conducted Separately for Each Sleep Period

Sleep Period	Source	Sum of Squares	*df*	Mean Square	*F*	p value
BL1	Between Groups	34,46.623	2	1,723.311	1.956	0.152
	Within Groups	42,280.289	48	880.839	–	–
BL2	Between Groups	12,049.712	2	6,024.856	7.462	0.002
	Within Groups	38,755.494	48	807.406	–	–
W1	Between Groups	38,984.030	2	19,492.015	22.148	0.000
	Within Groups	42,243.509	48	880.073	–	–
W2	Between Groups	29,862.147	2	14,931.074	16.174	0.000
	Within Groups	44,311.363	48	923.153	–	–
R	Between Groups	11,471.716	2	5,735.858	4.600	0.015
	Within Groups	59,850.205	48	1,246.879	–	–

Table 13. REM Sleep: Post-Hoc Comparisons Among Conditions at Each Sleep Period for Which There Was a Significant Condition Effect (see Table 12)

Sleep Period	(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
BL2	Night	Day	37.91	9.81	0.001
		Split	16.37	9.49	0.272
	Day	Night	-37.91	9.81	0.001
		Split	-21.54	10.07	0.112
	Split	Night	-16.37	9.49	0.272
		Day	21.54	10.07	0.112
W1	Night	Day	65.82	10.25	0.000
		Split	44.38	9.90	0.000
	Day	Night	-65.83	10.25	0.000
		Split	-21.45	10.51	0.140
	Split	Night	-44.38	9.90	0.000
		Day	21.45	10.51	0.140
W2	Night	Day	50.33	10.49	0.000
		Split	49.79	10.14	0.000
	Day	Night	-50.33	10.49	0.000
		Split	-0.54	10.76	1.000
	Split	Night	-49.79	10.14	0.000
		Day	0.54	10.76	1.000
R	Night	Day	36.99	12.20	0.012
		Split	16.56	11.79	0.500
	Day	Night	-36.99	12.20	0.012
		Split	-20.44	12.51	0.327
	Split	Night	-16.56	11.79	0.500
		Day	20.44	12.51	0.327

Table 14. REM Sleep: One-Way ANOVAs for Sleep Period, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	12,848.94	4	3,212.23	3.59	0.009
	Within Groups	80,459.05	90	894.00	–	–
Day	Between Groups	6,654.08	4	1,663.52	1.63	0.176
	Within Groups	71,303.87	70	1,018.63	–	–
Split	Between Groups	16,459.46	4	4,114.87	4.35	0.003
	Within Groups	75,677.94	80	945.97	–	–

Table 15. REM Sleep: Post-Hoc Comparisons Among Sleep Periods for Each Condition for Which There Was a Significant Sleep Period Effect (see Table 14)

Condition	(*I*) Period	(*J*) Period	Mean Difference (*I-J*)	Std. Error	p value
Night	BL1	BL2	-29.4211*	9.7007	0.032
		W1	-32.1316*	9.7007	0.013
		W2	-26.8421	9.7007	0.069
		R	-18.3684	9.7007	0.615
	BL2	BL1	29.4211*	9.7007	0.032
		W1	-2.7105	9.7007	1.000
		W2	2.5789	9.7007	1.000
		R	11.0526	9.7007	1.000
	W1	BL1	32.1316*	9.7007	0.013
		BL2	2.7105	9.7007	1.000
		W2	5.2895	9.7007	1.000
		R	13.7632	9.7007	1.000
	W2	BL1	26.8421	9.7007	0.069
		BL2	-2.5789	9.7007	1.000
		W1	-5.2895	9.7007	1.000
		R	8.4737	9.7007	1.000
	R	BL1	18.3684	9.7007	0.615
		BL2	-11.0526	9.7007	1.000
		W1	-13.7632	9.7007	1.000
		W2	-8.4737	9.7007	1.000
Split	BL1	BL2	-1.5000	10.5495	1.000
		W1	23.7941	10.5495	0.268
		W2	34.5000*	10.5495	0.016
		R	9.7353	10.5495	1.000
	BL2	BL1	1.5000	10.5495	1.000
		W1	25.2941	10.5495	0.188
		W2	36.0000*	10.5495	0.010
		R	11.2353	10.5495	1.000
	W1	BL1	-23.7941	10.5495	0.268
		BL2	-25.2941	10.5495	0.188
		W2	10.7059	10.5495	1.000
		R	-14.0588	10.5495	1.000
	W2	BL1	-34.5000*	10.5495	0.016
		BL2	-36.0000*	10.5495	0.010
		W1	-10.7059	10.5495	1.000
		R	-24.7647	10.5495	0.214
	R	BL1	-9.7353	10.5495	1.000
		BL2	-11.2353	10.5495	1.000
		W1	14.0588	10.5495	1.000
		W2	24.7647	10.5495	0.214

Table 16. REM Sleep: Post-Hoc Comparisons Among Conditions (for Condition Main Effect, Omnibus ANOVA, see Table 11)

(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
Night	Day	39.03	7.30	0.000
	Split	22.10	7.06	0.003
Day	Night	-39.03	7.30	0.000
	Split	-16.93	7.40	0.027
Split	Night	-22.10	7.06	0.003
	Day	16.93	7.40	0.027

Table 17. REM Sleep: Post-Hoc Comparisons Among Sleep Period (for Sleep Period Main Effect, Omnibus ANOVA, see Table 11)

(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
BL1	BL2	-10.31	3.78	0.009
	W1	5.02	4.43	0.263
	W2	6.99	4.47	0.124
	R	-.21	5.80	0.971
BL2	BL 1	10.31	3.78	0.009
	W1	15.33	4.42	0.001
	W2	17.31	4.76	0.001
	R	10.10	5.71	0.083
W1	BL1	-5.02	4.43	0.263
	BL2	-15.33	4.42	0.001
	W2	1.97	5.64	0.728
	R	-5.23	6.22	0.405
W2	BL1	-6.99	4.47	0.124
	BL2	-17.31	4.76	0.001
	W1	-1.97	5.64	0.728
	R	-7.20	5.33	0.183
R	BL1	.21	5.80	0.971
	BL2	-10.10	5.71	0.083
	W1	5.23	6.22	0.405
	W2	7.20	5.33	0.183

Table 18. N2 Sleep: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	8,648.93	6247.88	2, 47	1.38	0.261
Sleep Period	42,668.81	2,290.20	3.1, 144	18.63	0.000
Sleep Period × Condition	11,346.26	2,290.20	6.1, 144	4.95	0.000

Table 19. N2 Sleep: One-Way ANOVAs for Condition, Conducted Separately for Each Sleep Period

Sleep Period	Source	Sum of Squares	*df*	Mean Square	*F*	p value
BL1	Between Groups	2,109.39	2.00	1,054.69	0.41	0.666
	Within Groups	123,490.27	48.00	2,572.71	–	–
BL2	Between Groups	2,612.40	2.00	1,306.20	0.92	0.404
	Within Groups	67,848.02	48.00	1,413.50	–	–
W1	Between Groups	38,378.13	2.00	19,189.06	6.67	0.003
	Within Groups	138,025.05	48.00	2,875.52	–	–
W2	Between Groups	23,967.19	2.00	11,983.60	4.21	0.021
	Within Groups	136,763.29	48.00	2,849.24	–	–
R	Between Groups	19,942.95	2.00	9,971.47	2.94	0.063
	Within Groups	163,032.59	48.00	3,396.51	–	–

Table 20. N2 Sleep: Post-Hoc Comparisons Among Conditions at Each Sleep Period for Which There Was a Significant Condition Effect (see Table 19)

Sleep Period	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
W1	Night	Day	66.03	18.52	0.003
		Split	41.84	17.90	0.071
	Day	Night	-66.03	18.52	0.003
		Split	-24.19	19.00	0.627
	Split	Night	-41.84	17.90	0.071
		Day	24.19	19.00	0.627
W2	Night	Day	53.15	18.44	0.018
		Split	28.51	17.82	0.349
	Day	Night	-53.15	18.44	0.018
		Split	-24.64	18.91	0.596
	Split	Night	-28.51	17.82	0.349
		Day	24.64	18.91	0.596

Table 21. N2 Sleep: One-Way ANOVAs for Sleep Period, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	28,455.27	4	7,113.82	3.44	0.012
	Within Groups	186,153.47	90	2,068.37	–	–
Day	Between Groups	97,827.81	4	24,456.95	10.01	0.000
	Within Groups	171,028.13	70	2,443.26	–	–
Split	Between Groups	66,381.87	4	16,595.47	4.88	0.001
	Within Groups	271,977.62	80	3,399.72	–	–

Table 22. N2 Sleep: Post-Hoc Comparisons Among Sleep Periods for Each Condition, for Which There Was a Significant Condition Effect (see Table 21)

Condition	(*I*) Sleep Period	(*J*) Sleep Period	Mean Difference (*I-J*)	Std. Error	p value
Night	BL1	BL2	18.84	14.76	1.000
		W1	20.47	14.76	1.000
		W2	34.16	14.76	0.229
		R	52.03	14.76	0.007
	BL2	BL1	-18.84	14.76	1.000
		W1	1.63	14.76	1.000
		W2	15.32	14.76	1.000
		R	33.18	14.76	0.270
	W1	BL1	-20.47	14.76	1.000
		BL2	-1.63	14.76	1.000
		W2	13.68	14.76	1.000
		R	31.55	14.76	0.352
	W2	BL1	-34.16	14.76	0.229
		BL2	-15.32	14.76	1.000
		W1	-13.68	14.76	1.000
		R	17.87	14.76	1.000
	R	BL1	-52.03	14.76	0.007
		BL2	-33.18	14.76	0.270
		W1	-31.55	14.76	0.352
		W2	-17.87	14.76	1.000
Day	BL1	BL2	-13.80	18.05	1.000
		W1	71.00	18.05	0.002
		W2	71.80	18.05	0.002
		R	13.03	18.05	1.000
	BL2	BL1	13.80	18.05	1.000
		W1	84.80	18.05	0.000
		W2	85.60	18.05	0.000
		R	26.83	18.05	1.000
	W1	BL1	-71.00	18.05	0.002
		BL2	-84.80	18.05	0.000
		W2	0.80	18.05	1.000
		R	-57.97	18.05	0.020
	W2	BL1	-71.80	18.05	0.002
		BL2	-85.60	18.05	0.000
		W1	-0.80	18.05	1.000
		R	-58.77	18.05	0.017
	R	BL1	-13.03	18.05	1.000
		BL2	-26.83	18.05	1.000
		W1	57.97	18.05	0.020
		W2	58.77	18.05	0.017
Split	BL1	BL2	3.68	20.00	1.000
		W1	58.35	20.00	0.046

Condition	(*I*) Sleep Period	(*J*) Sleep Period	Mean Difference (*I-J*)	Std. Error	p value
		W2	58.71	20.00	0.043
		R	0.94	20.00	1.000
	BL2	BL1	-3.68	20.00	1.000
		W1	54.68	20.00	0.077
		W2	55.03	20.00	0.073
		R	-2.74	20.00	1.000
	W1	BL1	-58.35	20.00	0.046
		BL2	-54.67	20.00	0.077
		W2	0.35	20.00	1.000
		R	-57.41	20.00	0.052
	W2	BL1	-58.71	20.00	0.043
		BL2	-55.03	20.00	0.073
		W1	-0.35	20.00	1.000
		R	-57.77	20.00	0.050
	R	BL1	-0.94	20.00	1.000
		BL2	2.74	20.00	1.000
		W1	57.41	20.00	0.052
		W2	57.77	20.00	0.050

Table 23. N2 Sleep: Post-Hoc Comparisons Among Sleep Periods (for Sleep Period Main Effect, Omnibus ANOVA, see Table 18)

(*I*) Sleep Period	(*J*) Sleep Period	Mean Difference (*I-J*)	Std. Error	p value
BL1	BL2	1.50	5.42	0.784
	W1	49.06	8.20	0.000
	W2	54.40	8.50	0.000
	R	21.99	9.56	0.027
BL2	BL 1	-1.50	5.42	0.784
	W1	47.57	6.08	0.000
	W2	52.90	6.96	0.000
	R	20.40	9.59	0.039
W1	BL1	-49.06	8.20	0.000
	BL2	-47.567	6.08	0.000
	W2	5.34	7.59	0.486
	R	-27.16	10.39	0.012
W2	BL1	-54.40	8.50	0.000
	BL2	-52.90	6.95	0.000
	W1	-5.34	7.59	0.486
	R	-32.50	10.13	0.002
R	BL1	-21.99	9.57	0.027
	BL2	-20.40	9.59	0.039
	W1	27.16	10.39	0.012
	W2	32.50	10.13	0.002

Table 24. N1 Sleep: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	210.15	396.41	2, 47	0.53	0.592
Sleep	857.51	309.04	2.2, 105	2.78	0.061
Sleep × Condition	555.93	309.04	4.5, 105	1.80	0.127

Table 25. Sleep Latency: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	2,746.81	1,214.91	2, 47	2.26	0.115
Sleep Period	3,169.69	940.51	2.2, 102.7	3.37	0.034
Sleep Period × Condition	4,201.97	940.51	4.4, 102.7	4.47	0.002

Table 26. Sleep Latency: One-Way ANOVAs for Condition, Conducted Separately for Each Sleep Period

Sleep Period	Source	Sum of Squares	*df*	Mean Square	*F*	p value
BL1	Between Groups	1,733.36	2	866.68	0.69	0.508
	Within Groups	60,617.29	48	1262.86	–	–
BL2	Between Groups	2,116.78	2	1058.39	2.41	0.100
	Within Groups	21,047.70	48	438.49	–	–
W1	Between Groups	3,666.15	2	1833.08	7.50	0.001
	Within Groups	11,725.60	48	244.28	–	–
W2	Between Groups	8,076.84	2	4038.42	8.84	0.001
	Within Groups	21,928.33	48	456.84	–	–
R	Between Groups	7,948.94	2	3974.47	4.71	0.014
	Within Groups	40,492.98	48	843.60	–	–

Table 27. Sleep Latency: Post-Hoc Comparisons Among Conditions at Each Sleep Period, for Which There Was a Significant Condition Effect (see Table 26)

Sleep Period	(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
W1	Night	Day	20.90	5.40	0.001
		Split	8.50	5.22	0.330
	Day	Night	-20.90	5.40	0.001
		Split	-12.40	5.54	0.089
	Split	Night	-8.50	5.22	0.330
		Day	12.40	5.54	0.089
W2	Night	Day	30.93	7.38	0.000
		Split	15.94	7.14	0.091
	Day	Night	-30.93	7.38	0.000
		Split	-14.99	7.57	0.161
	Split	Night	-15.94	7.14	0.091
		Day	14.99	7.57	0.161
R	Night	Day	18.92	10.03	0.196
		Split	29.24	9.70	0.012
	Day	Night	-18.92	10.03	0.196
		Split	10.33	10.29	0.962
	Split	Night	-29.24	9.70	0.012
		Day	-10.33	10.29	0.962

Table 28. Sleep Latency: One-Way ANOVAs for Sleep Period, Conducted Separately for Each Condition

Condition		Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	1,1907.15	4	2,976.79	4.55	0.002
	Within Groups	58,829.08	90	653.66	–	–
Day	Between Groups	12,448.22	4	3,112.06	4.15	0.005
	Within Groups	52,511.00	70	750.16	–	–
Split	Between Groups	279.37	4	69.84	0.13	0.973
	Within Groups	44,471.82	80	555.90	–	–

Table 29. Sleep Latency: Post-Hoc Comparisons Among Sleep Periods for Each Condition, for Which There Was a Significant Sleep Period Effect (see Table 25)

Condition	(*I*) Period	(*J*) Period	Mean Difference (*I*-*J*)	Std. Error	p value
Night	BL1	BL2	-4.71	8.30	1.000
		W1	-9.40	8.30	1.000
		W2	-20.66	8.30	0.146
		R	-30.82	8.30	0.004
	BL2	BL 1	4.71	8.30	1.000
		W1	-4.68	8.30	1.000
		W2	-15.95	8.30	0.577
		R	-26.11	8.30	0.022
	W1	BL1	9.40	8.30	1.000
		BL2	4.68	8.30	1.000
		W2	-11.26	8.30	1.000
		R	-21.42	8.30	0.114
	W2	BL1	20.66	8.30	0.146
		BL2	15.95	8.30	0.577
		W1	11.26	8.30	1.000
		R	-10.16	8.30	1.000
	R	BL1	30.82	8.30	0.004
		BL2	26.11	8.30	0.022
		W1	21.42	8.30	0.114
		W2	10.16	8.30	1.000
Day	BL1	BL2	-4.47	10.00	1.000
		W1	25.83	10.00	0.119
		W2	24.60	10.00	0.164
		R	2.43	10.00	1.000
	BL2	BL 1	4.47	10.00	1.000
		W1	30.30	10.00	0.034
		W2	29.07	10.00	0.049
		R	6.90	10.00	1.000
	W1	BL1	-25.83	10.00	0.119
		BL2	-30.30	10.00	0.034
		W2	-1.23	10.00	1.000
		R	-23.40	10.00	0.222
	W2	BL1	-24.60	10.00	0.164
		BL2	-29.07	10.00	0.049
		W1	1.23	10.00	1.000
		R	-22.17	10.00	0.299
	R	BL1	-2.43	10.00	1.000
		BL2	-6.90	10.00	1.000
		W1	23.40	10.00	0.222
		W2	22.17	10.00	0.299

Table 30. Sleep Latency: Post-Hoc Comparisons Among Sleep Periods (for Sleep Period Main Effect, Omnibus ANOVA, see Table 25)

(*I*) Sleep Period	(*J*) Sleep Period	Mean Difference (*I*-*J*)	Std. Error	p value
BL1	BL2	-2.84	3.63	0.438
	W1	7.55	4.41	0.094
	W2	1.44	4.61	0.756
	R	-8.57	6.92	0.221
BL2	BL 1	2.84	3.63	0.438
	W1	10.38	2.54	0.000
	W2	4.28	3.12	0.176
	R	-5.74	5.56	0.308
W1	BL1	-7.55	4.41	0.094
	BL2	-10.38	2.54	0.000
	W2	-6.10	2.06	0.005
	R	-16.12	4.71	0.001
W2	BL1	-1.44	4.61	0.756
	BL2	-4.28	3.12	0.176
	W1	6.10	2.06	0.005
	R	-10.02	5.61	0.081
R	BL1	8.57	6.92	0.221
	BL2	5.74	5.56	0.308
	W1	16.12	4.71	0.001
	W2	10.02	5.61	0.081

Table 31. Slow Wave Sleep (N3) Latency: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	231.92	164.15	2, 47	1.41	0.254
Sleep	650.98	185.82	2.1, 99.2	3.50	0.032
Sleep × Condition	660.41	185.82	4.2, 99.2	3.55	0.008

Table 32. N3 Sleep Latency: One-Way ANOVAs for Condition, Conducted Separately for Each Sleep Period

Sleep Period	Source	Sum of Squares	*df*	Mean Square	*F*	p value
BL1	Between Groups	260.40	2	130.20	2.11	0.133
	Within Groups	2,965.73	48	61.79	–	–
BL2	Between Groups	48.09	2	24.05	.31	0.732
	Within Groups	3,671.56	48	76.49	–	–
W1	Between Groups	762.07	2	381.03	5.23	0.009
	Within Groups	3,495.27	48	72.82	–	–
W2	Between Groups	1,205.53	2	602.76	2.16	0.127
	Within Groups	13,404.33	48	279.26	–	–
R	Between Groups	1,078.67	2	539.34	9.70	0.000
	Within Groups	2,668.46	48	55.59	–	–

Table 33. N3 Sleep Latency: Post-Hoc Comparisons Among Conditions at Each Sleep Period, for Which There Was a Significant Condition Effect (see Table 32)

Sleep Period	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
W1	Night	Day	-1.46	2.95	1.000
		Split	-8.75	2.85	0.011
	Day	Night	1.46	2.95	1.000
		Split	-7.29	3.02	0.059
	Split	Night	8.75	2.85	0.011
		Day	7.29	3.02	0.059
R	Night	Day	-11.04	2.58	0.000
		Split	-2.64	2.49	0.885
	Day	Night	11.04	2.58	0.000
		Split	8.406	2.64	0.008
	Split	Night	2.64	2.49	0.885
		Day	-8.406	2.64	0.008

Table 34. N3 Sleep Latency: One-Way ANOVAs for Sleep Period, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	491.247	4	122.812	1.012	0.405
	Within Groups	10,919.474	90	121.327	–	–
Day	Between Groups	977.820	4	244.455	5.330	0.001
	Within Groups	3,210.767	70	45.868	–	–
Split	Between Groups	2,752.375	4	688.094	4.559	0.002
	Within Groups	12,075.103	80	150.939	–	–

Table 35. N3 Sleep Latency: Post-Hoc Comparisons for Each Sleep Period Among Conditions, for Which There Was a Significant Sleep Period Effect (see Table 34)

Condition	(*I*) Sleep Period	(*J*) Sleep Period	Mean Difference (*I-J*)	Std. Error	p value
Day	BL1	BL2	1.63	2.47	1.000
		W1	-1.40	2.47	1.000
		W2	-2.57	2.47	1.000
		R	-8.90	2.47	0.006
	BL2	BL1	-1.63	2.47	1.000
		W1	-3.03	2.47	1.000
		W2	-4.20	2.47	0.939
		R	-10.53	2.47	0.001
	W1	BL1	1.40	2.47	1.000
		BL2	3.03	2.47	1.000
		W2	-1.17	2.47	1.000
		R	-7.50	2.47	0.034
	W2	BL1	2.57	2.47	1.000
		BL2	4.20	2.47	0.939
		W1	1.17	2.47	1.000
		R	-6.33	2.47	0.126
	R	BL1	8.90	2.47	0.006
		BL2	10.53	2.47	0.001
		W1	7.50	2.47	0.034
		W2	6.33	2.47	0.126
Split	BL1	BL2	-2.21	4.21	1.000
		W1	-10.13	4.21	0.185
		W2	-14.84	4.21	0.007
		R	-1.94	4.21	1.000
	BL2	BL1	2.21	4.21	1.000
		W1	-7.93	4.21	0.636
		W2	-12.64	4.21	0.036
		R	0.26	4.21	1.000
	W1	BL1	10.13	4.21	0.185
		BL2	7.93	4.21	0.636
		W2	-4.71	4.21	1.000
		R	8.19	4.21	0.554
	W2	BL1	14.84	4.21	0.007
		BL2	12.63	4.21	0.036
		W1	4.71	4.21	1.000
		R	12.90	4.21	0.030
	R	BL1	1.94	4.21	1.000
		BL2	-0.26	4.21	1.000
		W1	-8.19	4.21	0.554
		W2	-12.90	4.21	0.030

Table 36. N3 Sleep Latency: Post-Hoc Comparisons Among Sleep Periods (for Sleep Period Main Effect, Omnibus ANOVA, see Table 31)

(*I*) Sleep Period	(*J*) Sleep Period	Mean Difference (*I*-*J*)	Std. Error	p value
BL1	BL2	0.89	1.28	0.488
	W1	-2.63	1.45	0.076
	W2	-5.86	2.73	0.037
	R	-1.72	1.43	0.236
BL2	BL 1	-0.89	1.28	0.488
	W1	-3.52	1.34	0.011
	W2	-6.75	2.66	0.014
	R	-2.61	1.47	0.083
W1	BL1	2.63	1.45	0.076
	BL2	3.52	1.34	0.011
	W2	-3.23	2.71	0.239
	R	0.92	1.10	0.411
W2	BL1	5.86	2.73	0.037
	BL2	6.75	2.66	0.014
	W1	3.23	2.71	0.239
	R	4.14	2.58	0.115
R	BL1	1.72	1.43	0.236
	BL2	2.61	1.47	0.083
	W1	-0.92	1.10	0.411
	W2	-4.14	2.58	0.115

Table 37. REM Sleep Latency: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	527.18	2,841.05	2, 47	0.19	0.831
Sleep Period	11,444.70	1,900.51	2.97, 139.79	6.02	0.001
Sleep Period × Condition	3,460.98	1,900.51	5.95, 139.79	1.82	0.100

Table 38. REM Sleep Latency: Post-Hoc Comparisons Among Sleep Periods (for Sleep Period Main Effect, Omnibus ANOVA, see Table 37)

(*I*) Sleep Period	(*J*) Sleep Period	Mean Difference (*I-J*)	Std. Error	p value
BL1	BL2	9.61	7.17	0.186
	W1	26.64	9.34	0.006
	W2	31.92	7.07	0.000
	R	22.69	8.88	0.014
BL2	BL 1	-9.61	7.17	0.186
	W1	17.03	8.92	0.062
	W2	22.31	5.44	0.000
	R	13.08	6.18	0.040
W1	BL1	-26.64	9.34	0.006
	BL2	-17.03	8.92	0.062
	W2	5.28	6.86	0.445
	R	-3.95	9.02	0.663
W2	BL1	-31.92	7.07	0.000
	BL2	-22.31	5.44	0.000
	W1	-5.28	6.86	0.445
	R	-9.23	5.05	0.074
R	BL1	-22.69	8.88	0.014
	BL2	-13.08	6.18	0.040
	W1	3.95	9.02	0.663
	W2	9.23	5.05	0.074

Table 39. Effect of Nap Type (Morning Versus Afternoon): One-Way ANOVAs for Each of the Sleep Parameters

Sleep Variable	Source	Sum of Squares	*df*	Mean Square	*F*	p value
TST	Between Groups	286,147.12	1	286,147.12	117.16	0.000
	Within Groups	244,234.05	100	2442.34	–	–
SE %	Between Groups	315,84.96	1	31,584.96	114.81	0.000
	Within Groups	27,511.80	100	275.12	–	–
REM	Between Groups	32,207.41	1	32,207.41	67.27	0.000
	Within Groups	47,876.92	100	478.769	–	–
SWS	Between Groups	15,676.08	1	15,676.08	21.14	0.000
	Within Groups	74,149.81	100	741.498	–	–
SL	Between Groups	511.88	1	511.89	0.95	0.332
	Within Groups	53,860.30	100	538.60	–	–

TST = total sleep time; SE% = percentage sleep efficiency; REM = rapid eye movement sleep; SWS = slow wave sleep (N3); SL = sleep latency

APPENDIX B: ANALYSIS OF VARIANCE TABLES FOR PSYCHOMOTOR VIGILANCE TEST LAPSES

All statistical analysis results shown in tables in Appendix B were derived from a three-way Condition (between-groups factor: Night Sleep, Day Sleep, and Split Sleep) x Workday (repeated-measures factor: 1–5) x Time (repeated-measures factor: 1–8) repeated-measures ANOVA. Greenhouse-Geisser (G-G) correction factor was applied to all repeated-measures factors to reduce the likelihood of detecting false positives ("Type I" errors). Significant interactions were followed by one-way ANOVAs (e.g., one-way ANOVA for Condition at each Workday) and then further analyzed using post-hoc *t* tests with Bonferroni corrections (corrected for multiple comparisons). Interactions that were not significant were not followed by one-way ANOVAs or post-hoc *t* tests.

Differences in error degrees of freedom across analyses are due to missing data points (resulting from occasional technical difficulties during data collection).

Table 40. PVT Lapses: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	6,370.28	106.82	2, 40	0.95	0.40
Workday	25.71	8.92	2.78, 111.3	2.88	0.04
Time	83.75	6.13	4.76, 190.2	13.67	0.00
Condition × Workday	5.21	8.92	5.57, 111.3	0.58	0.73
Condition × Time	35.24	6.13	9.51, 190.2	5.75	0.00
Condition × Workday × Time	7.34	6.87	23.3, 466.2	1.07	0.38

Table 41. PVT Lapses: One-Way ANOVAs for Condition, Conducted Separately at Each Time

Time	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	33.61	2	16.81	3.95	0.021
	Within Groups	901.19	212	4.25	–	–
	Total	934.81	214	–	–	–
2	Between Groups	45.67	2	22.84	3.47	0.033
	Within Groups	1,393.66	212	6.57	–	–
	Total	1,439.33	214	–	–	–
3	Between Groups	30.33	2	15.16	3.81	0.024
	Within Groups	843.07	212	3.98	–	–
	Total	873.35	214	–	–	–
4	Between Groups	85.06	2	42.53	8.33	0.000
	Within Groups	1,082.26	212	5.11	–	–
	Total	1,167.32	214	–	–	–
5	Between Groups	93.40	2	46.70	6.97	0.001
	Within Groups	1,420.81	212	6.70	–	–
	Total	1,514.21	214	–	–	–
6	Between Groups	60.31	2	30.15	5.24	0.006
	Within Groups	1,219.49	212	5.75	–	–
	Total	1,279.80	214	–	–	–
7	Between Groups	58.38	2	29.19	4.71	0.010
	Within Groups	1,312.80	212	6.19	–	–
	Total	1,371.18	214	–	–	–
8	Between Groups	130.24	2	65.12	7.49	0.001
	Within Groups	1,842.76	212	8.69	–	–
	Total	1,972.99	214	–	–	–

Table 42. PVT Lapses: Post-Hoc Comparisons Among Conditions at Each Time

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
1	Night	Day	.95	0.35	0.023
		Split	0.17	0.33	1.000
	Day	Night	-.95	0.35	0.023
		Split	-0.78	0.36	0.092
	Split	Night	-0.17	0.33	1.000
		Day	0.78	0.36	0.092
2	Night	Day	1.15	0.44	0.027
		Split	0.49	0.41	0.705
	Day	Night	-1.15	0.44	0.027
		Split	-0.66	0.44	0.410
	Split	Night	-0.49	0.41	0.705
		Day	0.66	0.44	0.410
3	Night	Day	0.65	0.34	0.168
		Split	-0.29	0.32	1.000
	Day	Night	-0.65	0.34	0.168
		Split	-.94	0.35	0.021
	Split	Night	0.29	0.32	1.000
		Day	.940*	0.35	0.021
4	Night	Day	0.08	0.39	1.000
		Split	-1.28	0.36	0.001
	Day	Night	-0.08	0.39	1.000
		Split	-1.36	0.39	0.002
	Split	Night	1.28	0.36	0.001
		Day	1.36	0.39	0.002
5	Night	Day	-0.02	0.44	1.000
		Split	-1.39	0.42	0.003
	Day	Night	0.02	0.44	1.000
		Split	-1.37	0.45	0.007
	Split	Night	1.39	0.42	0.003
		Day	1.37	0.45	0.007
6	Night	Day	0.43	0.41	0.888
		Split	-0.87	0.39	0.076
	Day	Night	-0.43	0.41	0.888
		Split	-1.30	0.42	0.006
	Split	Night	0.87	0.39	0.076
		Day	1.30	0.42	0.006
7	Night	Day	-0.68	0.43	0.341
		Split	-1.23	0.40	0.007
	Day	Night	0.68	0.43	0.341
		Split	-0.55	0.43	0.610
	Split	Night	1.23	0.40	0.007
		Day	0.55	0.43	0.610

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
8	Night	Day	-1.93	0.50	0.001
		Split	-1.06	0.47	0.079
	Day	Night	1.93	0.50	0.001
		Split	0.87	0.51	0.270
	Split	Night	1.06	0.47	0.079
		Day	-0.87	0.51	0.270

Table 43. PVT Lapses: One-Way ANOVAs for Time, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	25.94	7	3.71	0.57	0.782
	Within Groups	4,125.49	632	6.53	–	–
	Total	4,151.42	639		–	–
Day	Between Groups	423.87	7	60.55	14.66	0.000
	Within Groups	1,950.10	472	4.13	–	–
	Total	2,373.97	479		–	–
Split	Between Groups	227.71	7	32.53	4.89	0.000
	Within Groups	3,940.45	592	6.66	–	–
	Total	4,168.16	599		–	–

Table 44. PVT Lapses: Post-Hoc Comparisons at Each Time for Each Condition, for Which There Was a Significant Condition Effect (see Table 43)

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
Day	1	2	-0.23	0.37	1.000
		3	-0.38	0.37	1.000
		4	-0.93	0.37	0.343
		5	-0.82	0.37	0.791
		6	-0.93	0.37	0.343
		7	-1.60	0.37	0.001
		8	-3.17	0.37	0.000
	2	1	0.23	0.37	1.000
		3	-0.15	0.37	1.000
		4	-0.70	0.37	1.000
		5	-0.58	0.37	1.000
		6	-0.70	0.37	1.000
		7	-1.37	0.37	0.007
		8	-2.93	0.37	0.000
	3	1	0.38	0.37	1.000
		2	0.15	0.37	1.000
		4	-0.55	0.37	1.000
		5	-0.43	0.37	1.000
		6	-0.55	0.37	1.000
		7	-1.22	0.37	0.031
		8	-2.78	0.37	0.000
	4	1	0.93	0.37	0.343
		2	0.70	0.37	1.000
		3	0.55	0.37	1.000
		5	0.12	0.37	1.000
		6	0.00	0.37	1.000
		7	-0.67	0.37	1.000
		8	-2.23	0.37	0.000
	5	1	0.82	0.37	0.791
		2	0.58	0.37	1.000
		3	0.43	0.37	1.000
		4	-0.12	0.37	1.000
		6	-0.12	0.37	1.000
		7	-0.78	0.37	0.989
		8	-2.35	0.37	0.000
	6	1	0.93	0.37	0.343
		2	0.70	0.37	1.000
		3	0.55	0.37	1.000
		4	0.00	0.37	1.000
		5	0.12	0.37	1.000
		7	-0.67	0.37	1.000
		8	-2.23	0.37	0.000

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I-J*)	Std. Error	p value
	7	1	1.60	0.37	0.001
		2	1.37	0.37	0.007
		3	1.22	0.37	0.031
		4	0.67	0.37	1.000
		5	0.78	0.37	0.989
		6	0.67	0.37	1.000
		8	-1.57	0.37	0.001
	8	1	3.17	0.37	0.000
		2	2.93	0.37	0.000
		3	2.78	0.37	0.000
		4	2.23	0.37	0.000
		5	2.35	0.37	0.000
		6	2.23	0.37	0.000
		7	1.57	0.37	0.001
Split	1	2	-0.12	0.42	1.000
		3	-0.55	0.42	1.000
		4	-1.52	0.42	0.009
		5	-1.41	0.42	0.024
		6	-1.45	0.42	0.017
		7	-1.37	0.42	0.033
		8	-1.52	0.42	0.009
	2	1	0.12	0.42	1.000
		3	-0.43	0.42	1.000
		4	-1.40	0.42	0.026
		5	-1.29	0.42	0.063
		6	-1.33	0.42	0.046
		7	-1.25	0.42	0.085
		8	-1.40	0.42	0.026
	3	1	0.55	0.42	1.000
		2	0.43	0.42	1.000
		4	-0.97	0.42	0.594
		5	-0.87	0.42	1.000
		6	-0.91	0.42	0.890
		7	-0.83	0.42	1.000
		8	-0.97	0.42	0.594
	4	1	1.52	0.42	0.009
		2	1.40	0.42	0.026
		3	0.97	0.42	0.594
		5	0.11	0.42	1.000
		6	0.07	0.42	1.000
		7	0.15	0.42	1.000
		8	0.00	0.42	1.000
	5	1	1.41	0.42	0.024
		2	1.29	0.42	0.063

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
		3	0.87	0.42	1.000
		4	-0.11	0.42	1.000
		6	-0.04	0.42	1.000
		7	0.04	0.42	1.000
		8	-0.11	0.42	1.000
	6	1	1.45	0.42	0.017
		2	1.33	0.42	0.046
		3	0.91	0.42	0.890
		4	-0.07	0.42	1.000
		5	0.04	0.42	1.000
		7	0.08	0.42	1.000
		8	-0.07	0.42	1.000
	7	1	1.37	0.42	0.033
		2	1.25	0.42	0.085
		3	0.83	0.42	1.000
		4	-0.15	0.42	1.000
		5	-0.04	0.42	1.000
		6	-0.08	0.42	1.000
		8	-0.15	0.42	1.000
	8	1	1.52	0.42	0.009
		2	1.40	0.42	0.026
		3	0.97	0.42	0.594
		4	0.00	0.42	1.000
		5	0.11	0.42	1.000
		6	0.07	0.42	1.000
		7	0.15	0.42	1.000

Table 45. PVT Lapses: Post-Hoc Comparisons for Workday (for Workday Main Effect, Omnibus ANOVA, see Table 40)

(*I*) Day	(*J*) Day	Mean Difference (*I-J*)	Std. Error	p value
1	2	-0.06	0.16	0.713
	3	-0.45	0.19	0.021
	4	-0.23	0.18	0.205
	5	-0.52	0.25	0.043
2	1	0.06	0.16	0.713
	3	-0.39	0.18	0.037
	4	-0.17	0.14	0.239
	5	-0.46	0.24	0.060
3	1	0.45	0.19	0.021
	2	0.39	0.18	0.037
	4	0.22	0.18	0.241
	5	-0.08	0.22	0.736
4	1	0.23	0.18	0.205
	2	0.17	0.14	0.239
	3	-0.22	0.18	0.241
	5	-0.29	0.15	0.053
5	1	0.52	0.25	0.043
	2	0.46	0.24	0.060
	3	0.08	0.22	0.736
	4	0.29	0.15	0.053

Table 46. PVT Lapses: Post-Hoc Comparisons for Time (for Time Main Effect, Omnibus ANOVA, see Table 40)

(*I*) Time	(*J*) Time	Mean Difference (*I-J*)	Std. Error	p value
1	2	-0.26	0.21	0.218
	3	-0.34	0.11	0.005
	4	-0.84	0.19	0.000
	5	-0.70	0.18	0.000
	6	-0.93	0.17	0.000
	7	-0.98	0.22	0.000
	8	-1.66	0.22	0.000
2	1	0.26	0.21	0.218
	3	-0.08	0.20	0.700
	4	-0.58	0.24	0.022
	5	-0.43	0.22	0.056
	6	-0.67	0.27	0.019
	7	-0.72	0.25	0.007
	8	-1.39	0.27	0.000
3	1	0.34	0.11	0.005
	2	0.08	0.20	0.700
	4	-0.50	0.17	0.004
	5	-0.35	0.13	0.010
	6	-0.59	0.19	0.003
	7	-0.64	0.20	0.003
	8	-1.32	0.21	0.000
4	1	0.84	0.19	0.000
	2	0.58	0.24	0.022
	3	0.50	0.17	0.004
	5	0.15	0.17	0.385
	6	-0.09	0.18	0.600
	7	-0.14	0.19	0.444
	8	-0.82	0.20	0.000
5	1	0.69	0.18	0.000
	2	0.43	0.22	0.056
	3	0.35	0.13	0.010
	4	-0.15	0.17	0.385
	6	-0.24	0.17	0.169
	7	-0.29	0.18	0.110
	8	-0.97	0.18	0.000
6	1	0.93	0.17	0.000
	2	0.67	0.27	0.019
	3	0.59	0.19	0.003
	4	0.09	0.18	0.600
	5	0.24	0.17	0.169
	7	-0.05	0.21	0.816
	8	-0.73	0.18	0.000

(*I*) Time	(*J*) Time	Mean Difference (*I-J*)	Std. Error	p value
7	1	0.98	0.22	0.000
	2	0.72	0.25	0.007
	3	0.64	0.20	0.003
	4	0.14	0.19	0.444
	5	0.29	0.18	0.110
	6	0.05	0.21	0.816
	8	-0.68	0.18	0.000
8	1	1.66	0.22	0.000
	2	1.39	0.27	0.000
	3	1.32	0.21	0.000
	4	0.82	0.20	0.000
	5	0.96	0.18	0.000
	6	0.73	0.18	0.000
	7	0.68	0.18	0.000

APPENDIX C: ANALYSIS OF VARIANCE TABLES FOR HIGH-FIDELITY DRIVING SIMULATOR VARIABLES

All statistical analysis results shown in tables in Appendix C were derived from a three-way Condition (between-groups factor: Night Sleep, Day Sleep, and Split Sleep) x Workday (repeated-measures factor: 1–5) x Time (repeated-measures factor: 1–4) repeated-measures ANOVA, accounting for participants' assignment to either simulator #1 or #2. Greenhouse-Geisser (G-G) correction factor was applied to all repeated-measures factors to reduce the likelihood of detecting false positives ("Type I" errors). Significant interactions were followed by one-way ANOVAs (e.g., one-way ANOVA for Condition at each Workday) and then further analyzed using post-hoc *t* tests with Bonferroni corrections (corrected for multiple comparisons). Interactions that were not significant were not followed by one-way ANOVAs or post-hoc *t* tests.

Differences in error degrees of freedom across analyses are due to missing data points (resulting from occasional technical difficulties during data collection).

Table 47. Average Speed: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	15.02	40.98	2,41	0.37	0.70
Day	0.86	1.45	2.88, 118.1	0.59	0.61
Time	0.06	0.31	2.5, 104	0.21	0.86
Condition × Day	4.18	1.45	5.8, 118.1	2.89	0.01
Condition × Time	0.317	0.31	5.1, 104	1.01	0.42
Condition × Day × Time	0.56	1.03	9.8, 200.9	0.55	0.85

Table 48. Average Speed: One-Way ANOVAs for Workday, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	9.70	4	2.43	2.38	0.052
	Within Groups	339.86	333	1.02	–	–
Day	Between Groups	28.10	4	7.02	1.87	0.116
	Within Groups	1,184.97	315	3.76	–	–
Split	Between Groups	2.54	4	0.63	0.25	0.910
	Within Groups	808.43	318	2.54	–	–

Table 49. Average Speed: Post-Hoc Comparisons Among Workdays for Each Condition

Condition	(*I*) Workday	(*J*) Day	Mean Difference (*I*-*J*)	Std. Error	p value
Night	1	2	-0.36	0.17	0.395
		3	-0.49	0.17	0.049
		4	-0.26	0.17	1.000
		5	-0.15	0.17	1.000
	2	1	0.36	0.17	0.395
		3	-0.13	0.17	1.000
		4	0.09	0.17	1.000
		5	0.21	0.17	1.000
	3	1	0.49	0.17	0.049
		2	0.13	0.17	1.000
		4	0.23	0.17	1.000
		5	0.35	0.17	0.480
	4	1	0.26	0.17	1.000
		2	-0.10	0.17	1.000
		3	-0.23	0.17	1.000
		5	0.12	0.17	1.000
	5	1	0.15	0.17	1.000
		2	-0.21	0.17	1.000
		3	-0.35	0.17	0.480
		4	-0.12	0.17	1.000

Table 50. Average Speed: One-Way ANOVAs for Condition, Conducted Separately at Each Workday

Workday	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	10.17	2	5.09	1.50	0.226
	Within Groups	654.21	193	3.39	–	–
2	Between Groups	0.31	2	0.15	0.07	0.933
	Within Groups	428.36	195	2.20	–	–
3	Between Groups	6.36	2	3.18	1.44	0.239
	Within Groups	421.11	191	2.21	–	–
4	Between Groups	14.38	2	7.19	3.45	0.034
	Within Groups	408.89	196	2.09	–	–
5	Between Groups	33.67	2	16.84	7.64	0.001
	Within Groups	420.70	191	2.20	–	–

Table 51. Average Speed: Post-Hoc Comparisons for Each Condition by Workday for Which There Was a Significant Condition Effect (see Table 50)

Workday	(*I*) condition	(*J*) condition	Mean Difference (*I*-*J*)	Std. Error	p value
4	Night	Day	-0.65	0.25	0.031
		Split	-0.22	0.25	1.000
	Day	Night	0.65	0.25	0.031
		Split	0.43	0.25	0.275
	Split	Night	0.22	0.25	1.000
		Day	-0.43	0.25	0.275
5	Night	Day	-1.01	0.26	0.000
		Split	-0.54	0.26	0.116
	Day	Night	1.01	0.26	0.000
		Split	0.47	0.26	0.239
	Split	Night	0.54	0.26	0.116
		Day	-0.47	0.26	0.239

Table 52. Lane Deviation: Omnibus ANOVA

Source	MS effect	MS error	*df*	*F*	p value
Condition	0.01	0.02	2,41	0.45	0.643
Day	0.00	0.00	2.87, 117.5	0.61	0.599
Time	0.00	0.03	2.15, 88.1	5.12	0.007
Condition × Day	0.00	0.00	5.7, 117.5	0.61	0.718
Condition × Time	0.00	0.00	4.3, 88.1	6.89	0.000
Condition × Day × Time	0.00	0.00	12.4, 253.5	0.96	0.487

Table 53. Lane Deviation: One-Way ANOVAs for Time, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	0.00	3	0.00	0.25	0.864
	Within Groups	0.47	334	0.00	–	–
Day	Between Groups	0.03	3	0.01	8.41	0.000
	Within Groups	0.43	316	0.00	–	–
Split	Between Groups	0.01	3	0.00	1.74	0.159
	Within Groups	0.59	319	0.00	–	–

Table 54. Lane Deviation: Post-Hoc Comparisons Among Times for Each Condition for Which There Was a Significant Condition Effect (see Table 53)

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
Day	1	2	0.00	0.01	1.000
		3	0.00	0.01	1.000
		4	-0.02	0.01	0.000
	2	1	0.00	0.01	1.000
		3	-0.01	0.01	1.000
		4	-0.03	0.01	0.000
	3	1	0.00	0.01	1.000
		2	0.01	0.01	1.000
		4	-0.02	0.01	0.005
	4	1	0.02	0.01	0.000
		2	0.03	0.01	0.000
		3	0.02	0.01	0.005

Table 55. Lane Deviation: One-Way ANOVAs for Condition, Conducted Separately at Each Time

Time	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	0.01	2	0.00	1.95	0.144
	Within Groups	0.34	243	0.00	–	–
2	Between Groups	0.00	2	0.00	1.11	0.331
	Within Groups	0.32	241	0.00	–	–
3	Between Groups	0.01	2	0.01	3.40	0.035
	Within Groups	0.36	244	0.00	–	–
4	Between Groups	0.02	2	0.01	4.58	0.011
	Within Groups	0.46	241	0.00	–	–

Table 56. Lane Deviation: Post-Hoc Comparisons for Each Time by Condition for Which There Was a Significant Time Effect (see Table 55)

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
3	Night	Day	0.00	0.01	1.000
		Split	0.01	0.01	0.597
	Day	Night	0.00	0.01	1.000
		Split	-0.01	0.01	0.172
	Split	Night	0.00	0.01	1.000
		Day	-0.02	0.01	0.040
4	Night	Day	0.01	0.01	0.172
		Split	0.02	0.01	0.040
	Day	Night	-0.02	0.01	0.010
		Split	-0.01	0.01	0.161
	Split	Night	0.02	0.01	0.010
		Day	0.01	0.01	0.918

Table 57. Lane Deviation: Post-Hoc Comparisons Among Times (for Time Main Effect, Omnibus ANOVA, see Table 52)

(*I*) Times	(*J*) Times	Mean Difference (*I*-*J*)	Std. Error	p value
1	2	0.00	0.00	0.272
	3	-0.01	0.00	0.002
	4	-0.01	0.00	0.001
2	1	-0.00	0.00	0.272
	3	-0.01	0.00	0.000
	4	-0.01	0.00	0.000
3	1	0.01	0.00	0.002
	2	0.01	0.00	0.000
	4	-0.00	0.00	0.054
4	1	0.01	0.00	0.001
	2	0.01	0.00	0.000
	3	0.00	0.00	0.054

Table 58. Braking Reaction Time: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	0.06	0.15	2,40	0.40	0.673
Day	0.02	0.02	2.7, 107.3	0.98	0.399
Time	0.03	0.01	2.4, 94.4	4.49	0.010
Condition × Day	0.03	0.02	5.4, 107.3	1.10	0.368
Condition × Time	0.01	0.01	4.7, 94.4	0.76	0.573
Condition × Day × Time	0.03	0.02	7.7, 153.4	1.79	0.086

Table 59. Braking Reaction Time: Post-Hoc Comparisons Among Times (for Time Main Effect, Omnibus ANOVA, see Table 58)

(*I*) Times	(*J*) Times	Mean Difference (*I*-*J*)	Std. Error	p value
1	2	0.00	0.01	0.507
	3	-0.00	0.01	0.767
	4	-0.01	0.01	0.185
2	1	-0.00	0.01	0.507
	3	-0.01	0.01	0.331
	4	-0.02	0.01	0.036
3	1	0.00	0.01	0.767
	2	0.01	0.01	0.331
	4	-0.01	0.01	0.128
4	1	0.01	0.01	0.185
	2	0.02	0.01	0.036
	3	0.01	0.01	0.128

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APPENDIX D: ANALYSIS OF VARIANCE TABLES FOR NEUROBEHAVIORAL VARIABLES

All statistical analysis results shown in tables in Appendix D were derived from a three-way Condition (between-groups factor: Night Sleep, Day Sleep, and Split Sleep) x Workday (repeated-measures factor: 1–5) x Time (repeated-measures factor: 1–4) repeated-measures ANOVA. G-G correction factor was applied to all repeated-measures factors to reduce the likelihood of detecting false positives ("Type I" errors). Significant interactions were followed by one-way ANOVAs (e.g., one-way ANOVA for Condition at each Workday) and then further analyzed using post-hoc *t* tests with Bonferroni corrections (corrected for multiple comparisons). Interactions that were not significant were not followed by one-way ANOVAs or post-hoc *t* tests.

Differences in error degrees of freedom across analyses are due to missing data points (resulting from occasional technical difficulties during data collection).

Table 60. KSS: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	84.87	15.90	2, 47	5.34	0.008
Day	1.25	2.55	3, 142.3	0.49	0.692
Time	48.94	3.20	2.4, 112.2	15.29	0.000
Condition × Day	9.11	2.55	3, 142.3	3.58	0.002
Condition × Time	41.968	3.20	2.8, 112.2	13.11	0.000
Condition × Day × Time	1.578	1.17	9.8, 200.9	1.35	0.152

Table 61. KSS: One-Way ANOVAs for Time, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	2.03	3	0.68	0.41	0.744
	Within Groups	583.17	356	1.64	–	–
Day	Between Groups	241.01	3	80.34	27.55	0.000
	Within Groups	918.42	315	2.92	–	–
Split	Between Groups	50.15	3	16.72	9.18	0.000
	Within Groups	612.19	336	1.82	–	–

Table 62. KSS: Post-Hoc Comparisons Among Conditions at Each Time for Which There Was a Significant Condition Effect (see Table 61)

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
Day	1	2	-0.41	0.27	0.788
		3	-1.21	0.27	0.000
		4	-2.28	0.27	0.000
	2	1	0.41	0.27	0.788
		3	-0.80	0.27	0.020
		4	-1.87	0.27	0.000
	3	1	1.21	0.27	0.000
		2	0.80	0.27	0.020
		4	-1.06	0.27	0.001
	4	1	2.28	0.27	0.000
		2	1.87	0.27	0.000
		3	1.06	0.27	0.001
Split	1	2	-1.07	0.21	0.000
		3	-0.47	0.21	0.142
		4	-0.38	0.21	0.420
	2	1	1.07	0.21	0.000
		3	0.60	0.21	0.024
		4	0.69	0.21	0.005
	3	1	0.47	0.21	0.142
		2	-0.60	0.21	0.024
		4	0.09	0.21	1.000
	4	1	0.38	0.21	0.420
		2	-0.69	0.21	0.005
		3	-0.09	0.21	1.000

Table 63. KSS: One-Way ANOVAs for Condition, Conducted Separately at Each Time

Time	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	10.73	2	5.37	4.17	0.017
	Within Groups	324.66	252	1.29	–	–
2	Between Groups	21.99	2	10.99	4.81	0.009
	Within Groups	574.03	251	2.29	–	–
3	Between Groups	68.62	2	34.31	14.39	0.000
	Within Groups	600.96	252	2.39	–	–
4	Between Groups	262.80	2	131.40	53.92	0.000
	Within Groups	614.12	252	2.44	–	–

Table 64. KSS: Post-Hoc Comparisons Among Times for Each Condition

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
1	Night	Day	0.08	0.17	1.000
		Split	0.47	0.17	0.021
	Day	Night	-0.08	0.17	1.000
		Split	0.39	0.18	0.090
	Split	Night	-0.47	0.17	0.021
		Day	-0.39	0.18	0.090
2	Night	Day	-0.43	0.23	0.203
		Split	-0.70	0.23	0.007
	Day	Night	0.43	0.23	0.203
		Split	-0.28	0.24	0.738
	Split	Night	0.70	0.23	0.007
		Day	0.28	0.24	0.738
3	Night	Day	-1.11	0.24	0.000
		Split	0.02	0.23	1.000
	Day	Night	1.11	0.24	0.000
		Split	1.13	0.24	0.000
	Split	Night	-0.02	0.23	1.000
		Day	-1.13	0.24	0.000
4	Night	Day	-2.08	0.24	0.000
		Split	0.20	0.24	1.000
	Day	Night	2.08	0.24	0.000
		Split	2.29	0.24	0.000
	Split	Night	-0.20	0.24	1.000
		Day	-2.29	0.24	0.000

Table 65. KSS: One-Way ANOVAs for Workday, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	19.29	4	4.82	3.03	0.018
	Within Groups	565.90	355	1.59	–	–
Day	Between Groups	23.89	4	5.97	1.65	0.161
	Within Groups	1,135.55	314	3.62	–	–
Split	Between Groups	2.12	4	0.53	0.27	0.898
	Within Groups	660.22	335	1.97	–	–

Table 66. KSS: Post-Hoc Comparisons Among Conditions at Each Workday for Which There Was a Significant Condition Effect (see Table 65)

Condition	(*I*) Workday	(*J*) Workday	Mean Difference (*I*-*J*)	Std. Error	p value
Night	1	2	-0.08	0.21	1.000
		3	-0.15	0.21	1.000
		4	-0.01	0.21	1.000
		5	-0.63	0.21	0.032
	2	1	0.08	0.21	1.000
		3	-0.07	0.21	1.000
		4	0.07	0.21	1.000
		5	-0.54	0.21	0.105
	3	1	0.15	0.21	1.000
		2	0.07	0.21	1.000
		4	0.14	0.21	1.000
		5	-0.47	0.21	0.254
	4	1	0.01	0.21	1.000
		2	-0.06	0.21	1.000
		3	-0.13	0.21	1.000
		5	-0.61	0.21	0.039
	5	1	0.63	0.21	0.032
		2	0.54	0.21	0.105
		3	0.47	0.21	0.254
		4	0.61	0.21	0.039

Table 67. KSS: One-Way ANOVAs for Condition, Conducted Separately for Each Workday

Workday	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	97.10	2	48.55	19.35	0.000
	Within Groups	504.25	201	2.51	–	–
2	Between Groups	35.14	2	17.57	7.66	0.001
	Within Groups	461.15	201	2.29	–	–
3	Between Groups	41.98	2	20.99	9.38	0.000
	Within Groups	449.72	201	2.24	–	–
4	Between Groups	29.95	2	14.97	6.54	0.002
	Within Groups	458.23	200	2.29	–	–
5	Between Groups	9.05	2	4.53	1.86	0.158
	Within Groups	488.30	201	2.43	–	–

Table 68. KSS: Post-Hoc Comparisons Among Workdays for Each Condition for Which There Was a Significant Workday Effect (see Table 67)

Workday	(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
1	Night	Day	-1.54	0.27	0.000
		Split	-0.11	0.27	1.000
	Day	Night	1.54	0.27	0.000
		Split	1.43	0.28	0.000
	Split	Night	0.11	0.27	1.000
		Day	-1.43	0.28	0.000
2	Night	Day	-0.91	0.26	0.002
		Split	-0.02	0.26	1.000
	Day	Night	0.91	0.26	0.002
		Split	0.88	0.26	0.003
	Split	Night	0.02	0.26	1.000
		Day	-0.88	0.26	0.003
3	Night	Day	-0.98	0.26	0.001
		Split	0.00	0.25	1.000
	Day	Night	0.97	0.26	0.001
		Split	0.98	0.26	0.001
	Split	Night	-0.00	0.25	1.000
		Day	-0.98	0.26	0.001
4	Night	Day	-0.93	0.26	0.001
		Split	-0.29	0.26	0.744
	Day	Night	0.93	0.26	0.001
		Split	0.63	0.27	0.053
	Split	Night	0.30	0.26	0.744
		Day	-0.63	0.27	0.053

Table 69. KSS: Post-Hoc Contrasts Among Conditions (for CONDITION Main Effect, Omnibus ANOVA, see Table 60)

(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
Night	Day	-0.90*	0.31	0.017
	Split	0.00	0.30	1.000
Day	Night	.090*	0.31	0.017
	Split	.090*	0.32	0.020
Split	Night	0.00	0.30	1.000
	Day	-.090*	0.32	0.020

Table 70. KSS: Post-Hoc Contrasts Among Time (for Time Main Effect, Omnibus ANOVA, see Table 61)

(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
1	2	-0.48	0.13	0.001
	3	-0.57	0.12	0.000
	4	-0.96	0.16	0.000
2	1	0.48	0.13	0.001
	3	-0.10	0.15	0.519
	4	-0.49	0.17	0.007
3	1	0.57	0.12	0.000
	2	0.10	0.15	0.519
	4	-0.39	0.12	0.002
4	1	0.96	0.16	0.000
	2	0.49	0.17	0.007
	3	0.39	0.12	0.002

Table 71. VASM: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	75.04	26.50	2,48	2.83	0.069
Day	1.49	1.38	3.6, 170.7	1.08	0.366
Time	5.25	1.44	2.1, 98.9	3.63	0.029
Condition × Day	3.72	1.38	7.1, 170.7	1.06	0.391
Condition × Time	1.80	1.44	4.1, 98.9	1.25	0.295
Condition × Day × Time	.74	0.72	16.9, 405.3	1.03	0.422

Table 72. VASM Scores: Post-Hoc Contrasts Among Times (for Time Main Effect, Omnibus ANOVA, see Table 71

(*I*) Times	(*J*) Times	Mean Difference (*I*-*J*)	Std. Error	p value
1	2	-0.16	0.07	0.027
	3	-0.18	0.08	0.026
	4	-0.29	0.12	0.021
2	1	0.16	0.07	0.027
	3	-0.02	0.07	0.726
	4	-0.13	0.09	0.159
3	1	0.18	0.08	0.026
	2	0.02	0.07	0.726
	4	-0.11	0.09	0.241
4	1	0.29	0.12	0.021
	2	0.13	0.09	0.159
	3	0.11	0.09	0.241

Table 73. PANAS Positive: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	2,652.97	1,288.86	2, 47	2.06	0.139
Day	95.88	29.23	2.9, 135.1	3.28	0.025
Time	193.93	20.39	2.3, 107.3	9.51	0.000
Condition × Day	33.99	29.23	5.7, 135.1	1.16	0.330
Condition × Time	68.38	20.39	4.6, 107.3	3.35	0.009
Condition × Day × Time	14.71	15.62	9.8, 200.9	0.94	0.513

Table 74. PANAS Positive: One-Way ANOVAs for Time, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	60.66	3	20.22	0.31	0.816
	Within Groups	22,979.33	356	64.55	–	–
Day	Between Groups	633.53	3	211.18	2.37	0.071
	Within Groups	28,124.77	315	89.29	–	–
Split	Between Groups	122.99	3	40.99	0.58	0.630
	Within Groups	23,828.00	336	70.92	–	–

Table 75. PANAS Positive: One-Way ANOVAs for Condition, Conducted Separately at Each Time

Time	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	1,497.78	2	748.89	9.65	0.000
	Within Groups	19,557.83	252	77.61	–	–
2	Between Groups	1,210.41	2	605.21	8.90	0.000
	Within Groups	1,7061.41	251	67.97	–	–
3	Between Groups	1,405.11	2	702.55	9.28	0.000
	Within Groups	19,077.30	252	75.70	–	–
4	Between Groups	1,701.37	2	850.69	11.15	0.000
	Within Groups	19,235.56	252	76.33	–	–

Table 76. PANAS Positive: Post-Hoc Comparisons Among Conditions for Each Time, for Which There Was a Significant Condition Effect (see Table 75)

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
1	Night	Day	-2.97	1.35	0.087
		Split	-5.85	1.33	0.000
	Day	Night	2.97	1.35	0.087
		Split	-2.88	1.37	0.111
	Split	Night	5.85	1.33	0.000
		Day	2.88	1.37	0.111
2	Night	Day	-3.08	1.27	0.048
		Split	-5.23	1.25	0.000
	Day	Night	3.08	1.27	0.048
		Split	-2.14	1.29	0.292
	Split	Night	5.23	1.25	0.000
		Day	2.14	1.29	0.292
3	Night	Day	-0.95	1.34	1.000
		Split	-5.36	1.32	0.000
	Day	Night	0.95	1.334	1.000
		Split	-4.41	1.36	0.004
	Split	Night	5.36	1.32	0.000
		Day	4.41	1.36	0.004
4	Night	Day	-0.21	1.34	1.000
		Split	-5.58	1.32	0.000
	Day	Night	0.21	1.34	1.000
		Split	-5.37	1.36	0.000
	Split	Night	5.58	1.32	0.000
		Day	5.37	1.36	0.000

Table 77. PANAS Positive: Post-Hoc Contrasts Among Times (for Time Main Effect, Omnibus ANOVA, see Table 73)

(*I*) Time	(*J*) Time	Mean Difference (*I-J*)	Std. Error	p -value
1	2	1.14	0.46	0.018
	3	1.17	0.34	0.001
	4	1.86	0.37	0.000
2	1	-1.14	0.46	0.018
	3	0.03	0.32	0.936
	4	0.72	0.36	0.051
3	1	-1.17	0.33	0.001
	2	-0.03	0.32	0.936
	4	0.69	0.22	0.004
4	1	-1.86	0.37	0.000
	2	-0.72	0.36	0.051
	3	-0.69	0.22	0.004

Table 78. PANAS Positive: Post-Hoc Contrasts Among Workdays (for Workday Main Effect, Omnibus ANOVA, see Table 73)

(*I*) Workday	(*J*) Workday	Mean Difference (*I-J*)	Std. Error	p value
1	2	0.73	0.38	0.063
	3	1.55	0.46	0.002
	4	1.19	0.45	0.011
	5	1.11	0.62	0.081
2	1	-0.73	0.38	0.063
	3	0.82	0.41	0.052
	4	0.46	0.38	0.231
	5	0.38	0.56	0.505
3	1	-1.55	0.46	0.002
	2	-0.82	0.41	0.052
	4	-0.36	0.39	0.354
	5	-0.44	0.47	0.355
4	1	-1.18	0.45	0.011
	2	-0.46	0.38	0.231
	3	0.36	0.39	0.354
	5	-0.08	0.40	0.843
5	1	-1.11	0.62	0.081
	2	-0.38	0.56	0.505
	3	0.44	0.47	0.355
	4	0.08	0.40	0.843

Table 79. PANAS Negative: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	29.30	38.04	2, 47	0.77	0.469
Day	11.65	4.53	2.2, 105.1	2.57	0.075
Time	5.21	3.49	1.8, 86.6	1.49	0.232
Condition × Day	3.72	4.53	4.5, 105.1	0.82	0.526
Condition × Time	3.89	3.49	3.7, 86.6	1.11	0.354
Condition × Day × Time	13.24	17.27	3.9, 91.1	0.77	0.545

Table 80. Performance Ratings: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	0.08	6.78	2, 47	0.01	0.989
Day	0.31	0.58	3.2, 151.9	0.53	0.677
Time	0.08	0.50	2.9, 135.8	0.17	0.912
Condition × Day	0.85	0.58	6, 151.9	1.47	0.189
Condition × Time	0.53	0.50	5.2, 135.8	1.07	0.383
Condition × Day × Time	0.72	0.77	17.7, 416.9	0.93	0.536

Table 81. Effort Ratings: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	2.14	6.32	2, 47	0.34	0.715
Day	0.18	0.29	3, 141	0.62	0.604
Time	0.28	0.25	2.6, 122.3	1.11	0.343
Condition × Day	0.77	0.29	6, 141	2.61	0.020
Condition × Time	0.77	0.25	5.2, 122.3	3.09	0.011
Condition × Day × Time	0.28	0.20	16.7, 392.7	1.43	0.121

Table 82. Effort Ratings: One-Way ANOVAs for Workday, Conducted Separately at Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	2.11	4	0.53	1.18	0.321
	Within Groups	159.39	355	0.45	–	–
Day	Between Groups	1.17	4	0.29	0.65	0.628
	Within Groups	141.99	314	0.45	–	–
Split	Between Groups	2.15	4	0.54	1.12	0.349
	Within Groups	161.25	335	0.48	–	–

Table 83. Effort Ratings: One-Way ANOVAs for Condition, Conducted Separately at Each Workday

Workday	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	2.59	2	1.30	3.36	0.037
	Within Groups	77.56	201	0.39	–	–
2	Between Groups	3.64	2	1.82	4.12	0.018
	Within Groups	88.69	201	0.44	–	–
3	Between Groups	1.76	2	0.88	1.88	0.156
	Within Groups	94.52	201	0.47	–	–
4	Between Groups	1.47	2	0.74	1.39	0.252
	Within Groups	105.94	200	0.53	–	–
5	Between Groups	0.252	2	0.126	0.265	0.768
	Within Groups	95.904	201	0.477	–	–

Table 84. Effort Rating: Post-Hoc Comparisons Among Conditions for Each Workday, for Which There Was a Significant Condition Effect (see Table 83)

Workday	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
1	Night	Day	-0.26	0.11	0.047
		Split	-0.04	0.11	1.000
	Day	Night	0.26	0.11	0.047
		Split	0.22	0.11	0.134
	Split	Night	0.04	0.11	1.000
		Day	-0.22	0.11	0.134
2	Night	Day	-0.27	0.11	0.058
		Split	-0.29	0.11	0.033
	Day	Night	0.27	0.11	0.058
		Split	-0.02	0.11	1.000
	Split	Night	0.29	0.11	0.033
		Day	0.02	0.11	1.000

Table 85. Effort Rating: One-Way ANOVAs for Time, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	0.63	3	0.21	0.47	0.705
	Within Groups	160.87	356	0.45	–	–
Day	Between Groups	2.58	3	0.86	1.93	0.125
	Within Groups	140.58	315	0.45	–	–
Split	Between Groups	2.13	3	0.71	1.48	0.221
	Within Groups	161.27	336	0.48	–	–

Table 86. Effort Rating: One-Way ANOVAs for Condition, Conducted Separately at Each Time

Time	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	1.16	2	0.58	1.42	0.243
	Within Groups	102.43	252	0.41	–	–
2	Between Groups	2.96	2	1.48	2.98	0.053
	Within Groups	124.74	251	0.50	–	–
3	Between Groups	0.62	2	0.31	0.64	0.527
	Within Groups	121.85	252	0.48	–	–
4	Between Groups	4.71	2	2.36	5.22	0.006
	Within Groups	113.70	252	0.45	–	–

Table 87. Effort Rating: Post-Hoc Comparisons Among Conditions for Each Time, for Which There Was a Significant Condition Effect (see Table 86)

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
2	Night	Day	-0.08	0.11	1.000
		Split	-0.26	0.11	0.053
	Day	Night	0.08	0.11	1.000
		Split	-0.18	0.11	0.322
	Split	Night	0.26	0.11	0.053
		Day	0.18	0.11	0.322
4	Night	Day	-0.32	0.10	0.007
		Split	-0.05	0.10	1.000
	Day	Night	0.32	0.10	0.007
		Split	0.26	0.11	0.040
	Split	Night	0.05	0.10	1.000
		Day	-0.26	0.11	0.040

Table 88. Digit-Symbol Substitution Test: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	9,085.62	5,103.49	2, 47	1.78	0.180
Day	1,557.12	85.60	2.5, 119.4	18.19	0.000
Time	45.58	44.66	2.5, 116.9	1.02	0.376
Condition × Day	64.29	85.60	6, 119.4	0.75	0.589
Condition × Time	4.97	44.66	5.2, 116.9	7.99	0.000
Condition × Day x Time	112.17	56.32	16.5, 388.2	1.99	0.012

Table 89. Digit-Symbol Substitution Test: One-Way ANOVAs for Time, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	451.48	3	150.49	0.71	0.546
	Within Groups	75383.06	356	211.75	–	–
Day	Between Groups	604.25	3	201.42	0.48	0.700
	Within Groups	133509.13	315	423.84	–	–
Split	Between Groups	601.48	3	200.49	0.77	0.510
	Within Groups	87122.09	336	259.29	–	–

Table 90. Digit-Symbol Substitution Test: One-Way ANOVAs for Condition, Conducted Separately at Each Time

Time	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	1,770.75	2	885.38	2.89	0.058
	Within Groups	77,300.03	252	306.75	–	–
2	Between Groups	6,677.17	2	3,338.59	10.84	0.000
	Within Groups	77,339.99	251	308.13	–	–
3	Between Groups	6,258.18	2	3,129.09	11.02	0.000
	Within Groups	71,578.82	252	284.04	–	–
4	Between Groups	6,564.55	2	3,282.28	11.851	0.000
	Within Groups	69,795.43	252	276.97	–	–

Table 91. Digit-Symbol Substitution Test: Post-Hoc Comparisons Among Conditions for each Time

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
1	Night	Day	4.67	2.69	0.253
		Split	6.07	2.65	0.069
	Day	Night	-4.67	2.69	0.253
		Split	1.40	2.73	1.000
	Split	Night	-6.07	2.65	0.069
		Day	-1.40	2.73	1.000
2	Night	Day	7.92	2.71	0.011
		Split	12.15	2.65	0.000
	Day	Night	-7.92	2.71	0.011
		Split	4.23	2.74	0.372
	Split	Night	-12.15	2.65	0.000
		Day	-4.23	2.74	0.372
3	Night	Day	10.29	2.59	0.000
		Split	10.44	2.55	0.000
	Day	Night	-10.287	2.59	0.000
		Split	0.15	2.63	1.000
	Split	Night	-10.44	2.55	0.000
		Day	-0.15	2.63	1.000
4	Night	Day	10.61	2.55	0.000
		Split	10.63	2.52	0.000
	Day	Night	-10.61	2.56	0.000
		Split	0.02	2.59	1.000
	Split	Night	-10.63	2.52	0.000
		Day	-0.02	2.59	1.000

Table 92. Digit-Symbol Substitution Test: Post Hoc Contrasts Among Workdays (for Workday Main Effect, Omnibus ANOVA, see Table 88)

(*I*) Workday	(*J*) Workday	Mean Difference (*I*-*J*)	Std. Error	p value
1	2	-2.68	0.72	0.001
	3	-2.96	0.84	0.001
	4	-4.84	0.87	0.000
	5	-5.78	1.04	0.000
2	1	2.68	0.72	0.001
	3	-0.28	0.56	0.613
	4	-2.17	0.72	0.004
	5	-3.10	0.79	0.000
3	1	2.96	0.84	0.001
	2	0.282	0.56	0.613
	4	-1.89	0.54	0.001
	5	-2.82	0.60	0.000
4	1	4.84	0.87	0.000
	2	2.17	0.72	0.004
	3	1.89	0.54	0.001
	5	-0.93	0.54	0.091
5	1	5.78	1.04	0.000
	2	3.10	0.79	0.000
	3	2.82	0.60	0.000
	4	0.93	0.54	0.091

APPENDIX E: ANALYSIS OF VARIANCE TABLES FOR BIOMEDICAL METRICS

All statistical analysis results shown in tables in Appendix E were derived from a three-way Condition (between-groups factor: Night Sleep, Day Sleep, and Split Sleep) x Week (repeated-measures factor: pre, post) x Time (repeated-measures factor: blood draw 1–7) mixed-effects ANOVA. This approach was taken to account for both within- and between-subject variability in blood results. Significant interactions were followed by one-way ANOVAs (e.g., one-way ANOVA for Condition at each Workday) and then further analyzed using post-hoc *t* tests with Bonferroni corrections (corrected for multiple comparisons).

For the BP variables, a two-way Condition (between-groups factor: Night Sleep, Day Sleep, and Split Sleep) X Workday (repeated-measures factor: 1–5) repeated-measures ANOVA. The between-subject factor was sleep condition (Night, Day, and Split). G-G corrected probabilities were used to determine statistical significance for all repeated-measures factors. Where significant interactions were observed, condition by workdays ANOVAs were conducted, and significant interactions were further analyzed using post-hoc *t* tests with Bonferroni corrections (corrected for multiple comparisons). Interactions that were not significant were not followed by one-way ANOVAs or post-hoc *t* tests.

Differences in error degrees of freedom across analyses are due to missing data points (resulting from occasional technical difficulties during data collection).

Table 93. Glucose: Mixed-Effects ANOVA

Source	*df*	*F*	p value
Intercept	1, 50.88	6,339.45	0.000
Condition	2, 50.88	1.42	0.250
Week	1, 658.43	85.97	0.000
Time	6, 657.97	132.98	0.000
Condition × Week	2, 658.42	11.33	0.000
Condition × Time	12, 657.97	6.50	0.000
Condition × Week × Time	12, 657.97	5.68	0.000

Table 94. Glucose: One-Way ANOVAs for Week, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	2,230.03	1	2,230.03	4.01	0.046
	Within Groups	146,433.95	263	556.78	–	–
Day	Between Groups	16,228.35	1	16,228.35	26.78	0.000
	Within Groups	149,102.46	246	606.11	–	–
Split	Between Groups	1,988.84	1	1,988.84	6.22	0.013
	Within Groups	75,420.56	236	319.58	–	–

Table 95. Glucose: One-Way ANOVAs for Condition, Conducted Separately for Each Week

Week	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Pre	Between Groups	3,232.68	2	1,616.34	4.28	0.015
	Within Groups	139,798.33	370	377.83	–	–
Post	Between Groups	4,777.36	2	2,388.68	3.88	0.022
	Within Groups	231,158.63	375	616.42	–	–

Table 96. Glucose: Post-Hoc Comparisons Among Workdays for Each Condition

Week	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
Pre	Night	Day	6.80	2.44	0.017
		Split	5.20	2.46	0.105
	Day	Night	-6.80	2.44	0.017
		Split	-1.60	2.50	1.000
	Split	Night	-5.20	2.46	0.105
		Day	1.60	2.50	1.000
Post	Night	Day	-3.58	3.09	0.740
		Split	5.22	3.13	0.290
	Day	Night	3.58	3.09	0.740
		Split	8.80	3.17	0.018
	Split	Night	-5.22	3.13	0.290
		Day	-8.80	3.17	0.018

Table 97. Glucose: One-Way ANOVA for Time, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	51,744.91	6	8,624.15	22.96	0.000
	Within Groups	96,919.07	258	375.66	–	–
Day	Between Groups	63,009.41	6	10,501.57	24.74	0.000
	Within Groups	102,321.39	241	424.57	–	–
Split	Between Groups	44,038.40	6	7,339.73	50.81	0.000
	Within Groups	33,371.00	231	144.46	–	–

Table 98. Glucose: Post-Hoc Comparisons Among Times for Each Condition

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
Night	0900	1000	-21.26	4.45	0.000
		1200	-1.97	4.45	1.000
		1400	-25.58	4.45	0.000
		1600	-6.12	4.48	1.000
		1800	1.40	4.45	1.000
		2000	-37.32	4.45	0.000
	1000	0900	21.26	4.45	0.000
		1200	19.29	4.45	0.000
		1400	-4.32	4.45	1.000
		1600	15.15	4.48	0.017
		1800	22.66	4.45	0.000
		2000	-16.05	4.45	0.008
	1200	0900	1.97	4.45	1.000
		1000	-19.29	4.45	0.000
		1400	-23.61	4.45	0.000
		1600	-4.14	4.48	1.000
		1800	3.37	4.45	1.000
		2000	-35.34	4.45	0.000
	1400	0900	25.579*	4.45	0.000
		1000	4.32	4.45	1.000
		1200	23.61	4.45	0.000
		1600	19.46	4.48	0.000
		1800	26.97	4.45	0.000
		2000	-11.74	4.45	0.185
	1600	0900	6.12	4.48	1.000
		1000	-15.15	4.48	0.017
		1200	4.14	4.48	1.000
		1400	-19.46	4.48	0.000
		1800	7.51	4.48	1.000
		2000	-31.20	4.48	0.000
	1800	0900	-1.40	4.48	1.000
		1000	-22.66	4.45	0.000
		1200	-3.37	4.45	1.000
		1400	-26.97	4.45	0.000
		1600	-7.51	4.48	1.000
		2000	-38.71	4.45	0.000
	2000	0900	37.32	4.45	0.000
		1000	16.05	4.45	0.008
		1200	35.34	4.45	0.000
		1400	11.74	4.45	0.185
		1600	31.20	4.48	0.000
		1800	38.71	4.45	0.000
Day	0900	1000	-38.42	4.86	0.000
		1200	-.36	4.86	1.000
		1400	-10.74	4.90	0.611
		1600	5.033	4.90	1.000
		1800	7.690	4.90	1.000

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
		2000	-25.481*	4.90	0.000
	1000	0900	38.417*	4.86	0.000
		1200	38.056*	4.86	0.000
		1400	27.679*	4.90	0.000
		1600	43.450*	4.90	0.000
		1800	46.107*	4.90	0.000
		2000	12.936	4.891	0.183
	1200	0900	0.36	4.86	1.000
		1000	-38.056*	4.86	0.000
		1400	-10.38	4.89	0.733
		1600	5.39	4.89	1.000
		1800	8.05	4.89	1.000
		2000	-25.120*	4.89	0.000
	1400	0900	10.74	4.89	0.611
		1000	-27.679*	4.89	0.000
		1200	10.38	4.89	0.733
		1600	15.771*	4.93	0.033
		1800	18.429*	4.93	0.005
		2000	-14.74	4.93	0.064
	1600	0900	-5.03	4.89	1.000
		1000	-43.450*	4.89	0.000
		1200	-5.39	4.89	1.000
		1400	-15.771*	4.93	0.033
		1800	2.66	4.93	1.000
		2000	-30.514*	4.93	0.000
	1800	0900	-7.69	4.89	1.000
		1000	-46.107*	4.89	0.000
		1200	-8.05	4.89	1.000
		1400	-18.429*	4.93	0.005
		1600	-2.66	4.93	1.000
		2000	-33.171*	4.93	0.000
	2000	0900	25.481*	4.89	0.000
		1000	-12.94	4.89	0.183
		1200	25.120*	4.89	0.000
		1400	14.74	4.93	0.064
		1600	30.514*	4.93	0.000
		1800	33.171*	4.93	0.000
Split	0900	1000	-25.765*	2.92	0.000
		1200	1.41	2.92	1.000
		1400	-22.706*	2.92	0.000
		1600	-4.56	2.92	1.000
		1800	1.59	2.92	1.000
		2000	-32.676*	2.92	0.000
	1000	0900	25.765*	2.92	0.000
		1200	27.176*	2.92	0.000
		1400	3.06	2.92	1.000
		1600	21.206*	2.92	0.000
		1800	27.353*	2.92	0.000

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
		2000	-6.91	2.92	0.390
	1200	0900	-1.41	2.92	1.000
		1000	-27.176*	2.92	0.000
		1400	-24.118*	2.92	0.000
		1600	-5.97	2.92	0.875
		1800	0.18	2.92	1.000
		2000	-34.088*	2.92	0.000
	1400	0900	22.706*	2.92	0.000
		1000	-3.06	2.92	1.000
		1200	24.118*	2.92	0.000
		1600	18.147*	2.92	0.000
		1800	24.294*	2.92	0.000
		2000	-9.971*	2.92	0.016
	1600	0900	4.56	2.92	1.000
		1000	-21.206*	2.92	0.000
		1200	5.97	2.92	0.875
		1400	-18.147*	2.92	0.000
		1800	6.15	2.92	0.757
		2000	-28.118*	2.92	0.000
	1800	0900	-1.59	2.92	1.000
		1000	-27.353*	2.92	0.000
		1200	-0.18	2.92	1.000
		1400	-24.294*	2.92	0.000
		1600	-6.15	2.92	0.757
		2000	-34.265*	2.92	0.000
	2000	0900	32.676*	2.92	0.000
		1000	6.91	2.92	0.390
		1200	34.088*	2.92	0.000
		1400	9.971*	2.92	0.016
		1600	28.118*	2.92	0.000
		1800	34.265*	2.92	0.000

Table 99. Glucose: One-Way ANOVAs for Condition, Conducted Separately for Each Time

Time	Source	Sum of Squares	*df*	Mean Square	*F*	p value
0900	Between Groups	771.14	2	385.57	8.109	0.001
	Within Groups	4,992.49	105	47.55	–	–
1000	Between Groups	9,130.03	2	4,565.01	5.365	0.006
	Within Groups	89,344.22	105	850.90	–	–
1200	Between Groups	1,463.22	2	731.61	3.180	0.046
	Within Groups	24,159.45	105	230.09	–	–
1400	Between Groups	2,767.28	2	1,383.64	3.856	0.024
	Within Groups	37,317.51	104	358.82	–	–
1600	Between Groups	1,369.76	2	684.88	4.317	0.016
	Within Groups	16,341.86	103	158.66	–	–
1800	Between Groups	390.43	2	195.22	5.556	0.005
	Within Groups	3,654.39	104	35.14	–	–
2000	Between Groups	1,977.94	2	988.97	1.811	0.169
	Within Groups	56,801.54	104	546.17	–	–

Table 100. Glucose: Post-Hoc Comparisons for Each Condition by Time for Which There Was a Significant Condition Effect (see Table 99)

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
0900	Night	Day	0.36	4.86	0.336
		Split	-38.06	4.86	0.045
	Day	Night	-10.38	4.89	0.336
		Split	5.39	4.89	0.000
	Split	Night	8.05	4.89	0.045
		Day	-25.12	4.89	0.000
1000	Night	Day	10.74	4.89	0.013
		Split	-27.68	4.89	1.000
	Day	Night	10.38	4.89	0.013
		Split	15.77	4.93	0.020
	Split	Night	18.43	4.93	1.000
		Day	-14.74	4.93	0.020
1200	Night	Day	-5.03	4.89	1.000
		Split	-43.45	4.89	0.123
	Day	Night	-5.39	4.89	1.000
		Split	-15.77	4.93	0.069
	Split	Night	2.66	4.93	0.123
		Day	-30.51	4.93	0.069
1400	Night	Day	-7.69	4.89	0.020
		Split	-46.11	4.89	0.377
	Day	Night	-8.05	4.89	0.020
		Split	-18.43	4.93	0.725
	Split	Night	-2.66	4.93	0.377
		Day	-33.17	4.93	0.725
1600	Night	Day	25.48	4.89	0.014
		Split	-12.94	4.89	0.195
	Day	Night	25.12	4.89	0.014
		Split	14.74	4.93	0.978
	Split	Night	30.51	4.93	0.195
		Day	33.17	4.93	0.978
1800	Night	Day	-25.76	2.92	0.025
		Split	1.41	2.92	0.010
	Day	Night	-22.71	2.92	0.025
		Split	-4.56	2.92	1.000
	Split	Night	1.59	2.92	0.010
		Day	-32.68	2.92	1.000

Table 101. Glucose: Post-Hoc Comparisons Among Times (for Time Main Effect, Omnibus ANOVA, see Table 93)

(*I*) Time	(*J*) Time	Mean Difference (*I-J*)	Std. Error	p value
0900	1000	-28.48	1.83	0.000
	1200	-0.31	1.83	1.000
	1400	-19.69	1.83	0.000
	1600	-2.00	1.84	1.000
	1800	3.45	1.83	1.000
	2000	-31.94	1.83	0.000
1000	0900	28.48	1.83	0.000
	1200	28.17	1.83	0.000
	1400	8.79	1.83	0.000
	1600	26.48	1.84	0.000
	1800	31.93	1.83	0.000
	2000	-3.45	1.83	1.000
1200	0900	0.31	1.83	1.000
	1000	-28.17	1.83	0.000
	1400	-19.38	1.83	0.000
	1600	-1.69	1.84	1.000
	1800	3.75	1.83	0.865
	2000	-31.63	1.83	0.000
1400	0900	19.69	1.83	0.000
	1000	-8.79	1.83	0.000
	1200	19.38	1.83	0.000
	1600	17.69	1.84	0.000
	1800	23.14	1.84	0.000
	2000	-12.25	1.84	0.000
1600	0900	2.00	1.84	1.000
	1000	-26.48	1.84	0.000
	1200	1.69	1.84	1.000
	1400	-17.69	1.84	0.000
	1800	5.45	1.84	0.068
	2000	-29.93	1.84	0.000
1800	0900	-3.45	1.83	1.000
	1000	-31.93	1.83	0.000
	1200	-3.75	1.83	0.865
	1400	-23.14	1.84	0.000
	1600	-5.45	1.84	0.068
	2000	-35.38	1.84	0.000
2000	0900	31.94	1.83	0.000
	1000	3.45	1.83	1.000
	1200	31.63	1.83	0.000
	1400	12.25	1.84	0.000
	1600	29.94	1.84	0.000
	1800	35.38	1.84	0.000

Table 102. IL-6: Mixed-Effects ANOVA

Source	*df*	*F*	p value
Intercept	1, 50.976	95.01	0.000
Condition	2, 50.976	1.07	0.351
Week	1, 656.177	15.78	0.000
Time	6, 655.258	24.27	0.000
Condition × Week	2, 656.166	1.08	0.339
Condition × Time	12, 655.256	0.82	0.626
Condition × Week × Time	12, 655.249	0.72	0.738

Table 103. IL-6: Post-Hoc Comparisons Among Times (for Time Main Effect, Omnibus ANOVA, see Table 102)

(*I*) Time Code	(*J*) Time Code	Mean Difference (*I-J*)	Std. Error	p value
0900	1000	-0.18	0.88	1.000
	1200	-1.63	0.88	1.000
	1400	-3.33	0.88	0.004
	1600	-5.51	0.88	0.000
	1800	-8.08	0.88	0.000
	2000	-5.72	0.88	0.000
1000	0900	0.18	0.88	1.000
	1200	-1.44	0.88	1.000
	1400	-3.15	0.88	0.008
	1600	-5.33	0.88	0.000
	1800	-7.89	0.88	0.000
	2000	-5.54	0.88	0.000
1200	0900	1.63	0.88	1.000
	1000	1.44	0.88	1.000
	1400	-1.71	0.88	1.000
	1600	-3.89	0.88	0.000
	1800	-6.45	0.88	0.000
	2000	-4.10	0.88	0.000
1400	0900	3.33	0.88	0.004
	1000	3.15	0.88	0.008
	1200	1.71	0.88	1.000
	1600	-2.18	0.88	0.292
	1800	-4.74	0.89	0.000
	2000	-2.39	0.88	0.147
1600	0900	5.51	0.88	0.000
	1000	5.33	0.88	0.000
	1200	3.89	0.88	0.000
	1400	2.18	0.88	0.292
	1800	-2.56	0.88	0.081
	2000	-0.21	0.88	1.000
1800	0900	8.08	0.88	0.000
	1000	7.89	0.88	0.000
	1200	6.45	0.88	0.000
	1400	4.74	0.89	0.000
	1600	2.56	0.88	0.081
	2000	2.35	0.88	0.168
2000	0900	5.72	0.88	0.000
	1000	5.54	0.88	0.000
	1200	4.10	0.88	0.000
	1400	2.39	0.88	0.147
	1600	0.21	0.88	1.000
	1800	-2.35	0.88	0.168

Table 104. Leptin: Mixed-Effects ANOVA

Source	*df*	*F*	p value
Intercept	1, 50.94	112.24	0.000
Condition	2, 50.94	1.28	0.286
Week	1, 641.04	6.06	0.014
Time	6, 640.98	90.92	0.000
Condition × Week	2, 641.04	1.37	0.255
Condition × Time	12, 640.98	2.75	0.001
Condition × Week × Time	12, 640.96	2.65	0.002

Table 105. Leptin: One-Way ANOVA Results for Time, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	139.15	6	23.19	2.45	0.025
	Within Groups	2,381.24	252	9.45	–	–
Day	Between Groups	194.59	6	32.43	2.45	0.026
	Within Groups	3,058.62	231	13.24	–	–
Split	Between Groups	78.83	6	13.14	2.35	0.032
	Within Groups	1,285.04	230	5.59	–	–

Table 106. Leptin: Post-Hoc Comparisons for Each Condition by Time

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
Night	1	2	0.63	0.72	1.000
		3	0.15	0.72	1.000
		4	-0.01	0.72	1.000
		5	-0.88	0.71	1.000
		6	-1.28	0.71	1.000
		7	-1.43	0.71	0.933
	2	1	-0.63	0.72	1.000
		3	-0.48	0.72	1.000
		4	-0.64	0.72	1.000
		5	-1.51	0.71	0.752
		6	-1.91	0.71	0.168
		7	-2.06	0.71	0.089
	3	1	-0.15	0.72	1.000
		2	0.48	0.72	1.000
		4	-0.16	0.72	1.000
		5	-1.03	0.71	1.000
		6	-1.43	0.71	0.979
		7	-1.58	0.71	0.585
	4	1	0.01	0.72	1.000
		2	0.64	0.72	1.000
		3	0.16	0.72	1.000
		5	-0.87	0.71	1.000

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
		6	-1.27	0.71	1.000
		7	-1.42	0.71	0.997
	5	1	0.88	0.71	1.000
		2	1.51	0.71	0.752
		3	1.03	0.71	1.000
		4	0.87	0.71	1.000
		6	-0.40	0.71	1.000
		7	-0.55	0.71	1.000
	6	1	1.28	0.71	1.000
		2	1.91	0.71	0.168
		3	1.43	0.71	0.979
		4	1.27	0.71	1.000
		5	0.40	0.71	1.000
		7	-0.15	0.71	1.000
	7	1	1.43	0.71	0.933
		2	2.06	0.71	0.089
		3	1.58	0.71	0.585
		4	1.42	0.71	0.997
		5	0.55	0.71	1.000
		6	0.15	0.71	1.000
Day	1	2	1.12	0.88	1.000
		3	0.77	0.88	1.000
		4	0.31	0.89	1.000
		5	-0.68	0.88	1.000
		6	-1.20	0.88	1.000
		7	-1.42	0.88	1.000
	2	1	-1.12	0.88	1.000
		3	-0.35	0.88	1.000
		4	-0.81	0.88	1.000
		5	-1.80	0.88	0.860
		6	-2.32	0.88	0.181
		7	-2.54	0.88	0.087
	3	1	-0.77	0.88	1.000
		2	0.35	0.88	1.000
		4	-0.46	0.89	1.000
		5	-1.45	0.88	1.000
		6	-1.97	0.88	0.557
		7	-2.19	0.88	0.294
	4	1	-0.31	0.89	1.000
		2	0.81	0.88	1.000
		3	0.46	0.89	1.000
		5	-0.99	0.89	1.000
		6	-1.51	0.89	1.000

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
		7	-1.73	0.89	1.000
	5	1	0.68	0.88	1.000
		2	1.80	0.88	0.860
		3	1.45	0.88	1.000
		4	0.99	0.89	1.000
		6	-0.52	0.88	1.000
		7	-0.74	0.88	1.000
	6	1	1.20	0.88	1.000
		2	2.32	0.88	0.181
		3	1.97	0.88	0.557
		4	1.51	0.89	1.000
		5	0.52	0.88	1.000
		7	-0.21	0.88	1.000
	7	1	1.42	0.88	1.000
		2	2.54	0.88	0.087
		3	2.19	0.88	0.294
		4	1.73	0.89	1.000
		5	0.74	0.88	1.000
		6	0.21	0.88	1.000
Split	1	2	0.38	0.57	1.000
		3	0.24	0.57	1.000
		4	-0.05	0.57	1.000
		5	-0.73	0.57	1.000
		6	-1.08	0.57	1.000
		7	-1.10	0.58	1.000
	2	1	-0.38	0.57	1.000
		3	-0.14	0.57	1.000
		4	-0.43	0.57	1.000
		5	-1.11	0.57	1.000
		6	-1.46	0.57	0.238
		7	-1.48	0.58	0.228
	3	1	-0.24	0.57	1.000
		2	0.14	0.57	1.000
		4	-0.29	0.57	1.000
		5	-0.97	0.57	1.000
		6	-1.32	0.57	0.469
		7	-1.34	0.58	0.448
	4	1	0.05	0.57	1.000
		2	0.43	0.57	1.000
		3	0.29	0.57	1.000
		5	-0.68	0.57	1.000
		6	-1.03	0.57	1.000
		7	-1.05	0.58	1.000

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
	5	1	0.73	0.57	1.000
		2	1.11	0.57	1.000
		3	0.97	0.57	1.000
		4	0.68	0.57	1.000
		6	-0.35	0.57	1.000
		7	-0.37	0.58	1.000
	6	1	1.08	0.57	1.000
		2	1.46	0.57	0.238
		3	1.32	0.57	0.469
		4	1.03	0.57	1.000
		5	0.35	0.57	1.000
		7	-0.02	0.58	1.000
	7	1	1.10	0.58	1.000
		2	1.48	0.58	0.228
		3	1.34	0.58	0.448
		4	1.05	0.58	1.000
		5	0.37	0.58	1.000
		6	0.02	0.58	1.000

Table 107. Leptin: One-Way ANOVAs for Condition, Conducted Separately for Each Time

Time	Source	Sum of Squares	*df*	Mean Square	*F*	p value
0900	Between Groups	61.32	2	30.66	3.53	0.033
	Within Groups	885.36	102	8.68	–	–
1000	Between Groups	24.83	2	12.41	2.09	0.129
	Within Groups	606.64	102	5.95	–	–
1200h	Between Groups	37.85	2	18.93	2.73	0.070
	Within Groups	699.32	101	6.92	–	–
1400	Between Groups	41.80	2	20.90	2.80	0.066
	Within Groups	746.46	100	7.47	–	–
1600	Between Groups	60.508	2	30.25	2.83	0.063
	Within Groups	1,099.71	103	10.68	–	–
1800	Between Groups	71.15	2	35.58	2.69	0.073
	Within Groups	1,362.86	103	13.23	–	–
2000	Between Groups	84.15	2	42.08	3.24	0.043
	Within Groups	1,324.55	102	12.99	–	–

Table 108. Leptin: Post-Hoc Comparisons for Each Condition by Time for Which There Was a Significant Condition Effect (see Table 107)

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
0900	Night	Day	-0.78	0.70	0.799
		Split	1.11	0.70	0.350
	Day	Night	0.78	0.70	0.799
		Split	1.89	0.71	0.028
	Split	Night	-1.11	0.70	0.350
		Day	-1.89	0.71	0.028
1200	Night	Day	-0.16	0.63	1.000
		Split	1.20	0.63	0.178
	Day	Night	0.16	0.63	1.000
		Split	1.36	0.64	0.106
	Split	Night	-1.20	0.63	0.178
		Day	-1.36	0.64	0.106
1400	Night	Day	-0.46	0.66	1.000
		Split	1.07	0.65	0.313
	Day	Night	0.46	0.66	1.000
		Split	1.54	0.67	0.071
	Split	Night	-1.07	0.65	0.313
		Day	-1.54	0.67	0.071
1600	Night	Day	-0.58	0.77	1.000
		Split	1.26	0.77	0.318
	Day	Night	0.58	0.77	1.000
		Split	1.84	0.79	0.066
	Split	Night	-1.26	0.77	0.318
		Day	-1.84	0.79	0.066
1800	Night	Day	-0.70	0.86	1.000
		Split	1.31	0.86	0.390
	Day	Night	0.70	0.86	1.000
		Split	2.01	0.88	0.074
	Split	Night	-1.31	0.86	0.390
		Day	-2.01	0.88	0.074
2000	Night	Day	-0.77	0.85	1.000
		Split	1.44	0.86	0.287
	Day	Night	0.77	0.85	1.000
		Split	2.21	0.88	0.041
	Split	Night	-1.44	0.86	0.287
		Day	-2.21	0.88	0.041

Table 109. Leptin: Post-Hoc Comparisons Among Times (for Time Main Effect, Omnibus ANOVA, see Table 104)

(*I*) Time Code	(*J*) Time Code	Mean Difference (*I*-*J*)	Std. Error	p value
0900	1000	-0.18	0.88	1.000
	1200	-1.63	0.88	1.000
	1400	-3.33	0.88	0.004
	1600	-5.51	0.88	0.000
	1800	-8.08	0.88	0.000
	2000	-5.72	0.88	0.000
1000	0900	0.18	0.88	1.000
	1200	-1.44	0.88	1.000
	1400	-3.15	0.88	0.008
	1600	-5.33	0.88	0.000
	1800	-7.89	0.88	0.000
	2000	-5.54	0.88	0.000
1200	0900	1.63	0.88	1.000
	1000	1.44	0.88	1.000
	1400	-1.71	0.88	1.000
	1600	-3.89	0.88	0.000
	1800	-6.45	0.88	0.000
	2000	-4.10	0.88	0.000
1400	0900	3.33	0.88	0.004
	1000	3.15	0.88	0.008
	1200	1.71	0.88	1.000
	1600	-2.18	0.88	0.292
	1800	-4.74	0.89	0.000
	2000	-2.39	0.88	0.147
1600	0900	5.51	0.88	0.000
	1000	5.33	0.88	0.000
	1200	3.89	0.88	0.000
	1400	2.18	0.88	0.292
	1800	-2.56	0.88	0.081
	2000	-0.21	0.88	1.000
1800	0900	8.08	0.88	0.000
	1000	7.89	0.88	0.000
	1200	6.45	0.88	0.000
	1400	4.74	0.89	0.000
	1600	2.56	0.88	0.081
	2000	2.35	0.88	0.168
2000	0900	5.72	0.88	0.000
	1000	5.54	0.88	0.000
	1200	4.10	0.88	0.000

(*I*) Time Code	(*J*) Time Code	Mean Difference (*I*-*J*)	Std. Error	p value
	1400	2.39	0.88	0.147
	1600	0.21	0.88	1.000
	1800	-2.35	0.88	0.168

Table 110. Testosterone: Mixed-Effects ANOVA

Source	*df*	*F*	p value
Intercept	1, 50.84	676.41	0.000
Condition	2, 50.84	1.25	0.294
Week	1, 652.02	0.07	0.797
Time	6, 651.89	96.33	0.000
Condition × Week	2, 652.01	8.82	0.000
Condition × Time	12, 651.89	2.05	0.019
Condition × Week × Time	12, 651.88	0.88	0.567

Table 111. Testosterone: One-Way ANOVA for Week, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	10,431.38	1	10,431.38	1.25	0.265
	Within Groups	2,195,945.59	263	8,349.60	–	–
Day	Between Groups	15,744.08	1	15,744.08	0.67	0.413
	Within Groups	5,697,417.49	243	23,446.16	–	–
Split	Between Groups	13,527.44	1	13,527.44	1.21	0.272
	Within Groups	2,599,978.84	233	11,158.71	–	–

Table 112. Testosterone: One-Way ANOVAs for Condition, Conducted Separately for Each Week

Week	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Pre	Between Groups	77,477.77	2	38,738.88	2.55	0.080
	Within Groups	5,565,674.48	366	15,206.76	–	–
Post	Between Groups	304,498.93	2	152,249.46	11.53	0.000
	Within Groups	4,927,667.43	373	13,210.91	–	–

Table 113. Testosterone: Post-Hoc Comparisons for Each Condition by Week for Which There Was a Significant Condition Effect (see Table 112)

Week	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
Post	Night	Day	-61.78	14.32	0.000
		Split	-3.03	14.54	1.000
	Day	Night	61.78	14.32	0.000
		Split	58.75	14.75	0.000
	Split	Night	3.03	14.54	1.000
		Day	-58.75	14.75	0.000

Table 114. Testosterone: One-Way ANOVAs for Time, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	596,897.73	6	99,482.96	15.95	0.000
	Within Groups	1,609,479.23	258	6,238.29	–	–
Day	Between Groups	909,125.87	6	151,520.98	7.51	0.000
	Within Groups	4,804,035.69	238	20,185.02	–	–
Split	Between Groups	625,263.72	6	104,210.62	11.95	0.000
	Within Groups	1,988,242.57	228	8,720.36	–	–

Table 115. Testosterone: Post-Hoc Comparisons for Each Time by Condition

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I-J*)	Std. Error	p value
Night	0900	1000	104.63	18.24	0.000
		1200	126.03	18.12	0.000
		1400	141.71	18.12	0.000
		1600	147.84	18.12	0.000
		1800	84.40	18.12	0.000
		2000	130.16	18.12	0.000
	1000	0900	-104.6	18.24	0.000
		1200	21.39	18.24	1.000
		1400	37.08	18.24	0.906
		1600	43.21	18.24	0.390
		1800	-20.24	18.24	1.000
		2000	25.53	18.24	1.000
	1200	0900	-126.03	18.12	0.000
		1000	-21.39	18.24	1.000
		1400	15.68	18.12	1.000
		1600	21.82	18.12	1.000
		1800	-41.63	18.12	0.470
		2000	4.13	18.12	1.000
	1400	0900	-141.71	18.12	0.000
		1000	-37.08	18.24	0.906
		1200	-15.68	18.12	1.000
		1600	6.13	18.12	1.000
		1800	-57.32	18.12	0.037
		2000	-11.55	18.12	1.000
	1600	0900	-147.84	18.12	0.000
		1000	-43.21	18.24	0.390
		1200	-21.82	18.12	1.000
		1400	-6.13	18.12	1.000
		1800	-63.45	18.12	0.011
		2000	-17.68	18.12	1.000
	1800	0900	-84.40	18.12	0.000
		1000	20.24	18.24	1.000
		1200	41.63	18.12	0.470
		1400	57.316*	18.12	0.037
		1600	63.447*	18.12	0.011
		2000	45.76	18.12	0.255
	2000	0900	-130.16	18.12	0.000
		1000	-25.53	18.24	1.000
		1200	-4.13	18.12	1.000
		1400	11.55	18.12	1.000
		1600	17.68	18.12	1.000
		1800	-45.76	18.12	0.255
Day	0900	1000	119.94	33.49	0.009
		1200	143.28	33.98	0.001
		1400	166.12	33.73	0.000
		1600	174.44	33.73	0.000
		1800	98.16	33.98	0.089

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
		2000	194.01	33.73	0.000
	1000	0900	-119.94	33.49	0.009
		1200	23.33	33.98	1.000
		1400	46.18	33.73	1.000
		1600	54.49	33.73	1.000
		1800	-21.78	33.98	1.000
		2000	74.06	33.73	0.610
	1200	0900	-143.28	33.98	0.001
		1000	-23.33	33.98	1.000
		1400	22.84	34.21	1.000
		1600	31.16	34.21	1.000
		1800	-45.12	34.46	1.000
		2000	50.73	34.21	1.000
	1400	0900	-166.121*	33.73	0.000
		1000	-46.18	33.73	1.000
		1200	-22.84	34.21	1.000
		1600	8.31	33.96	1.000
		1800	-67.96	34.21	1.000
		2000	27.89	33.96	1.000
	1600	0900	-174.435*	33.73	0.000
		1000	-54.49	33.73	1.000
		1200	-31.16	34.21	1.000
		1400	-8.31	33.96	1.000
		1800	-76.28	34.21	0.561
		2000	19.57	33.96	1.000
	1800	0900	-98.16	33.98	0.089
		1000	21.78	33.98	1.000
		1200	45.12	34.46	1.000
		1400	67.96	34.21	1.000
		1600	76.28	34.21	0.561
		2000	95.85	34.21	0.116
	2000	0900	-194.006*	33.73	0.000
		1000	-74.06	33.73	0.610
		1200	-50.73	34.21	1.000
		1400	-27.89	33.96	1.000
		1600	-19.57	33.96	1.000
		1800	-95.85	34.21	0.116
Split	0900	1000	109.643*	22.82	0.000
		1200	143.424*	22.99	0.000
		1400	160.791*	22.82	0.000
		1600	156.496*	22.82	0.000
		1800	126.091*	22.99	0.000
		2000	147.349*	22.82	0.000
	1000	0900	-109.643*	22.82	0.000
		1200	33.78	22.82	1.000
		1400	51.15	22.65	0.522
		1600	46.85	22.65	0.834
		1800	16.45	22.82	1.000

Condition	(*I*) Time	(*J*) Time	Mean Difference (*I-J*)	Std. Error	p value
		2000	37.71	22.65	1.000
	1200	0900	-143.424*	22.99	0.000
		1000	-33.78	22.82	1.000
		1400	17.37	22.82	1.000
		1600	13.07	22.82	1.000
		1800	-17.33	22.99	1.000
		2000	3.93	22.82	1.000
	1400	0900	-160.791*	22.82	0.000
		1000	-51.15	22.65	0.522
		1200	-17.37	22.82	1.000
		1600	-4.29	22.65	1.000
		1800	-34.70	22.82	1.000
		2000	-13.44	22.65	1.000
	1600	0900	-156.496*	22.82	0.000
		1000	-46.85	22.65	0.834
		1200	-13.07	22.82	1.000
		1400	4.29	22.65	1.000
		1800	-30.41	22.82	1.000
		2000	-9.15	22.65	1.000
	1800	0900	-126.091*	22.99	0.000
		1000	-16.45	22.82	1.000
		1200	17.33	22.99	1.000
		1400	34.70	22.82	1.000
		1600	30.41	22.82	1.000
		2000	21.26	22.82	1.000
	2000	0900	-147.349*	22.82	0.000
		1000	-37.71	22.65	1.000
		1200	-3.93	22.82	1.000
		1400	13.44	22.65	1.000
		1600	9.15	22.65	1.000
		1800	-21.26	22.82	1.000

Table 116. Testosterone: One-Way ANOVAs for Condition, Conducted Separately for Each Time

Time	Source	Sum of Squares	*df*	Mean Square	*F*	p value
0900	Between Groups	95,477.56	2	47,738.78	2.72	0.071
	Within Groups	1,828,395.00	104	17,580.72	–	–
1000	Between Groups	58,188.13	2	29,094.07	2.58	0.080
	Within Groups	1,171,663.01	104	11,265.99	–	–
1200	Between Groups	61,358.91	2	30,679.46	3.27	0.042
	Within Groups	956,464.08	102	9,377.10	–	–
1400	Between Groups	48,170.20	2	24,085.09	2.52	0.085
	Within Groups	993,452.96	104	9,552.43	–	–
1600	Between Groups	36,633.15	2	18,316.57	1.91	0.153
	Within Groups	997,525.28	104	9,591.59	–	–
1800	Between Groups	109,383.28	2	54,691.64	3.65	0.029
	Within Groups	1,528,193.26	102	14,982.28	–	–
2000	Between Groups	734.82	2	367.41	0.04	0.960
	Within Groups	926,063.91	104	8,904.46	–	–

Table 117. Testosterone: Post-Hoc Comparisons for Each Condition by Time for Which There Was a Significant Condition Effect (see Table 116)

Time	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p *v*alue
1200	Night	Day	-52.947	22.860	0.068
		Split	-2.902	23.042	1.000
	Day	Night	52.947	22.860	0.068
		Split	50.045	23.663	0.111
	Split	Night	2.902	23.042	1.000
		Day	-50.045	23.663	0.111
1800	Night	Day	-56.433	28.895	0.161
		Split	21.396	29.125	1.000
	Day	Night	56.433	28.895	0.161
		Split	77.830*	29.911	0.032
	Split	Night	-21.396	29.125	1.000
		Day	-77.830*	29.911	0.032

Table 118. Testosterone: Post-Hoc Comparisons Among Times (for Time Main Effect, Omnibus ANOVA, see Table 110)

(*I*) Time	(*J*) Time	Mean Difference (*I*-*J*)	Std. Error	p value
0900	1000	110.95	8.26	0.000
	1200	133.51	8.30	0.000
	1400	158.57	8.26	0.000
	1600	162.06	8.26	0.000
	1800	103.82	8.31	0.000
	2000	159.55	8.26	0.000
1000	0900	-110.95	8.26	0.000
	1200	22.56	8.30	0.141
	1400	47.62	8.25	0.000
	1600	51.10	8.25	0.000
	1800	-7.13	8.30	1.000
	2000	48.59	8.25	0.000
1200	0900	-133.51	8.30	0.000
	1000	-22.56	8.30	0.141
	1400	25.06	8.30	0.055
	1600	28.54	8.30	0.013
	1800	-29.69	8.35	0.008
	2000	26.03	8.30	0.038
1400	0900	-158.57	8.26	0.000
	1000	-47.62	8.25	0.000
	1200	-25.06	8.30	0.055
	1600	3.49	8.25	1.000
	1800	-54.75	8.30	0.000
	2000	0.98	8.25	1.000
1600	0900	-162.05	8.26	0.000
	1000	-51.13	8.25	0.000
	1200	-28.54	8.30	0.013
	1400	-3.49	8.25	1.000
	1800	-58.23	8.30	0.000
	2000	-2.51	8.25	1.000
1800	0900	-103.82	8.31	0.000
	1000	7.13	8.30	1.000
	1200	29.69	8.35	0.008
	1400	54.75	8.30	0.000
	1600	58.23	8.30	0.000
	2000	55.73	8.30	0.000
2000	0900	-159.55	8.26	0.000
	1000	-48.60	8.25	0.000
	1200	-26.04	8.30	0.038
	1400	-0.98	8.25	1.000
	1600	2.51	8.25	1.000
	1800	-55.73	8.30	0.000

Table 119. Systolic BP: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	463.89	306.10	2,32	1.52	0.24
Day	76.75	94.62	3.6, 115.2	0.81	0.51
Condition × Day	151.48	94.62	7.2, 115.2	1.60	0.14

Table 120. Diastolic BP: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	350.99	183.32	2,31	1.92	0.16
Day	333.17	56.92	3.6, 111.8	5.85	0.000
Condition × Day	238.352	56.92	7.2, 111.8	4.19	0.003

Table 121. Diastolic BP: One-Way ANOVAs for Workday, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	307.22	4	76.81	1.19	0.322
	Within Groups	5,431.77	84	64.66	–	–
Day	Between Groups	137.81	4	34.45	0.51	0.729
	Within Groups	5,408.59	80	67.61	–	–
Split	Between Groups	1,979.16	4	494.79	5.23	0.001
	Within Groups	6,054.68	64	94.60	–	–

Table 122. Diastolic BP: Post-Hoc Comparisons Among Workdays by Condition for Which There Was a Significant Workday Effect (see Table 121)

Condition	(*I*) Workday	(*J*) Workday	Mean Difference (*I*-*J*)	Std. Error	p value
Split	1	2	5.30	3.77	1.000
		3	5.71	3.71	1.000
		4	-9.62	4.17	0.242
		5	5.60	3.71	1.000
	2	1	-5.30	3.77	1.000
		3	0.41	3.50	1.000
		4	-14.92	3.97	0.004
		5	0.29	3.50	1.000
	3	1	-5.71	3.71	1.000
		2	-0.41	3.50	1.000
		4	-15.33	3.92	0.002
		5	-0.11	3.44	1.000
	4	1	9.62	4.17	0.242
		2	14.92	3.97	0.004
		3	15.33	3.92	0.002
		5	15.22	3.92	0.002
	5	1	-5.60	3.71	1.000
		2	-0.30	3.50	1.000
		3	0.11	3.44	1.000
		4	-15.22	3.92	0.002

Table 123. Diastolic BP: One-Way ANOVAs for Condition, Conducted Separately for Each Workday

Workday	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	400.44	2	200.22	2.49	0.094
	Within Groups	3,451.40	43	80.27	–	–
2	Between Groups	246.92	2	123.45	1.76	0.184
	Within Groups	3,086.19	44	70.14	–	–
3	Between Groups	458.96	2	229.48	3.15	0.052
	Within Groups	3,495.05	48	72.81	–	–
4	Between Groups	1,724.60	2	862.30	11.74	0.000
	Within Groups	3,231.12	44	73.44	–	–
5	Between Groups	147.16	2	73.58	0.99	0.378
	Within Groups	3,631.27	49	74.11	–	–

Table 124. Diastolic BP: Post-Hoc Comparisons Among Workdays by Condition for Which There Was a Significant Condition Effect (see Table 123)

Workday	(*I*) Condition	(*J*) Condition	Mean Difference (*I-J*)	Std. Error	p value
3	Night	Day	-5.29	2.89	0.219
		Split	1.70	2.97	1.000
	Day	Night	5.29	2.89	0.219
		Split	6.99	2.93	0.063
	Split	Night	-1.70	2.97	1.000
		Day	-6.99	2.93	0.063
4	Night	Day	-8.39	2.82	0.014
		Split	-15.76	3.35	0.000
	Day	Night	8.39	2.82	0.014
		Split	-7.36	3.38	0.104
	Split	Night	15.76	3.35	0.000
		Day	7.36	3.38	0.104

Table 125. Diastolic BP: Post-Hoc Comparisons Among Workdays (for Workday Main Effect Omnibus ANOVA, see Table 120)

(*I*) Workday	(*J*) Workday	Mean Difference (*I-J*)	Std. Error	p value
1	2	-1.980	1.907	1.000
	3	-0.900	2.017	1.000
	4	-7.703*	1.817	0.002
	5	-0.055	1.782	1.000
2	1	1.980	1.907	1.000
	3	1.080	1.561	1.000
	4	-5.723	1.998	0.074
	5	1.925	1.842	1.000
3	1	0.900	2.017	1.000
	2	-1.080	1.561	1.000
	4	-6.803*	2.123	0.031
	5	0.845	1.947	1.000
4	1	7.703*	1.817	0.002
	2	5.723	1.998	0.074
	3	6.803*	2.123	0.031
	5	7.648*	1.758	0.001
5	1	0.055	1.782	1.000
	2	-1.925	1.842	1.000
	3	-0.845	1.947	1.000
	4	-7.648*	1.758	0.001

Table 126. MAP Score: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	543.94	234.55	2, 32	2.32	0.12
Day	1,517.69	164.23	2.3, 71.2	9.241	0.000
Condition × Day	975.743	164.23	4.5, 71.2	5.941	0.000

Table 127. MAP Score: One-Way ANOVAs for Workday, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	Sig.
Night	Between Groups	302.76	4	75.69	1.11	0.359
	Within Groups	5,745.11	84	68.39	–	–
Day	Between Groups	81.42	4	20.36	0.28	0.887
	Within Groups	5,730.83	80	71.64	–	–
Spit	Between Groups	1,451.35	4	362.84	5.16	0.001
	Within Groups	4,502.91	64	70.36	–	–

Table 128. MAP Score: Post-Hoc Comparisons Among Workdays by Condition for Which There Was a Significant Workday Effect (see Table 127)

Condition	(*I*) Workday	(*J*) Workday	Mean Difference (*I-J*)	Std. Error	p value
Split	1	2	3.56	3.25	1.000
		3	3.47	3.20	1.000
		4	-9.58	3.59	0.097
		5	3.78	3.20	1.000
	2	1	-3.56	3.25	1.000
		3	-0.09	3.01	1.000
		4	-13.14	3.42	0.003
		5	0.22	3.01	1.000
	3	1	-3.47	3.20	1.000
		2	0.09	3.01	1.000
		4	-13.05	3.38	0.003
		5	0.31	2.97	1.000
	4	1	9.58	3.59	0.097
		2	13.14	3.42	0.003
		3	13.06	3.38	0.003
		5	13.36	3.38	0.002
	5	1	-3.78	3.20	1.000
		2	-0.22	3.01	1.000
		3	-0.31	2.97	1.000
		4	-13.36	3.38	0.002

Table 129. MAP Score: One-Way ANOVAs for Condition, Conducted Separately for Each Workday

Day	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	592.38	2	296.19	4.06	0.024
	Within Groups	3,136.74	43	72.95	–	–
2	Between Groups	190.80	2	95.40	1.66	0.201
	Within Groups	2,525.27	44	57.39	–	–
3	Between Groups	320.08	2	160.04	2.26	0.116
	Within Groups	3,404.83	48	70.93	–	–
4	Between Groups	1,330.60	2	665.30	9.20	0.000
	Within Groups	3,182.42	44	72.33	–	–
5	Between Groups	122.00	2	61.00	0.80	0.454
	Within Groups	3,729.59	49	76.11	–	–

Table 130. MAP Score: Post-Hoc Comparisons Among Conditions by Workday for Which There Was a Significant Condition Effect (see Table 129)

Workday	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
1	Night	Day	-8.15	2.93	0.024
		Split	-5.68	3.18	0.244
	Day	Night	8.15	2.93	0.024
		Split	2.46	3.26	1.000
	Split	Night	5.68	3.18	0.244
		Day	-2.45	3.26	1.000
4	Night	Day	-7.02	2.79	0.048
		Split	-13.96	3.32	0.000
	Day	Night	7.02	2.79	0.048
		Split	-6.94	3.35	0.133
	Split	Night	13.96	3.32	0.000
		Day	6.94	3.35	0.133

Table 131. MAP Score: Post-Hoc Comparisons Among Workdays (for Workday Main Effect, Omnibus ANOVA, see Table 126)

(*I*) Workday	(*J*) Workday	Mean Difference (*I*-*J*)	Std. Error	p value
1	2	-1.21	1.76	1.000
	3	-8.65	1.92	0.001
	4	-9.28	1.78	0.000
	5	2.59	3.31	1.000
2	1	1.21	1.76	1.000
	3	-7.44	1.58	0.000
	4	-8.07	1.61	0.000
	5	3.79	3.32	1.000
3	1	8.65	1.92	0.001
	2	7.44	1.58	0.000
	4	-0.63	1.77	1.000
	5	11.24	3.39	0.023
4	1	9.28	1.78	0.000
	2	8.07	1.61	0.000
	3	0.63	1.77	1.000
	5	11.87	3.22	0.008
5	1	-2.59	3.31	1.000
	2	-3.80	3.32	1.000
	3	-11.24	3.39	0.023
	4	-11.87	3.22	0.008

Table 132. Pulse Rate: Omnibus ANOVA

Source	MS Effect	MS Error	*df*	*F*	p value
Condition	282.84	313.21	2, 31	0.90	0.42
Day	53.37	66.71	3.6, 110.6	0.80	0.52
Condition × Day	248.14	66.71	7.1, 110.6	3.72	0.001

Table 133. Pulse Rate: One-Way ANOVAs for Workday, Conducted Separately for Each Condition

Condition	Source	Sum of Squares	*df*	Mean Square	*F*	p value
Night	Between Groups	1,042.37	4	260.59	3.20	0.017
	Within Groups	6,832.17	84	81.34	–	–
Day	Between Groups	1,228.63	4	307.16	2.58	0.044
	Within Groups	9,528.70	80	119.11	–	–
Split	Between Groups	184.17	4	46.04	0.44	0.781
	Within Groups	6,725.52	64	105.09	–	–

Table 134. Pulse Rate: Post-Hoc Comparisons for Each Workday by Condition for Which There Was a Significant Workday Effect (see Table 133)

Condition	(*I*) Workday	(*J*) Workday	Mean Difference (*I*-*J*)	Std. Error	p value
Night	1	2	-6.17	3.05	0.462
		3	-5.05	3.05	1.000
		4	-0.10	2.97	1.000
		5	-8.51	3.01	0.058
	2	1	6.17	3.05	0.462
		3	1.12	3.09	1.000
		4	6.08	3.01	0.468
		5	-2.34	3.05	1.000
	3	1	5.05	3.05	1.000
		2	-1.12	3.09	1.000
		4	4.96	3.01	1.000
		5	-3.46	3.05	1.000
	4	1	0.10	2.97	1.000
		2	-6.08	3.01	0.468
		3	-4.96	3.01	1.000
		5	-8.42	2.97	0.057
	5	1	8.51	3.01	0.058
		2	2.34	3.05	1.000
		3	3.46	3.05	1.000
		4	8.42	2.97	0.057
Day	1	2	9.19	3.92	0.216
		3	8.99	3.75	0.188
		4	3.88	3.75	1.000
		5	9.91	3.75	0.099
	2	1	-9.19	3.92	0.216
		3	-0.20	3.82	1.000
		4	-5.31	3.82	1.000
		5	0.71	3.82	1.000
	3	1	-8.99	3.75	0.188
		2	0.20	3.82	1.000
		4	-5.11	3.64	1.000
		5	0.91	3.64	1.000
	4	1	-3.88	3.75	1.000
		2	5.31	3.82	1.000
		3	5.11	3.64	1.000
		5	6.02	3.64	1.000
	5	1	-9.91	3.75	0.099
		2	-0.71	3.82	1.000
		3	-0.91	3.64	1.000
		4	-6.02	3.64	1.000

Table 135. Pulse Rate: One-Way ANOVAs for Condition, Conducted Separately by Each Workday

Workday	Source	Sum of Squares	*df*	Mean Square	*F*	p value
1	Between Groups	1,869.27	2	934.64	10.45	0.000
	Within Groups	3,844.95	43	89.42	–	–
2	Between Groups	95.38	2	47.69	0.45	0.640
	Within Groups	4,661.83	44	105.95	–	–
3	Between Groups	161.54	2	80.77	0.78	0.464
	Within Groups	4,968.94	48	103.52	–	–
4	Between Groups	766.47	2	383.23	3.91	0.027
	Within Groups	4,309.39	44	97.94	–	–
5	Between Groups	699.57	2	349.79	3.23	0.048
	Within Groups	5,301.29	49	108.19	–	–

Table 136. Pulse Rate: Post-Hoc Comparisons for Each Condition by Workday for Which There Was a Significant Condition Effect (see Table 135)

Workday	(*I*) Condition	(*J*) Condition	Mean Difference (*I*-*J*)	Std. Error	p value
1	Night	Day	-12.53	3.25	0.001
		Split	1.92	3.52	1.000
	Day	Night	12.53*	3.25	0.001
		Split	14.44	3.61	0.001
	Split	Night	-1.92	3.52	1.000
		Day	-14.44	3.61	0.001
4	Night	Day	-8.543	3.26	0.036
		Split	-0.74	3.87	1.000
	Day	Night	8.543	3.26	0.036
		Split	7.80	3.90	0.155
	Split	Night	0.74	3.87	1.000
		Day	-7.80	3.90	0.155
5	Night	Day	5.90	3.47	0.286
		Split	8.86	3.57	0.050
	Day	Night	-5.90	3.47	0.286
		Split	2.96	3.57	1.000
	Split	Night	-8.86	3.57	0.050
		Day	-2.96	3.57	1.000

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