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Extended workdays: effects of 8-hour and 12-hour rotating shift schedules on performance, subjective alertness, sleep patterns, and psychosocial variables

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A newly instituted 3–4 day/12-h rotating shift schedule was compared to the previous 5–7 day/8-h schedule using standard laboratory-type measures of performance and alertness, and a questionnaire on sleep patterns and other personal habits. After seven months adaptation to the new schedule, there were decrements in the laboratory-type tests of performance/alertness which could be attributed to the extra 4 h of work per day. There were also reductions in sleep, and disruptions of other personal activities during 12-h workdays. However, increases in self-reported stress were attenuated by the shortened workweek. These results are discussed in terms of trade-offs between longer workdays and shorter workweeks.

Keywords: Shift work; Compressed work week; Performance stress; Alertness; Sleep.

1. Introduction

There is a considerable body of literature suggesting that shiftwork in general, and nightwork in particular, may have adverse consequences for the health and well-being of the worker (e.g., Johnson *et al.* 1981, Rutenfranz 1977). These problems have been attributed to the fact that individuals are required to work at times which are disruptive to their physiological, psychological, and social circadian rythms (Aschoff 1981, Wever 1981). Consequently, there has been a growing interest in exploring alternative work schedules. One of these schedules is the 12 h/day compressed work week. Although there are a number of variations (see Colligan and Tepas 1986), the underlying strategy is to shorten the work week to 3 or 4 days by increasing the length of the work shift to 12 h. The presumed advantage of this schedule is that the shiftworker has more non-working days per week, thereby gaining larger blocks of time for recuperation and leisure. A potential risk, however, is that the additional 4 h per shift may produce fatigue-related decrements in performance which could result in increased accident susceptibility.

Our review of the literature on compressed workweeks (Rosa and Colligan 1986, Rosa *et al.* 1985) revealed persistent concerns about feelings of increased fatigue associated with long workdays. These concerns have made some organizations hesitant to change from the conventional 5-day/40 h week to some form of compressed week requiring longer workdays. They are hesitant despite employees' overall satisfaction with the compressed week and their willingness to tolerate or adapt to increased subjective fatigue. Concerns about increased fatigue are supported by both laboratory (Colquhoun *et al.* 1968, 1969, Rosa *et al.* 1985) and worksite (Volle *et al.* 1979) comparisons of 8-h and 12-h days. These concerns pointed to a need for systematic study of long workdays, preferably at the worksite.

Our own efforts in this area began with laboratory development of a test battery for assessing performance and subjective fatigue and alertness associated with long wordays. The battery was designed for worksite testing in a manner which minimizes interference with the worker's job responsibilities. As such, it is portable, short, and easy to administer. Specific tasks in the battery require minimal subject training. The built-in flexibility of the battery makes it easy to select any subset of the tests for a particular application. Our laboratory evaluations of the sensitivity of the battery to long workdays and different work schedules are reported in Rosa and Colligan (1988) and Rosa *et al.* (1985).

The present investigation was the first worksite assessment using the NIOSH fatigue test battery. We were asked to assist in evaluating potential changes in a range of variables associated with a switch from an 8-h shift schedule with three rotations to a 12-h shift schedule with two rotations. The workers experiencing these schedules were control room operators at a continuous processing plant. In addition to testing on the battery, the operators kept a log of sleep patterns and other activities potentially affected by shiftwork.

2. Method

2.1 *Subjects*

Control panel and computer monitoring were the main activities required of the operators. Physical demands were light. All subjects first worked under the 8-h schedule then subsequently under the 12-h schedule.

2.1.1. *NIOSH fatigue test battery*

Fifty two subjects were tested during the 8-h workdays and 55 subjects during the 12-h workdays. Of these, 24 responded under both the 8-h and 12-h schedules. These subjects provided the data for most of the (repeated measures) statistical analyses. Age and sex data were available from 23 of these subjects. Twenty-one (91%) were male and 20 (87%) were between 25 and 34 with the remaining subjects over 34. Analyses within schedules included all subjects who responded during those times.

2.1.2. *Daily sleep and habits questionnaire*

Fifty-three persons responded during the 8-h schedule and 67 persons responded during the 12-h schedule. The respondents to the computerized test battery also completed questionnaires and were included in this sample. Analyses *within* a particular schedule included all subjects. The comparison of the 8-h and the 12-h schedules was based on fifty subjects who respondedconsistently during both schedules. Age and sex were available from 49 of these persons. Forty-five (92%) were male and thity-five (71%) were between 25 and 35 years old with the rest being over 34.

2.2. *NIOSH fatigue test battery*

Details of the complete test battery are reported elsewhere (Rosa and Colligan, 1986, 1988; Rosa *et al.* 1985). Four performance tasks were selected to test both abilities analogous to the job and more general indices of alertness or fatigue. The job under study placed a large demand on cognitive abilities and required monitoring several different information

```
                          8-Hr Schedule

Day    M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S

Shift D D D D D . . . . S S S S S S S . . T D D T T T . . N N N N N N N . .

                          12-Hr Schedule

Day    M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S

Shift T T T T o o o N N N N o o o D D D D . . . . . . o N N N o o o . D D D

D=Day     S=Swing    N=Night    T=Training/Support    .=Rest    o=On call
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Figure 1. 8-h and 12-h schedules for a typical crew.

displays. Therefore, a test of mental arithmetic (speed of digit addition) and a test of grammatical reasoning while simultaneously monitoring a signal (dual task) were chosen. The reasoning portion of the dual task was a variation of Baddeley's (1968) test except that response time was measured for each conditional statement rather than for the entire test. Simple reaction time to a randomly presented auditory signal and a hand steadiness task were selected as more general indices of fatigue.

2.3. *Design*

The 8-h and 12-h rotating shift schedules are illustrated in figure 1. Under the 8-h schedule, operators often worked up to seven days in a row while, under the 12-h schedule, they typically worked for 3 or 4 days. Training/support days were 8-h day shifts (0730 to 1600 h) regardless of schedule. Shift times under the 8-h schedule were: 0730 to 1600 h (day), 1530 to 2400 h (swing), and 2330 to 0800 h (night). Shift times under the 12-h schedule were: 0630 to 1900 h (day) and 1830 to 0700 h (night).

Data were collected in two phases. The first phase occurred during the final five weeks of the 8-h schedule and the first five weeks of the 12-h schedule. Because we had only short notice before implementing the study, there was no opportunity for the operators to practise the tasks before the first test phase. Thus, they were not at an asymptotic level of performance before critical testing began. As a consequence, practice effects complicated the statistical analyses.

The second phase occurred after approximately seven months on the 12 h schedule and lasted ten weeks. The critical comparisons were between the final weeks of 8 h days during phase one and the 12-h days during phase two. By that time, the subjects had several months to adapt to the new schedule.

Test battery performance was sampled on all shifts under both the 8 h and 12 h schedules. Our original test schedule was designed so that the beginning, middle, and end of each workshift or worksheet could be compared. In practice, however, test times varied considerably because of job demands and worker preferences. As a result, participation rates were fairly even across shifts, but more frequent on the first three days of the work week under either schedule.

2.4. *Procedure*

Six Kaypro II computers were distributed in accessible places in the plant. The Kaypro II controlled the instructions for, and presentation of all tasks and scales and also stored all data. A brief introduction to the computers and test battery was the only experimenter intervention required before regular testing began. During regular testing, the subject simply sat before the console and typed one command to begin the battery.

2.5. *Test battery data analysis*

Multiple regression techniques were used to control for practice effects, varied participation rates, and correlations among targeted parameters assumed to influence performance.

2.5.1. *Model parameters*

The following regression parameters were entered into the analysis in three steps. The first step involved parameters assumed to be the most critical dimensions influencing performance on our test battery. They were:

1. the intercept
2. a practice effect modeled as a monotonically increasing power function (see below),
3. a dummy code for the first 12-h test phase,
4. a dummy code for the second 12 h test phase, 7 months later,
5. time-on-shift in hours,
6. a sinusoidal circadian function modeled as the inverse of body temperature (peaks at 0600 h and troughs at 1800 h),
7. the interaction of time-on-shift with the circadian function. (This is considered a primary parameter because the circadian rhythm of arousal can be expected to oppose fatigue effects from time-on-shift during the day, and to intensify fatigue effects from time-on-shift during the night), and
8. the number of consecutive days worked.

In the second step, the following parameters were entered:

1. the interaction of the first 12 h test phase with the circadian function,
2. the interaction of the second 12 h test phase with the circadian function,
3. the interaction of days worked with time-on-shift,
4. the interaction of days worked with the circadian function, and
5. the interaction of days worked with type of schedule.

In the third step, amount of sleep prior to work and time since awakening were entered.

Average regression coefficients (beta weights) for each parameter were obtained by first calculating individual regression equations, for each of 24 subjects, on each of the dependent variables from our test battery. The distribution of beta weights (across 24 subjects' equations) for each parameter, from each dependent variable, were then tested for difference from zero using sign-rank tests.

2.5.2. *Fitting practice curves*

Practice effects needed to be statistically controlled to clarify the influence of the other parameters. A curve of best fit was determined by first selecting several negatively accelerated curves (see Kintch 1977) as possibilities for best fit. The terms for these curves were then entered in a stepwise manner into the individual regression equations (along with all of the other parameters) in standardized form. The term with the highest median standardized beta weight was then selected as the practice curve for a particular dependent variable. The significance of the beta's for the other parameters were then determined with the best-fitting practice curve included in the regression.

2.5.3. *Analysis of variance (ANOVA)*

Two ANOVAs and corresponding Newman-Keuls tests separately analysed changes *within* either the 8-h or 12-h schedules. Scores from all participants who responded under either schedule were used in these ANOVAs. For the 8-h schedule, scores for each subject ($n = 52$)

were averaged for each shift (day, swing and night) across seven consecutive workdays. A 3 (shifts) by 7 (workdays) repeated measures ANOVA was then performed. For the 12-h schedule, scores for each subject ($n=55$) were averaged for each shift (day or night) across four consecutive workdays. A 2 (shifts) by 4 (workdays) repeated measures ANOVA was then performed. Note that the F-ratios from these analyses are not exact and degrees of freedom do not conform to a balanced design because of missing values.

2.6. *Daily sleep and habits questionnaire*

A questionnaire containing items about sleep and other personal factors known to be affected by shiftwork (see Johnson *et al.* 1981, for reviews) was given at the beginning of every workshift. It asked about times of retiring and arising (including nap times), sleep latency, number of awakenings, depth of sleep, and quality of sleep for the 24 h preceding the workshift. The operators also gave their subjective evaluation of psychological stress and gastro-intestinal state, and reported personal schedule adjustments attributable to shiftwork, adjustments of mealtimes, and exercise periods.

2.7. *Questionnaire Data Analysis*

Effects for type of shift schedule and consecutive days worked were explored with ANOVAs on each dependent measure. One analysis compared 8-h day, swing, and night shifts to 12-h day and night shifts. The scores for each subject ($n=50$) were first averaged within each shift (8-h day, swing and night, or 12-h day and night). A one-way repeated-measures ANOVA (across the five shifts) was then performed on these scores.

Two other ANOVAs tested differences as a function of consecutive workday and shift *within* a schedule. For these ANOVAs, the scores for each subject were first averaged for each shift, across consecutive workdays, within each schedule. A 3 (shifts) by 7 (workdays) repeated measures ANOVA was then performed on scores from the 8-h schedule ($n=53$), and a 2 (shifts) by 4 (workdays) repeated measures ANOVA was performed on scores from the 12-h schedule ($n=67$). The F-ratios and degrees of freedom from all of these analyses are not exact because of missing values.

3. Results

3.1. *NIOSH fatigue test battery*

3.1.1. *Regression analysis*

The regression analysis revealed statistically significant effects for: 1. type of schedule (grammatical reasoning response time and errors, digit addition no. correct and errors[1], dual reaction time *RT* and misses), 2. time-on-shift (digit addition no. correct, dual reaction time, simple reaction time, hand steadiness, Stanford sleepiness scale), 3. circadian rhythm (grammatical reasoning response time and errors, digit addition no. correct), and 4. the interaction of time-on-shift with the circadian rhythm (grammatical reasoning errors, Stanford sleepiness scale). The number of consecutive days worked and interactions with days worked, the amount of sleep, time since awakening, or their interactions had little effect when considered in concert with the other parameters in the regression analysis.

Predicted scores were calculated from the multiple regression equations by inserting appropriate values for test phase, time-on-shift, or circadian time as required by a particular equation. If there was a significant practice effect, the predicted values were arbitrarily calculated at the median level of 36 repetitions of the test.

Figures 2 and 3 illustrate values for two variables having both time-on-shift and the circadian rhythm, or the interaction of time on-shift and the circadian rhythm, as parameters in the regression equation.

Figure 2 shows errors in the grammatical reasoning task as a function of time of day for each shift under both schedules. It can be seen in the figure that, after statistically controlling for practice, we would expect 1·33 or 187% (at 36 repetitions intercept =0·71) more errors under the 12-h schedule.

Figure 3 shows subjective sleepiness as a function of time of day for each shift under the two schedules. Subjective sleepiness would be expected to increase by 0·10 units for each hour on shift (27% increase after 8-h and 41% increase after 12-h). As shown in the figure, however, the circadian rhythm, and its interaction with time-on-shift, would be expected to intensify this increase in sleepiness in the late evening and early morning hours (e.g. 42% increase after the 8-h night shift and 66% increase after the 12-h night shift).

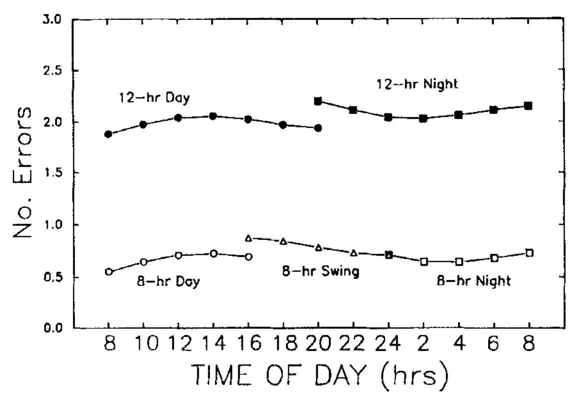

Figure 2. Grammatical reasoning errors for each shift under the 8-h and 12-h schedules.

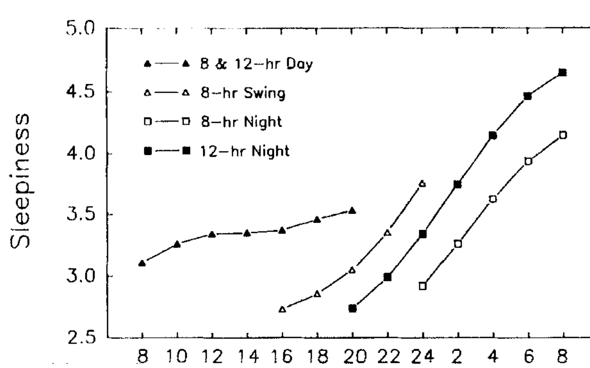

Figure 3. Stanford sleepiness scale for each shift under the 8-h and 12-h schedules. Note that values for the 8-h and 12-h day shifts overlap.

Table 1. Significant fatigue test battery scores across the 12-h/4-day workweek.

		Day				F	
		1	2	3	4	(3, 84)	p
Grammatical reasoning response time (sec)	*M*	3·49	3·44	3·30	3·16	9·17	0·001
	SD	1·02	1·00	1·03	0·96		
Errors	*M*	2·35	2·07	1·94	1·62	3·24	0·03
	SD	1·95	2·07	1·98	1·73		
Digit addition no. correct	*M*	54·82	57·12	58·52	60·04	13·36	0·001
	SD	12·36	12·68	11·26	7·96		
Errors	*M*	4·82	4·89	3·25	2·43	3·86	0·02
	SD	11·83	15·38	9·58	2·04		
Dual reaction time (msec)	*M*	312	285	290	284	10·32	0·001
	SD	136	100	109	109		
Missed signals	*M*	0·16	0·15	0·24	0·47	11·92	0·001
	SD	0·36	0·35	0·47	2·03		

3.1.2. *Within-schedule analysis of variance*

ANOVAs and Newman-Keuls tests within schedules revealed that performance gradually improved across the 12-h/4-day week. As shown in Table 1, this improvement was statistically significant for grammatical reasoning (response time and errors), digit addition (no. correct and errors), and dual reaction time. Missed signals in the dual reaction time task, however, increased across the 12-h workweek. Changes across the 8-h/7-day week were inconsistent for all but one dependent measure with respect to days worked. Grammatical reasoning errors were most frequent on the sixth workday, $F(6,200) = 3{\cdot}57$, $p < 0{\cdot}003$.

3.2. *Daily sleep and habits questionnaire*

Table 2 shows means for each dependent variable for each shift under the 8-h and 12-h schedules. Significant F-values testing for differences between shifts are also shown.

The following mean differences are the results of *post hoc* tests. Total sleep time was shortest after day shifts regardless of schedule. Swing and night shifts were similar regardless of schedule. Napping frequency after night shift decreased under the new schedule. No differences were apparent in time reported to fall asleep. Awakenings were most frequent after night shift regardless of schedule and highest overall after the 12-h night shift. Sleep depth was lightest and sleep quality was poorest after night shift under either schedule. Self-reported stress ratings did not differ between schedules but day shifts were generally more stressful. Gastro-intestinal state was worst during the 8-h night shift and improved from that level during the 12-h night shift. Missed social events on workdays increased during the 12-h day shift but not to the level of the 8-h swing shift. Therefore, the longer 12-h day shift (covering part of the old swing shift) seems to reflect a compromise between the two 8-h shifts. Adjustment of personal schedules ('schedule adjustments') decreased under the 12-h schedule and absenteeism due to shift remained the same. Adjustment of mealtimes increased and exercise frequency decreased under the 12-h shift.

Tables 3 and 4 show the results of the analyses within a particular schedule. Table 3 presents means and F-values for statistically significant variables across consecutive workdays under the 8-h schedule. Table 4 presents means and F-values for statistically significant variables across consecutive workdays under the 12-h schedule.

Table 2. Means by shift under the 8-h and 12-h schedules for variables in the daily sleep and habits questionnaire.

		8-h Day	8-h Swing	8-h Night	12-h Day	12-h Night	F (4,185)	p
Total sleep time (hrs)	M	6·76	7·47	7·39	6·96	7·63	5·39	0·001
	SD	0·63	0·78	0·72	2·16	1·08		
Naps (average percent)	M	02	10	29	04	18	26·64	0·001
	SD	06	20	18	15	20		
Latency to sleep (min)	M	14·72	12·86	10·61	18·94	10·95	NS	
	SD	10·41	9·07	7·34	33·49	10·87		
No. awakenings	M	1·32	1·16	1·75	1·26	2·38	3·09	0·02
	SD	0·74	0·85	1·09	1·15	4·21		
Sleep depth rating	M	6·58	6·84	6·21	6·50	6·22	4·25	0·003
(1 = light, 9 = deep)	SD	1·29	1·09	1·36	1·44	1·68		
Sleep quality rating	M	6·41	6·71	5·99	6·34	6·14	4·26	0·003
(1 = poor, 9 = good)	SD	1·24	1·18	1·33	1·54	1·71		
Self-reported stress	M	5·50	5·92	6·08	5·69	6·04	2·54	0·05
(1 = stress, 9 = relax)	SD	0·97	1·11	0·94	1·60	1·47		
Gastro-intestinal state	M	7·12	7·36	6·77	7·13	7·08	2·78	0·03
(1 = nausea, 9 = fine)	SD	1·51	1·54	1·39	1·40	1·61		
Missed social events	M	11	24	24	18	27	4·80	0·002
(average percent)	SD	13	28	23	28	32		
Schedule adjustments	M	06	07	15	02	07	6·64	0·001
(average percent)	SD	10	13	15	05	18		
Absent due to shift	M	01	02	01	01	00	NS	
(average percent)	SD	04	08	04	03	00	NS	
Special meals	M	15	30	29	75	64	24·42	0·001
(average percent)	SD	24	40	38	34	41		
Exercise periods	M	38	45	34	25	19	11·96	0·001
(average percent)	SD	30	39	26	28	26		

Table 3. Means across the 8-h/7-day week for significant variables in the daily sleep and habits questionnaire.

		Workday 1	2	3	4	5	6	7	F (6,194)	p
Total sleep time (hrs)	M	8·43	7·00	7·42	7·57	7·22	7·44	7·24	6·95	0·001
	SD	2·15	1·24	1·05	1·38	1·50	1·11	1·18		
Latency to sleep (min)	M	16	11	11	13	16	14	12	2·42	0·03
	SD	18	09	06	11	25	10	11		
Self-reported stress	M	6·51	5·59	5·22	4·97	5·40	5·35	5·76	3·44	0·003
(1 = stress, 9 = relaxed)	SD	2·19	1·91	1·83	1·76	1·78	2·12	1·77		
Mealtime adjustments	M	09	15	19	30	25	30	36	4·31	0·001
(average percent)	SD	26	36	39	46	43	46	48		
Exercise periods	M	53	33	35	30	41	28	22	4·69	0·001
(average percent)	SD	50	47	46	46	50	46	42		

As shown in the tables, self-reported total sleep time was highest before the first workday under either schedule and declined progressively under the 12-h schedule. Total sleep time remained fairly stable under the 8-h schedule. Napping frequency declined across the 12-h week. Latency to sleep decreased across the first four days of either schedule then increased slightly during the 8-h schedule. Depth of sleep increased across the 12-h week. Self-reported stress increased across both weeks. There was a statistically significant shift by day interaction, $F(11,63) = 5{\cdot}81$, $p < 0{\cdot}001$, under the 8-h schedule. The greatest increases in reported stress occurred on the fourth through sixth consecutive day shifts.

Missed social events and personal schedule adjustments increased across the 12-h workweek and the amount of exercise decreased across both workweeks. Mealtime adjustments decreased across the 12-h week.

4. Discussion

4.1. *NIOSH fatigue test battery*

The regression analysis revealed an overall decline in alertness even after seven months of adaptation to the new schedule. After accounting for practice, there were statistically significant schedule differences in two performance tasks, and decrements with time-on-shift in four performance tasks and subjective sleepiness. In no case did the 12-h schedule result in better performance/alertness scores. Thus, the extra worktime per day is a major factor producing poorer scores during the 12-h schedule.

It might be suggested that boredom with the computerized tests contributed to poorer performance since most operators had performed them more than 30 times by the end of the seven month evaluation. However, boredom with the tests does not explain declines with

Table 4. Means across the 12-h/4-day week for significant variables in the daily sleep and habits questionnaire.

		Workday				*F*	
		1	2	3	4	(3,150)	*p*
Total sleep time (hrs)	*M*	7·33	7·03	6·58	6·48	3·56	0·02
	SD	2·02	1·80	1·07	1·18		
Naps (average percent)	*M*	17	09	07	05	7·18	0·001
	SD	27	22	20	19		
Latency to sleep (min)	*M*	21	11	10	10	3·21	0·03
	SD	34	10	11	06		
Sleep depth rating	*M*	6·15	6·66	6·62	6·96	3·15	0·03
(1 = light, 9 = deep)	*SD*	1·80	1·46	1·74	1·86		
Self-reported stress	*M*	7·18	5·34	5·37	4·88	44·26	0·001
(1 = stress, 9 = relaxed)	*SD*	1·37	1·43	1·38	1·79		
Gastro-intestinal state	*M*	7·22	7·14	6·88	6·86	4·00	0·01
(1 = nausea, 9 = fine)	*SD*	1·59	1·42	1·78	1·88		
Missed social events	*M*	17	21	27	17	3·41	0·02
(average percent)	*SD*	31	31	34	33		
Schedule adjustments	*M*	05	04	04	16	3·56	0·02
(average percent)	*SD*	19	13	14	33		
Mealtime adjustments	*M*	76	61	57	50	13·54	0·001
(average percent)	*SD*	35	44	41	46		
Exercise periods	*M*	46	13	13	19	14·77	0·001
(average percent)	*SD*	42	25	28	37		

time-on-shift because the participants rarely took the battery more than once or twice a day. Other factors not specifically associated with reduced alertness or fatigue might also account for some of the overall differences attributable to type of schedule (in the grammatical reasoning and dual reaction time tasks). However, fatigue as a potential contributing factor to this parameter can not be excluded. It is possible that there were cumulative fatigue effects which built up over time under the new schedule. These effects could be reflected in the overall performance level on the grammatical reasoning and dual reaction time tests. Since those tests were performed together, it may take a task of that level of complexity to be sensitive to cumulative fatigue effects.

From these results it may be tempting to conclude that the 12-h schedule is inferior. However, the analysis of consecutive days worked revealed some improvements in performance across the 12-h/3–4 day week. No such improvements were apparent over the 8-h/5–7 day week. Thus, some of the disadvantages of the longer workday may be offset by the shorter workweek. We make that suggestion with caution, however, since less frequent test battery participation in the latter days of the 8-h/5–7 day week might have weakened the power to detect effects.

Other trade-offs in the schedule will depend on operational considerations. For example, at 1600 h the individuals on the 8-h swing shift are fresh while those on the 12-h day shift are more fatigued. At 1900 h the 12-h night shift is fresh and the 8-h swing shift is more fatigued. Thus, advantages of either schedule will depend on what is required of the operator at those times. Night shift is still night shift, however, and the early morning hours may be worse under the 12-h shift because the operators have worked more consecutive hours by that time.

4.2. *Daily sleep and habits questionnaire*

Under the new work schedule, the operators reported fairly normal sleep but not enough of it. That is, they reported being able to fall asleep easily, they did not awaken often, and they rated their sleep as fair to good. These results indicate that the workers slept well when they wanted to, but often sacrificed sleep to accomplish non-work activities on workdays. Times of retiring under the different schedules support this assertion. Median bedtime after night shift was adjusted 2 h earlier (0923 vs 1108 h) under the new schedule while bedtime after day shift remained virtually the same (2144 vs 2147 h).

Analysis of sleep patterns within each work schedule revealed that total sleep time and napping decreased across the 12-h/4 day workweek. These results suggest an accumulating sleep debt which could affect performance and alertness (Carskadon and Dement 1981, Webb and Agnew 1974). The decrease in sleep latency and the increase in depth of sleep across that workweek also suggest a cumulative sleep debt (Carskadon and Dement 1981, Rosa and Bonnet 1985).

The other variables in the questionnaire showed mixed results under the new schedule. Most measures were poorest at night and remained that way under the new schedule. One exception was stress which was consistently higher on the day shift. We suspect that day stress was highest because of increased activity and more varied job demands at those times.

Gastro-intestinal function appeared better on the 12-h night shift as compared to the 8-h night shift. However, this 'improvement' may be an artifact of differences in the time of questioning (circa 2400 h under the 8-h schedule vs 1900 h under the 12-h schedule). Since gastro-intestinal problems are reported most frequently during night shift (Carpentier and Cazamian 1977), future studies will sample in the early morning hours to determine if the present relationship still holds.

5. Concluding comments

The results indicate sufficient decrements in alertness and disruptions of sleep to warrant three-year follow-up testing currently under way. This testing will allow us to further track adaptation, if any, to the new schedule. It is possible that seven months was not enough time to adapt to the new routine.

In closing, we note that the new compressed workweek is quite popular since more than 80% of the employees voted to retain the new work schedule after a one-year trial period. Interviews with plant employees suggest that the extra days off are valuable for social and other personal pursuits. It seems, then, that the workers are willing to tolerate greater fatigue and loss of sleep for the social gain. But what is the cost?

At this point, it is difficult to speculate on the magnitude of risk associated with the decrements in alertness, or the partial sleep deprivation we have observed. There is no heuristic available to translate, for example, a 10% change in reaction time into some safety or health consequence. Accidents and injuries, the usual outcome measures of risk assessment in this arena, are infrequent events which yield little information over our relatively short observation period. However, plant management has concluded that overall plant performance was unchanged under the new schedule. While their conclusions are reassuring in terms of plant efficiency, it is important to consider the worker's well-being within a broader context than job performance. Impaired performance and alertness attributable to night work, extended workdays, or sleep debt can also affect safety and efficiency off the job. Right now we can not estimate the magnitude of that risk, but the present investigation emphasizes the possibility of such risk.

Note

1. During the first phase of the study, the operators were required to add 8 to the initial sum in the digit addition task. In the second phase, they were required to add a randomly generated constant between 3 and 9. This change was in response to frequent complaints of boredom with the task. Consequently, overall differences between the two schedules are not comparable with respect to this task. Comparisons *within* a schedule, however, can still be made.

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