Comparison of Two Watch Schedules for Personnel at the White House Military Office President's Emergency Operations Center

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Objective: The aim of this study was to assess effectiveness of an alternative, 24-hr-on/72-hr-off watchstanding schedule on sleep and morale of personnel assigned to the President's Emergency Operations Center (PEOC).

Background: As part of the White House Military Office, PEOC personnel historically worked a 12-hr "Panama" watch schedule. Personnel reported experiencing chronic insufficient and disrupted sleep patterns and sought advice for improving their watchstanding schedule.

Method: Participants (N = 14 active-duty military members, ages 29 to 42 years) completed the Profile of Mood State (POMS) three times: before, during, and after switching to the alternative schedule with 5-hr sleep periods built into their workday. Participants completed a poststudy questionnaire to assess individual schedule preferences. Sleep was measured actigraphically, supplemented by activity logs.

Results: As indicated by POMS scores, mood improved significantly on the new schedule. Although average total sleep amount did not change substantively, the timing of sleep was more consistent on the new schedule, resulting in better sleep hygiene. PEOC personnel overwhelmingly preferred the new schedule, reporting not only that they felt more rested but that the new schedule was more conducive to the demands of family life.

Conclusions: Demands of family life and time spent commuting were found to be critical factors for acceptance of the alternative schedule. This new schedule will be most effective if personnel adhere to the scheduled rest periods assigned during their 24-hr duty.

Application: A successful schedule should avoid conflicts between social life and operational demands. Results may lead to changes in the work schedules of other departments with similar 24/7 responsibilities.

Keywords: shiftwork, sleep deprivation, fatigue, continuous operations, Profile of Mood State

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INTRODUCTION

Although an integral part of modern society, shift work is an abnormal activity for humans. Human physiological processes are dictated by the circadian clock such that sleep and its associated functions occur primarily at night, whereas wakefulness is promoted during the biological day (Dijk & Czeisler, 1995; Dijk & Edgar, 1999; Drake & Wright, 2011). Shift work impacts normal physiological functions and performance through circadian desynchrony, that is, the disruption of naturally occurring, internal circadian rhythms (Colquhon, Blake, & Edwards, 1969a) and disturbances in the sleep/ wakefulness cycle (Åkerstedt, 2003). Adaptation of circadian diurnal rhythms to nocturnal rhythms may take at least a week (Monk, 1986), although some researchers have reported this adjustment taking 12 or more days (Colquhon, Blake, & Edwards, 1969b; Hockey, 1983).

Shift work is associated with chronic and acute sleep deprivation, fragmented sleep episodes, and elevated levels of fatigue (Arendt, Middleton, Williams, Francis, & Luke, 2006). Shifts greater than 12 hr in length have been shown to have a negative effect on the sleep afforded to shift workers, leading to increased sleepiness (Åkerstedt & Wright, 2009; Sallinen & Kecklund, 2010). As a result of excessive sleepiness, shift work can lead to vigilance impairments that are equivalent to performance of individuals at 0.04% to 0.05% blood alcohol concentration (Arnedt, Owens, Crouch, Stahl, & Carskadon, 2005). In addition, shift work has been associated with significant challenges for maintaining a healthy work–life balance (Albertsen, Rafnsdóttir, Grimsmo, Tómasson, & Kauppinen, 2008).

Research findings also suggest that shift work is associated with the development of specific health problems. For example, shift work is associated

with increased incidence of obesity, gastrointestinal disorders, cardiovascular heart disease, compromised pregnancy outcome, breast cancer, prostate cancer, metabolic syndrome, and diabetes (Drake & Wright, 2011; Folkard & Tucker, 2003; Harrington, 2001; Knutsson, 2003; Wang, Armstrong, Cairns, Key, & Travis, 2011). Of particular note, the International Agency for Research on Cancer has recently classified "shift work that involves circadian disruption" as a probable human carcinogen (Stevens et al., 2011).

Given these negative outcomes, it is alarming to see that rates of shift work are increasing worldwide. According to the International Labour Organization, more than two and a half billion people are officially recognized as shift workers (IARC Monographs Working Group on the Evaluation of Carcinogenic Risks to Humans, 2010). Shift work is common in the European Union (EU), involving around 17% of the total work population. However, there are large variations in the percentage of shift workers among EU member states, with rates of shift work ranging from 6.4% to 30% of the total workforce.

The U.S. Bureau of Labor Statistics (BLS) collects data on the prevalence of shift work in the U.S. population. In 2005, BLS reported that for calendar year 2004, almost 15% of full-time salaried personnel were shift workers (IARC Monographs Working Group on the Evaluation of Carcinogenic Risks to Humans, 2010). They also found that rates of shift work varied according to gender (more common for males than for females) and age (more common in younger workers than older workers) and is most common in service industry workers (32% overall). The prevalence of shift work in the protective service industry (which includes police, firefighters, and security guards) was 50.4%, followed by the food preparation and serving industry at 49.4%. Shift work is pervasive in military populations, which, when deployed, operate 24/7, often without weekends or holidays for rest and recovery.

Problem Statement and Study Objective

The President's Emergency Operations Center (PEOC) serves as the primary command-and-control center for the White House Military Office (WHMO). The WHMO ensures uninterrupted functioning of the presidency of the United States by providing operational control of Department of Defense resources and by integrating its efforts with those of other support entities. The PEOC provides situation awareness to the director of WHMO, the military aides to the president and vice president, and is also responsible for developing, implementing, and maintaining presidential and vice presidential operational plans. The nature of its work requires that the PEOC be staffed continuously. PEOC watchstanders execute emergency procedures, as well as activate, direct, and continuously monitor critical strategic assets that support the president and vice president of the United States. PEOC personnel must be ready to respond immediately to complex and critically important events.

The PEOC recently conducted an organizational research effort under the supervision of the Naval Postgraduate School (NPS) to assess an alternative watchstanding schedule that sought to address chronic insufficient sleep patterns experienced by their personnel. Anecdotal reports indicated that personnel assigned to work in the PEOC were not adapting to the circadian challenges posed by the "Panama" schedule to which they had been assigned for several months (the Panama schedule is described later). Their schedules were further complicated by lengthy commutes to and from the worksite to their homes, adding hours to their workday. Working the night shift was especially taxing for PEOC personnel, who reported increased levels of fatigue and problems getting adequate sleep.

The aim for this study was to monitor the sleep patterns of military shift workers over a period of 2 months following the implementation of the new schedule in order to determine if there was an improvement in the work schedule and quality of life. The implications of this study are far-reaching and could potentially result in a widescale revamping of the scheduling framework for military shift workers for the entire WHMO. The schedule may also be appropriate for consideration by other round-the-clock professions, such as firefighters, who live and work in communities in which commuting time plays a major role. From a human factors and macroergonomic perspective, altering the timing of the work and rest schedule in such a major way provides an innovative solution to addressing daily

Schedule	Teams	Section	M 1	T 2	W 3	T 4	F 5	S 6	S 7	M 8	T 9	W 10	T 11	F 12	S 13	S 14	M 15	T 16	W 17	T 18	F 19	S 20	S 21	M 22	T 23	W 24	T 25	F 26	S 27	S 28
Panama	1		N	N			N	N	N			N	N				D	D			D	D	D			D	D			
	2				D	D				N	N			N	N	N			N	N				D	D			D	D	D
	3		D	D			D	D	D			D	D				N	N			N	N	N			N	N			
	4				N	N				D	D			D	D	D			D	D				N	N			N	N	N
NEW	1	1		T/A	24				24			T/A	24				24			T/A	24				24			T/A	24	
		2		T/A		24				24		T/A		24				24		T/A		24				24		T/A		24
	2	3	24			T/A	24			T/A	24				24			T/A	24				24			T/A	24			
		4		24			T/A	24			T/A	24				24			T/A	24				24			T/A	24		

Figure 1. Two schedules used in the study: the Panama schedule and the revised 24/72 watchstanding schedule.

commute time and family demands. In addition, many of the typical nighttime tasks could potentially be shifted to 9-to-5 day workers, reducing the burden on the night crew.

METHOD

Schedule Descriptions

Originally, the PEOC used a schedule known as a Panama schedule, a slow rotating system of four teams covering two 12-hr shifts each day over a 28-day period (see Figure 1). Day shifts started at approximately 0600 and ended at approximately 1800; the night shift covered the remaining 12 hr of the day. Teams worked either day or night shifts for a 2-week period before transitioning to the other shift. For example, following a 3-day weekend, one team would work two consecutive 12-hr night shifts, followed by 2 consecutive days off duty, and three more consecutive 12-hr night shifts. After 2 more days off, the team would again work two consecutive night shifts before 3 days off and then transitioning to day shifts for the pattern to be repeated. Complete 24-hr coverage was maintained by the four-team arrangement shown in Figure 1. A detailed description of the Panama schedule and comparison with other shift schedules is provided by Miller (2006).

The newly designed schedule has 24-hr shifts starting around 0600 and ending the next day around 0600. Personnel work one 24-hr shift and then have 3 days off (24/72). Depending on scheduling requirements and the need to balance operational demands with personal requests, the average time off can be more or less than 3 days. For example, an individual may have 3 days off before working a 24-hr shift, to be followed by only 2 days off. Following this shorter 2-day off period, the individual may then have 4 days off following a 24-hr shift. When this model is extended, it works out to an average of 3 days off between shifts. While on shift, members are allowed 5 hr of sleep per night as operational requirements dictate. This period of scheduled sleep takes place sometime between 1900 and 0500. Members rotate their sleep time throughout the watch team so as to maintain the required manning level.

Additionally, in order to have PEOC members reengage with the wider WHMO mission, training and administrative (T/A) days have been added into the schedule as additional workdays, which further reduces the average time off between 24-hr shifts to less than 3 days. Each team is required to support between two and four T/A days per month. When it is implemented, a typical T/A day includes 3 to 5 hr of work, considerably less time than a regular workday.

Figure 1, above, shows the coverage provided by the two schedules. On the Panama schedule, *D* denotes a 12-hr day shift, whereas *N* denotes a 12-hr night shift. As can be seen in the diagram of the new schedule, each 24-hr work period is followed by 48 to 72 hr off. Annually, the revised schedule provides 65 weekend days off compared to only 52 weekend days off on the original Panama schedule.

Participants

Fourteen active-duty military members serving in the PEOC of the WHMO volunteered to participate in the study (13 males, 1 female; age 32.8 ± 3.8 years; service 13.3 ± 4.6 years).

All teams from both the old and new schedules were represented in the study sample. However, participants were not able to rotate through all sections of both schedules. Consequently, this issue resulted in uneven cell sizes for the statistical analysis.

Equipment

Actigraphic estimates of crew members' sleep were obtained using the Philips Respironics Spectrum Actiwatch. Actigraphic data were scored using Actiware software Version 6.0.0 (Phillips Respironics, Bend, OR). The medium sensitivity threshold (40 counts per epoch) was used with 10 immobile minutes the criterion for sleep onset and sleep end (all values are set to the default for this software). The combination of Phillips Respironics Actiwatches and the Actiware software has been validated against polysomnographic results for detecting sleep/wake patterns (Meltzer, Walsh, Traylor, & Westin, 2012; Rupp & Balkin, 2011).

Participants were instructed to wear the wrist activity monitors (WAMs) on their nondominant hand at all times of the day and night during the study period. They completed a daily activity log to indicate their activities in 15-min increments, to include sleep and naps during the study. Activities were classified in six categories: sleep (S), standing watch (W), commuting (C), private time (P), meals (E), and working out (PT).

To measure mood states and changes in mood, participants filled out the Profile of Mood States (POMS; McNair, Lorr, & Droppelman, 1971). The POMS is a standardized 65-item inventory originally developed to assess mood state in psychiatric populations. The questionnaire assesses the dimensions of the mood construct using six subscales: Anger-Hostility (range 0 to 48, 12 items,), Confusion-Bewilderment (range 0 to 28, 7 items), Depression (range 0 to 60, 15 items), Fatigue (range 0 to 28, 7 items), Tension-Anxiety (range 0 to 36, 9 items), and Vigor-Activity (range 0 to 32, 8 items). The total mood disturbance (TMD) score ranges from 0 to 200 and is computed by adding together all the subscales except Vigor, which is subtracted to obtain the final TMD score. The POMS was administered using the instruction, "Describe how you felt during the past 2 weeks." Positive mood has been associated with better within-team communication behaviors and enhanced team awareness (Pfaff, 2012).

The posttest survey included the Epworth Sleepiness Scale (ESS; Johns, 1991) and six questions in which participants assessed and compared the two schedules. Four questions required a simple answer ("Do you feel better rested?" "Do you feel more productive?" "Has your quality of sleep, and life overall, improved?" "Do you feel this change has been an improvement?"), and two were open-ended ("Which schedule do you prefer and why?" "Provide any miscellaneous comments you might have regarding the overall sleep study").

The Fatigue Avoidance Scheduling Tool (FAST), which is based on the Sleep and Fatigue Task Effectiveness (SAFTE) model, was used to estimate predicted effectiveness of the old and the new shift schedules (Hursh et al., 2004). Predicted effectiveness is a measure of cognitive performance, ranging from 100% (best) to 0% (worst). According to the documentation provided with the FAST program, predicted effectiveness between 100% and 90%, as noted in the green zone on the FAST graph, is the expected range of performance for an individual during a normal daytime duty day following an 8-hr period of excellent sleep at night. In the SAFTE model, sleep regulation depends on sleep duration, hours of wakefulness, sleep debt, circadian process, and sleep quality. Predicted effectiveness is affected by the recent sleep history, the circadian process, and sleep inertia (Hursh et al., 2004).

In advance of the data collection, FAST was used to assess the average predicted effectiveness in the Panama and the new schedule. Although the new 24/72 schedule was not ideal, the FAST predicted that effectiveness derived from the new schedule was considerably better than the predicted effectiveness from the Panama schedule (90% vs. 83%).

Procedures

The study protocol was approved by the NPS Institutional Review Board, and participants provided written informed consent before enrolling in the study. The researchers initially

gathered information from watchstanders about problems in the old work schedule. That information was considered along with the work demands of a shift, and a new work schedule was proposed. These new schedules were vetted with Steve Hursh and Lauren Waggoner (personal communication, September 20, 2013). Data collection occurred between December 2013 and February 2014 at the PEOC of the WHMO. Participants had been working the Panama schedule for several months before the data collection commenced. During the first phase of the study, from December 12 to 22, participants were on the original Panama watch schedule, working either day or night shifts for 2 weeks before rotating to the other shift condition. After December 23, all participants transitioned to the new watch schedule, in which they have remained. After enrolling in the study, participants completed a demographic questionnaire, including morningness–eveningness preference. Participants were issued Actiwatches and were asked to fill out daily activity logs in 15-min increments to indicate how they spent each day.

The POMS was completed three times: at the beginning of participation, when participants were on the original Panama schedule (approximately December 15); in the middle of the study, when participants had been on the new schedule for approximately 10 ± 5.2 days; and at the end of the data collection, when participants had been on the new schedule for approximately 31 ± 7.8 days. After using the new schedule for approximately two months, participants completed the posttest questionnaire.

Analytical Approach

All variables underwent descriptive statistical analysis to identify anomalous entries and to calculate demographic characteristics. Actigraphic recordings were used to determine bedtime, wakeup time, and sleep episode duration. These data were entered into a Microsoft Excel spreadsheet. Statistical analysis was conducted with JMP statistical software (JMP Pro 10; SAS Institute, Cary, NC). Average time in bed (TIB) and sleep amounts were calculated from actigraphic data by day and participant. Sleep episode duration and bedtime/wakeup time were

derived from the actigraphic recordings and were verified by the self-reported activity logs. After verifying the bedtime and wakeup times, Respironics Actiware software Version 6 was used to calculate TIB and sleep duration.

Two individuals were excluded from the sleep analysis because their actigraphic data were missing. In addition, some participants occasionally forgot to wear the actigraphs; these off-wrist periods were imputed using the average of nonmissing rest intervals calculated for each crew member. From the 787 rest intervals, 52 (6.6%) were imputed from the sleep logs. The amount of rest and sleep for each day was calculated from 0000 to 2359.

After assessing and rejecting the data for normality with the Shapiro-Wilk W test, comparisons were based on the nonparametric matched pairs Wilcoxon rank sum test (*JMP Statistics and Graphics Guide, Release 7*, 2007). An alpha level of .05 was used to determine statistical significance. For multiple comparisons, statistical significance was assessed using the Benjamini-Hochberg false discovery rate (BH-FDR) controlling procedure (Benjamini & Hochberg, 1995).

RESULTS

Due to missing data for two individuals, sleep analysis was based on 12 participants (11 males, 1 female), who were on average 31.9 ± 2.8 years old with 11.8 ± 3.7 years of service. Over the entire data collection period, participants slept an average of 7.29 ± 0.64 hr daily. We calculated each participant's average amount of daily sleep for periods when each participant was on the morning shift of the original schedule, the night shift of the original schedule, and the new schedule. In all cases, the period included all the days for the same shifts and its corresponding days off. Pairwise comparisons showed that when participants worked on the new schedule, they slept more (7.20 ± 0.64 hr daily) than when they worked the morning shift of the original schedule (6.91 ± 0.58 hr; Wilcoxon signed rank test, $S = 9.5$, $p = .062$) but somewhat less daily sleep than when they worked the night shift of the Panama schedule (7.37 ± 0.64 hr; $S = 9.0$, $p = .156$). These results are shown in Figure 2.
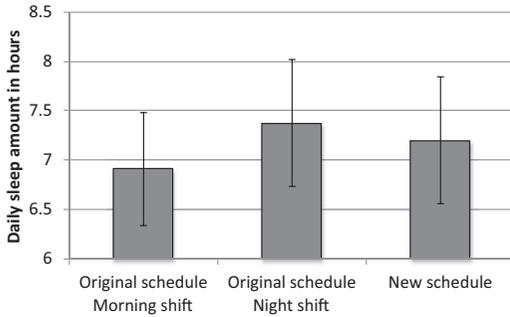
Figure 2. Daily sleep amount in hours by schedule and shift. Vertical bars represent one standard deviation.

It should be noted that the timing of sleep varied greatly during the days on duty. On the original schedule, participants working the night shift were not allowed to sleep while on duty. Therefore, their sleep occurred only at home, before going in for duty, or on the day following duty. On the new schedule, participants were deliberately scheduled to sleep during one of two 5-hr periods while on 24-hr duty. All study participants used these periods to sleep while on 24-hr duty, although compliance with this guidance varied. While on the new duty schedule, participants slept on average 87% of their duty days (range 15% to 100%). During these rest periods, they slept an average of 3.72 ± 1.04 hr each day. The participant with the least sleep while on duty (50 min) also had the poorest compliance with scheduled rest periods.

To further evaluate how the two schedules affect daily sleep, we classified the study days into eight categories. For the Panama schedule, we identified five distinct categories: days when working morning shifts ($n = 6$ participants), days when a night shift began ($n = 7$), days when the night shift ended ($n = 7$), days between consecutive night shifts ($n = 3$), and days off ($n = 11$). In the new schedule, we identified three categories of days: when a 24-hr shift began ($n = 12$ participants), days when a 24-hr shift ended ($n = 12$), and days off ($n = 12$). Parentheses show the number of participants experiencing the corresponding category. Because of operational constraints, all participants did not experience the entire cycle (28 days) of the old schedule during the data collection period of this study. Pairwise

comparisons showed that participants slept more during those days that the 12-hr night shift began (8.10 ± 2.3 hr) than on days before the 24-hr shift began (5.12 ± 1.1 hr; $S = 13.0$, $p = .031$). However, participants slept more during the days off on the 24-hr schedule (8.56 ± 1.1 hr) compared to the 12-hr schedule (7.42 ± 1.1 hr; $S = 30.0$, $p = .005$).

The differences in sleep between schedules were further investigated by calculating the average sleep time per 1-hr interval by day category. For example, the average sleep time between 0900 and 0959 for the three participants who had consecutive 12-hr night shifts was 60 min; hence, all three participants slept during this period. Results from this analytical process are shown in Figures 3 through 7. The timing of sleep during days with a 12-hr morning shift and days with a 24-hr shift is shown in Figure 3. It is evident that strong similarities exist in the timing of sleep events between the two schedules. Figure 4 shows the timing of sleep during days before 12-hr night shifts and before 24-hr shifts. There is a striking difference in the timing of sleep events for the two schedules. Sleep occurs primarily in the nighttime hours when personnel are working 24-hr shifts. As seen in the black vertical bars, little sleep occurred between the hours of 0600 and 2000. However, when working the night shift on the original schedule, sleep, denoted by gray vertical bars, is concentrated in the hours between midnight and 1500.

Figure 5 shows the timing of sleep during the days between 12-hr night shifts. The sleep pattern in these days suggests that personnel attempted to shift their circadian rhythms by 12 hr, undergoing daytime sleep almost exclusively. Figure 6 shows the timing of sleep during days following 12-hr night shifts and 24-hr shifts. There is a bimodal distribution of sleep following the sleep loss experienced following night shift work on both schedules. Last, Figure 7 shows the timing of sleep during days off on the 12-hr shift schedule and on the 24-hr shift schedule. For both schedules, sleep on days off occurs predominantly during nighttime hours, although this pattern is less evident on the original 12-hr shift schedule.

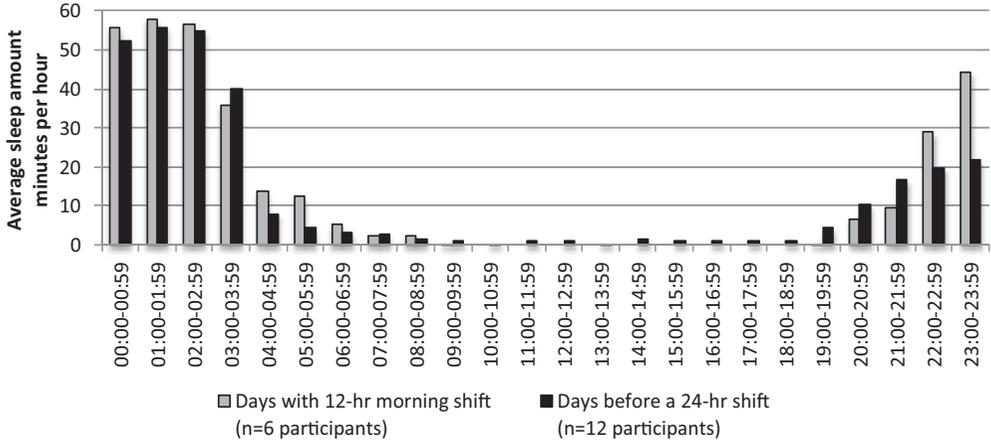Figures 3 through 7 show the following points of interest. Although some of them are expected,

Figure 3. Timing of sleep during days with a 12-hr morning shift and days with a 24-hr shift.
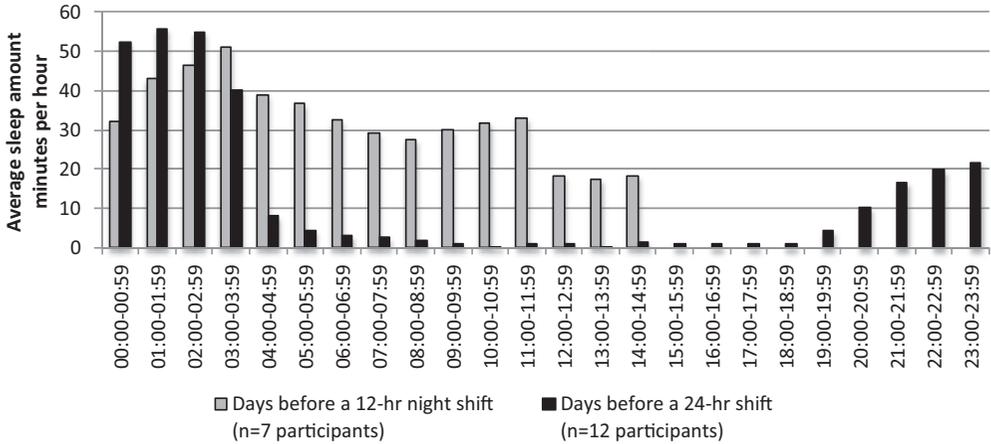

Figure 4. Timing of sleep during days before 12-hr night shifts and before 24-hr shifts.

they provide insight into the sleep patterns in the two schedules.

- On the original schedule, participants working a morning shift wake up between 0300 and 0400. In contrast, on the days when a night shift will follow, participants extend their sleep until noon or later.
- The day between consecutive 12-hr night shifts is the worst in terms of sleep hygiene. Although the number of participants on this schedule was small, each of them napped from 0800 until noon.
- The tendency to nap after a night shift is more evident following a 12-hr night shift than when following a 24-hr shift.

To assess the quality of sleep between the two schedules, we calculated the average percentage of daily sleep obtained from 2200 to 0600. As already noted, the Panama schedule has a cycle of 28 days. Within this cycle, there are two 14-day periods, one in which individuals work the morning shift and one in which they work the night shift. As shown in Figure 1, individuals on Team 1 are on the night shift portion of the Panama schedule during the first 14 days of the typical 28-day cycle (Days 1 to 14). These individuals rotate to the morning shift part of the 28-day cycle for the next 14 days (Days 15 to 28).

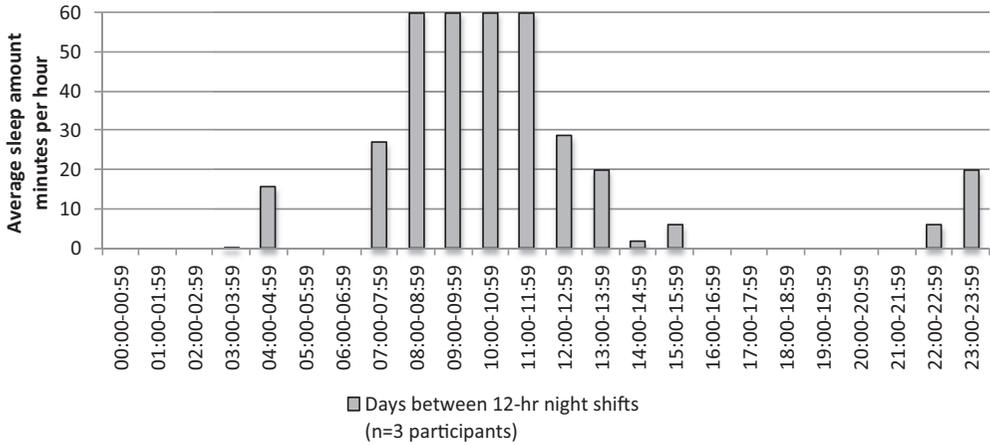We made two pairwise comparisons. The first was between the night shift period of the

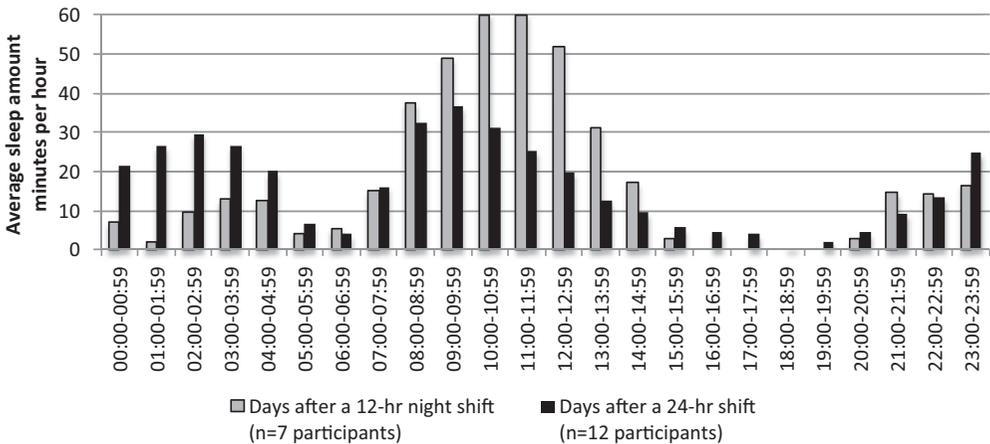*Figure 5.* Timing of sleep during the days between 12-hr night shifts.

Figure 6. Timing of sleep during days following 12-hr night shifts and 24-hr shifts.

Panama schedule and the new schedule. The second comparison was between the morning shift period of the Panama schedule and the new schedule. Analysis showed that participants on the 12-hr night shift increased their sleep between 2200 and 0600 from 43.6% to 65.2% ($S = 13.0$, $p = .03$). Daily sleep between the hours of 2200 and 0600 for participants on the 12-hr morning shift decreased from 85.7% to 71.8% ($S = 6.5$, $p = .125$). Although these differences are statistically nonsignificant (BH-FDR procedure), the pattern of these changes suggests that the new schedule is more consistent. Instead of watchstanders having considerable differences in their timing of sleep on the Panama schedule, 70% of the daily sleep of

individuals on the new schedule occurs between 2200 and 0600. These results are shown in Figure 8.

POMS

At the beginning of the study, when participants were on the Panama watch schedule, the average TMD score was 29.5 ± 25.7, ranging from 1 to 87. These scores dropped to 8.54 ± 24.5 (ranging from –18 to 62) at the middle of the study and then fell to 1.25 ± 21.5 (ranging from –20 to 55) by the end of the study. These results (Figure 9) suggest a significant improvement in TMD scores between the beginning and the end of the study ($S = 31$, $p = .006$).
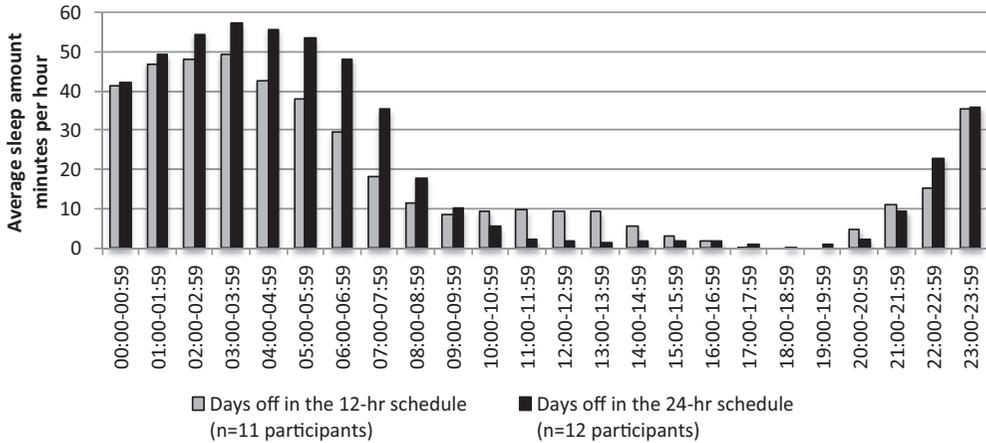
Figure 7. Timing of sleep during days off on 12-hr shift schedule and on 24-hr shift schedule.
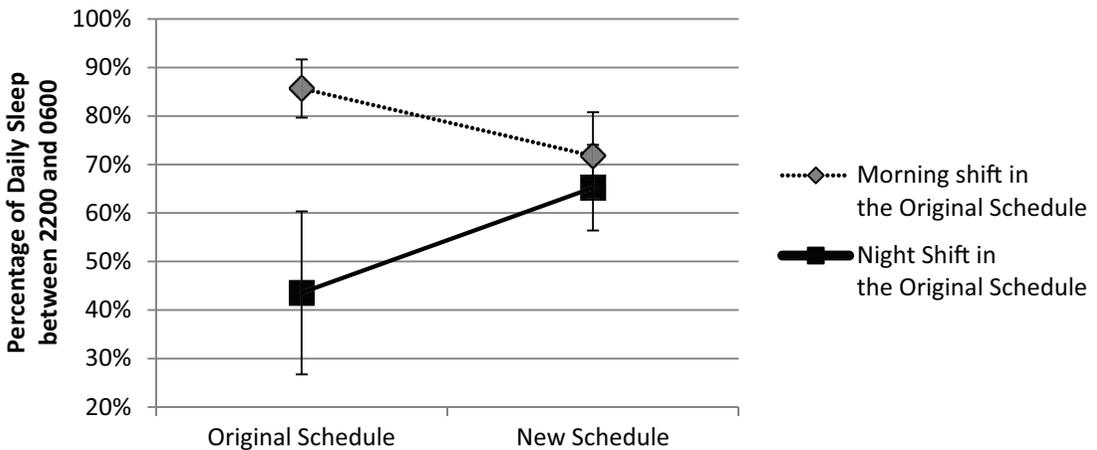

Figure 8. Percentage of daily sleep between 2200 and 0600 for the two schedules. Vertical bars represent one standard deviation.

In general, POMS scale scores improved significantly on the new schedule compared to the Panama schedule. Table 1, below, shows all the POMS scores. The right column shows the *p* values of the comparisons of scores between the beginning and end of the study using the Wilcoxon signed rank test. Analysis based on the BH-FDR controlling procedure showed that differences in all subscale scores, except for Confusion-Bewilderment, were statistically significant.

Posttest Questionnaires

Analysis of the posttest questionnaires was based on responses from 13 participants. An overwhelming 92% (*n* = 12) of the participants preferred the new schedule to the Panama schedule. Participants favoring the new schedule noted that they spent less time commuting (*n* = 8), they felt more rested (*n* = 6), and their overall daily schedule was more consistent and a better fit for family life (*n* = 6). They also mentioned that the new schedule afforded more time for additional work while on duty (*n* = 4) and that they felt more involved in the workplace activity and more engaged in their mission (*n* = 2). Two participants noted that the new schedule provided time for workouts while on duty. One participant, however, preferred the
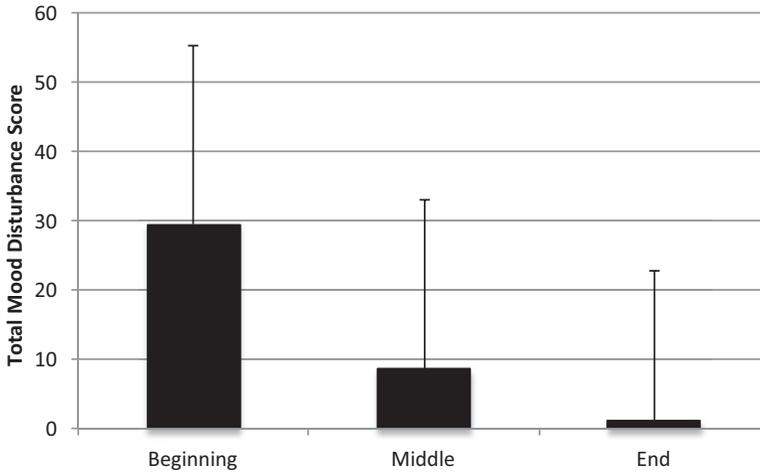
Figure 9. Profile of Mood State total mood disturbance scores at three time points. Vertical bars represent one standard deviation.

TABLE 1: POMS Subscale Scores

POMS Scale	Beginning $M \pm SD$ (Min, Max)	Middle $M \pm SD$ (Min, Max)	End $M \pm SD$ (Min, Max)	p Value[a]
Tension-Anxiety	8.77 ± 4.28 (4, 18)	5.92 ± 3.80 (1, 13)	4.83 ± 2.92 (2, 12)	.006
Depression	6.46 ± 8.89 (0, 30)	3.31 ± 4.89 (0, 15)	1.58 ± 2.68 (0, 8)	.037
Anger-Hostility	8.46 ± 7.10 (1, 25)	5.31 ± 5.84 (0, 21)	4.08 ± 6.90 (0, 25)	.002
Vigor-Activity	11.5 ± 2.88 (7, 78)	16.5 ± 5.75 (5, 24)	17.4 ± 6.79 (6, 25)	.019
Fatigue	10.4 ± 3.91 (1, 16)	5.77 ± 4.25 (1, 14)	4.0 ± 4.07 (0, 14)	.008
Confusion-Bewilderment	7.0 ± 4.0 (2, 19)	4.77 ± 3.72 (0, 14)	4.17 ± 2.59 (0, 9)	.068

Note. POMS = Profile of Mood State.
[a]Comparison of scores between the beginning and end of the study.

original schedule, identifying four reasons. This participant noted that on the original schedule, shift change turnover time was shorter, there was better control over the shift because of the shorter duty time, and more time was available for collateral duties. This participant also pointed out the poor quality of mattresses in the sleeping room.

Compared to the original schedule, participants noted that on the new watch schedule, they felt better rested (83%), they were more productive (85%), and their sleep (70%) and life quality (75%) was improved. Overall, they felt that the watch schedule change had been an improvement (92%). These results are shown in Figure 10. Only one participant preferred the original

schedule, reporting reduced situation awareness of events over consecutive shifts in the new schedule and a reported reduction in performance with simple day-to-day tasks.

FAST Predicted Effectiveness

The sleep patterns identified by actigraphy and activity logs were used as input to the FAST. Figures 11 and 12 show the actual FAST output of predicted effectiveness for a typical 56-day period of the Panama and the new shift schedules. In the Panama schedule, the 56-day period includes two rotations of the 28-day cycle. Black intervals indicate shift periods. The average predicted effectiveness during shifts does not differ substantively (Panama, 84%;
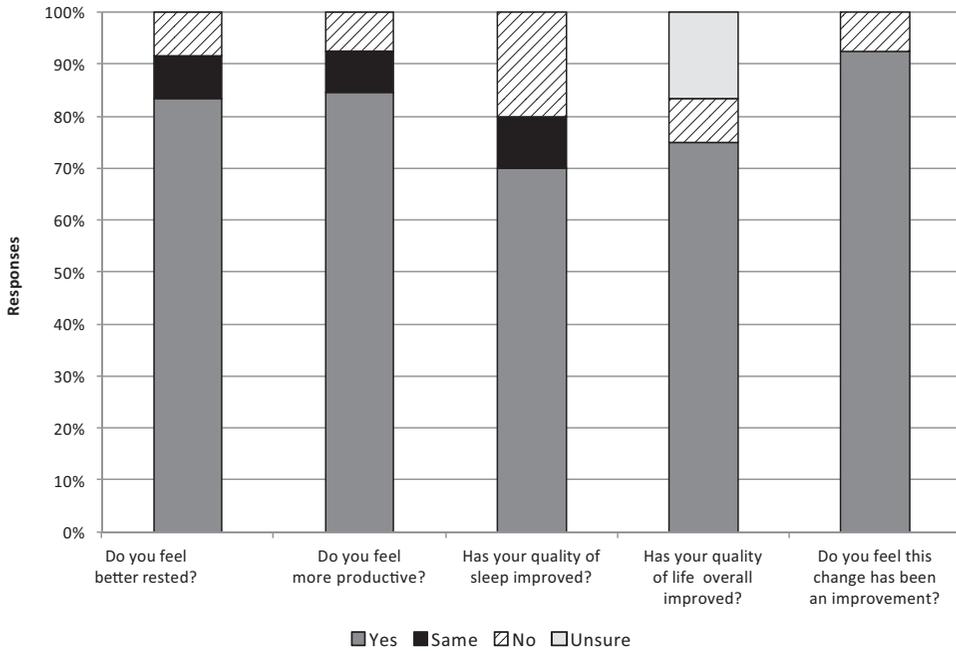
Figure 10. Participants' opinions about the new schedule.

new schedule, 86%). However, compared to performance on the Panama schedule, the new schedule results in higher minimum predicted effectiveness scores during shifts (72% vs. 62%), reduced ranges of predicted effectiveness (20% vs. 38%), and almost half the time spent below the 77.5% criterion while on shift (14.3% vs. 27%). This 77.5% criterion point equates to the performance of an individual with a blood alcohol content of 0.05%.

DISCUSSION

Results indicate that participants preferred the new schedule, felt better rested, and reported that family life was improved. Compared to the original schedule, the acceptance of the new schedule seems reasonable if we map its attributes to the "principles" that Miller (2006) proposed to describe essential qualities of shift systems. These principles fall into three groups: circadian stability, chronohygiene (short shift length, minimum consecutive night shifts, recovery after each night shift, maximum number of free days on weekends, at least 104 days off per year), and satisfaction (equity among

shift workers for types of work dates and free days, predictability of specific work and free days, and good quality of time off).

The new schedule provides better circadian stability because personnel are allowed to nap during the 24-hr shift at a time when they would normally be asleep. The circadian disruption due to the absence of sleep in the 12-hr night shift is ameliorated in the 24-hr shift whereby participants can sleep in the two 5-hr windows from 1900 to midnight, and from midnight to 0500. Chronohygiene is also better in the new schedule. On the original schedule, personnel had two to three consecutive nights without night sleep followed by a recovery day. On the new schedule, however, the worst case is sleep from 1900 to midnight on a single night. This situation may occur only once every 3 to 4 days, and it is always followed by a recovery day. The new schedule is also simpler than the Panama schedule because the shift day iterates every 3 to 4 days based on the needs of the watchstander. Finally, off-work time coincides with the normal waking hours for family members, a positive attribute emphasized by most participants.
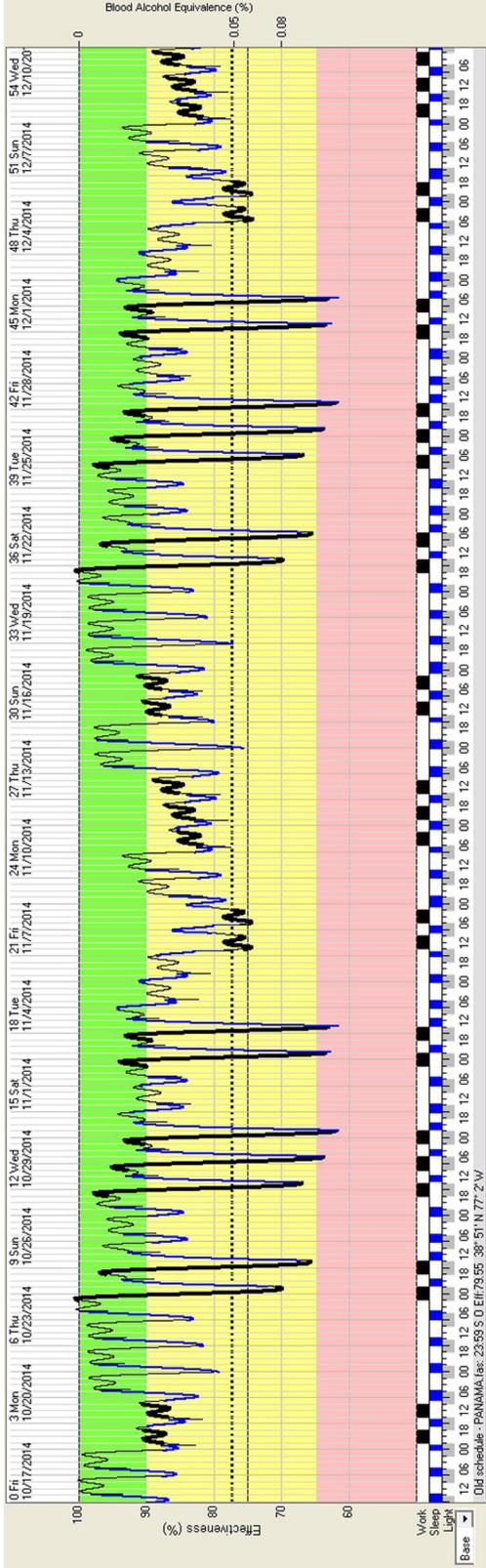
Figure 11. Fatigue Avoidance Scheduling Tool predicted effectiveness for a typical 56-day period of the Panama schedule.
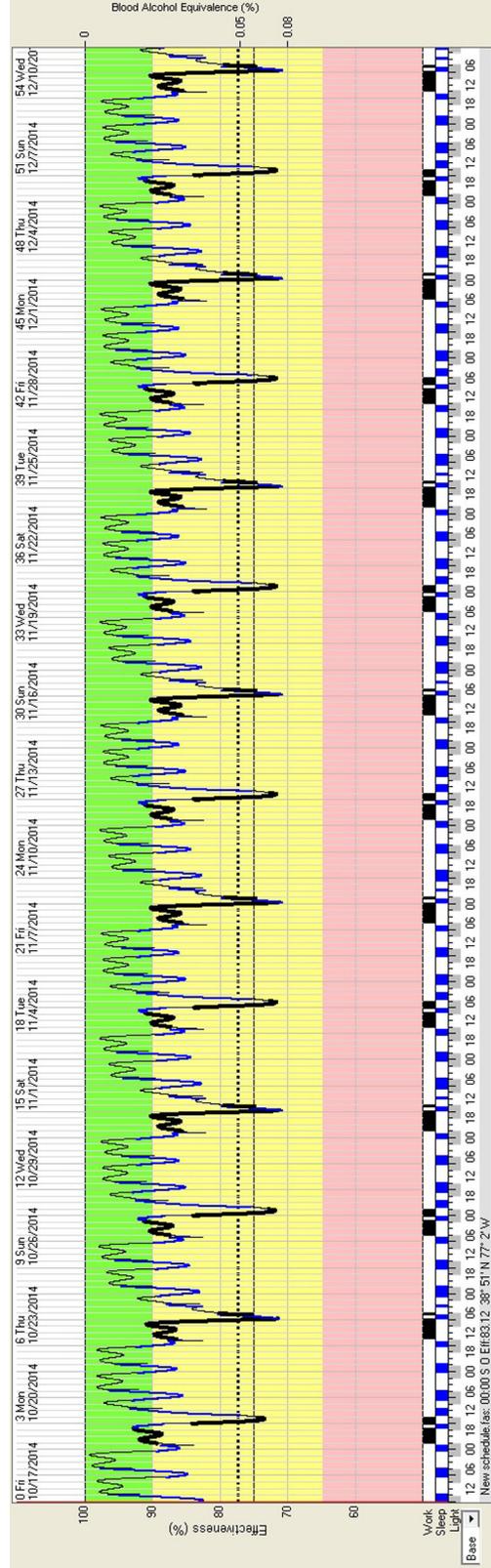

Figure 12. Fatigue Avoidance Scheduling Tool predicted effectiveness in a typical 56-day period of the new shift schedule.

Although the average sleep of participants was not different on either the Panama or new schedule, the sleep provided on the new schedule appeared more beneficial and restorative to participants. On the new schedule, participants nap much less during daytime hours, a phenomenon clearly evident in the original shift schedule. Sleeping during daytime hours is known to result in less refreshing sleep (Åkerstedt, Hume, Minors, & Waterhouse, 1997).

Extended wakefulness, such as seen in the new in the new 24-hr schedule, has been associated with degraded performance, reduced alertness, and was a major concern for the new schedule. To increase alertness levels during the early-morning circadian nadir, the new schedule required that personnel sleep for a scheduled period while on duty. Personnel were encouraged to avail themselves of the opportunity to take scheduled naps to increase their alertness levels. Although all participants took advantage of this sleep opportunity, compliance with scheduled napping while on duty varied. A few participants slept much less than the 5-hr window allotted for naps. A major concern for introducing naps into the new schedule was the potential for sleep inertia, that is, the performance impairment that occurs immediately after awakening. Sleep inertia affects reaction time and decision making and may still be evident 30 min after awakening (Buck & Pisani, 1997). This operational concern was discussed with the PEOC when developing the new schedule.

Although operational commitments did not allow for the collection of performance data, predicted effectiveness based on the FAST/SAFTE model provided positive results. Compared to the Panama schedule, the new schedule resulted in higher minimum predicted effectiveness scores during shifts and reduced ranges of predicted effectiveness. Furthermore, participants on the new schedule spent much less (almost half) time below the criterion point that equates to the performance of an individual with a blood alcohol content of 0.05%.

The significance of this study lies in the attributes of the proposed new schedule. Even though there is no increase in the average amount of time participants sleep, the new schedule results in improved sleep quality and better alignment of their work schedule with family and social needs. Most of the participants also pointed out the benefit of the new schedule in terms of less time spent commuting, a frequent problem in the Washington, D.C., area. Commuting, especially in highly congested regions, has been shown to interfere with patterns of everyday life by restricting free time and reducing the time available to sleep (Costa, Pickup, & Di Martino, 1988a, 1988b). Commuting time has also been associated with fitness-for-duty issues for airline pilots by affecting their fatigue level (National Research Council, 2011).

Although changing to the new schedule was positive in terms of personnel approval, subjective assessments of rest, and improved quality of family life, there are still areas for further improvement. The room assigned for scheduled rest periods while on duty should be assessed to ensure that sleep conditions are optimized. The schedule should be examined to determine if more time could be made available for collateral duties. The shift turnover process should also be evaluated to determine if it could be streamlined and made more efficient.

Follow-on research should continue to document the sleep patterns of personnel on this new schedule to ensure that these initial positive trends continue. A change in the time that the shift commences may also be beneficial. The new schedule will be most effective if personnel adhere to scheduled sleep during their 24-hr duty period. Personnel should sleep as much as possible within the allotted 5-hr window. In the study, approximately 80% of the participants slept on average less than 4 hr, whereas one participant used the sleep opportunity just once for a short period. The less-than-optimal use of the entire 5-hr sleep window explains the troughs in the predicted effectiveness of the new schedule in Figure 12. Furthermore, it explains the differences between average performance between the initial run of FAST before the data collection and the second FAST run using the actual sleep data. The model of the new schedule in Figure 12 was based on average nap duration of 3.5 hr instead of 5 hr.

Results of this study suggest that a macroergonomically designed work schedule should incorporate information about the social life of

the workers. Social considerations, such as the demands of family life, commuting distance and time, and traffic congestion, all have a considerable effect on the acceptance of a work schedule. Among other factors, a successful work schedule should, to the extent possible, avoid conflicts between social life and operational demands posed by the job. The news and acceptance of this watch schedule by the PEOC has filtered throughout the White House. Anecdotal reports indicate that other White House departments are trying out the new schedule. As results from the current study are released, changes in the work schedules of personnel assigned to other departments with similar 24/7 responsibilities could be expected. The study could potentially be adopted by other professions requiring round-the-clock operations—particularly in situations for which long commutes are required.

Study Limitations

This study has a number of limitations. Our sleep results are based on the analysis of only 12 participants, predominantly male. Although this number represented almost every member of this department, it is still a small number on which to assess sleep in operational settings. Future efforts should include a larger sample with male and female participants. In order to minimize the impact of participants' workload, performance tests were not used in our study. A follow-up study should assess how the new schedule affects cognitive performance, especially alertness and vigilance levels. Given the operational aspects of this study, a design balanced by schedule order could not be used in our study. All participants first experienced the Panama schedule followed by the new one. Furthermore, temporal changes in work conditions may have affected our results. Both these issues may have biased the POMS scores in the middle of the study. At that point in time, participants had been using the new schedule for approximately 10 days. However, we believe that the data obtained at the end of the study, after approximately 31 days on the new schedule, are not substantially biased. If the improvements in POMS scores shown in the middle of the data collection period were caused by an order effect or temporal changes, we could reasonably expect a plateau, or even a reversal of scores, by the end of the study. However, such a phenomenon was not observed; POMS scores at the end of the study continued to improve.

KEY POINTS

- Compared to a 12-hr shift schedule that rotates every 2 weeks between day and night shifts, a 24-hr-on/72-hr-off schedule with scheduled napping at work may be better tolerated by watchstanders.
- Macroergonomic interventions should address social needs and considerations of family life when optimizing shift schedules.
- Beyond looking simply at average sleep amounts, optimizing sleep quality by encouraging stable sleep practices results in considerably better shift schedules.

REFERENCES

Åkerstedt, T. (2003). Shift work and disturbed sleep/wakefulness. *Occupational Medicine*, *53*, 89–94.

Åkerstedt, T., Hume, K., Minors, D., & Waterhouse, J. (1997). Good sleep: Its timing and physiological sleep characteristics. *Journal of Sleep Research*, *6*, 221–229.

Åkerstedt, T., & Wright, K. P. (2009). Sleep loss and fatigue in shift work and shift work disorder. *Sleep Medicine Clinics*, *4*, 257–271.

Albertsen, K., Rafnsdóttir, G. L., Grimsmo, A., Tómasson, K., & Kauppinen, K. (2008). Workhours and worklife balance. *Scandinavian Journal of Work, Environment & Health, Suppl. 2008*(5), 14–21.

Arendt, J., Middleton, B., Williams, P., Francis, G., & Luke, C. (2006). Sleep and circadian phase in a ship's crew. *Journal of Biological Rhythms*, *21*, 214–221.

Arnedt, J. T., Owens, J., Crouch, M., Stahl, J., & Carskadon, M. A. (2005). Neurobehavioral performance of residents after heavy night call vs after alcohol ingestion. *JAMA*, *294*, 1025–1033.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, Series B (Methodological)*, *57*, 289–300.

Buck, D., & Pisani, D. L. (1997). The effects of sleep inertia on decision-making performance. *Journal of Sleep Research*, *8*, 95–103.

Colquhon, W. P., Blake, M. J. F., & Edwards, R. S. (1969a). Experimental studies of shift-work I: A comparison of "rotating" and "stabilized" 4-hour shift systems. *Ergonomics*, *11*, 437–453.

Colquhon, W. P., Blake, M. J. F., & Edwards, R. S. (1969b). Experimental studies of shift work III: Stabilized 12-hour shift systems. *Ergonomics*, *12*, 865–882.

Costa, G., Pickup, L., & Di Martino, V. (1988a). Commuting: A further stress factor for working people. Evidence from the European Community I. A review. *International Archives of Occupational and Environmental Health*, *60*, 371–376.

Costa, G., Pickup, L., & Di Martino, V. (1988b). Commuting: A further stress factor for working people. Evidence from the European Community II. An empirical study. *International Archives of Occupational and Environmental Health*, *60*, 377–385.

Dijk, D. J., & Czeisler, C. A. (1995). Contribution of the circadian pacemaker and the sleep homeostat to sleep propensity, sleep structure, electroencephalographic slow waves, and sleep spindle activity in humans. *Journal of Neuroscience*, *15*, 3526–3538.

Dijk, D. J., & Edgar, D. M. (1999). Circadian and homeostatic control of wakefulness and sleep. In F. W. Turek & P. C. Zee (Eds.), *Regulation of sleep and wakefulness* (pp. 111–147). New York, NY: Marcel Dekker.

Drake, C. L., & Wright, K. P. (2011). Shift work, shift-work disorder, and jet lag. In M. H. Kryger, T. Roth & W. C. Dement (Eds.), *Principles and practices of sleep medicine* (5th ed., pp. 784–798). St. Louis, MO: Elsevier Saunders.

Folkard, S., & Tucker, P. (2003). Shift work, safety and productivity. *Occupational Medicine*, *53*, 95–101.

Harrington, J. M. (2001). Health effects of shift work and extended hours of work. *Occupational and Environmental Medicine*, *58*, 68–72.

Hockey, R. (Ed.). (1983). *Stress and fatigue in human performance*. Durham, NC: Wiley.

Hursh, S. R., Redmond, D. P., Johnson, M. L., Thorne, D. R., Belenky, G., Balkin, T. J., . . . Eddy, D. R. (2004). Fatigue models for applied research in warfighting. *Aviation Space and Environmental Medicine*, *75*(3 Suppl.), A44–A53; discussion A54–A60.

IARC Monographs Working Group on the Evaluation of Carcinogenic Risks to Humans. (2010). Painting, firefighting, and shiftwork. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*, 98. Lyon, France: International Agency for Research on Cancer.

JMP statistics and graphics guide, Release 7. (2007). Cary, NC: SAS Institute.

Johns, M. W. (1991). A new method for measuring daytime sleepiness: The Epworth Sleepiness Scale. *Sleep*, *14*, 540–545.

Knutsson, A. (2003). Health disorders of shift workers. *Occupational Medicine*, *53*, 103–108.

McNair, D. M., Lorr, M., & Droppelman, L. F. (1971). *Manual of the Profile of Mood States*. San Diego, CA: Educational and Industrial Testing Service.

Meltzer, L. J., Walsh, C. M., Traylor, J., & Westin, A. M. L. (2012). Direct comparison of two new actigraphs and polysomnography in children and adolescents. *Sleep*, *35*, 159–166.

Miller, J. C. (2006). *Fundamentals of shiftwork scheduling*. Brooks City-Base, TX: Air Force Research Laboratory.

Monk, T. H. (1986). Advantages and disadvantages of rapidly rotating shift schedules: A circadian viewpoint. *Human Factors*, *28*, 553–557.

National Research Council. (2011). *The effects of commuting on pilot fatigue*. Washington, DC: National Academies Press.

Pfaff, M. S. (2012). Negative affect reduces team awareness: The effects of mood and stress on computer-mediated team communication. *Human Factors*, *54*, 560–571.

Rupp, T. L., & Balkin, T. J. (2011). Comparison of Motionlogger Watch and Actiwatch actigraphs to polysomnography for sleep/wake estimation in healthy young adults. *Behavior Research Methods*, *43*, 1152–1160.

Sallinen, M., & Kecklund, G. (2010). Shift work, sleep, and sleepiness: Differences between shift schedules and systems. *Scandinavian Journal of Work, Environment & Health*, *36*, 121–133.

Stevens, R. G., Hansen, J., Costa, G., Haus, E., Kauppinen, T., Aronson, K. J., . . . Straif, K. (2011). Considerations of circadian impact for defining "shift work" in cancer studies: IARC Working Group report. *Occupational and Environmental Medicine*, *68*, 154–162.

Wang, X.-S., Armstrong, M. E. G., Cairns, B. J., Key, T. J., & Travis, R. C. (2011). Shift work and chronic disease: The epidemiological evidence. *Occupational Medicine*, *61*, 78–89.

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