

Shift length as a determinant of retrospective on-shift alertness

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Objectives This study examined the combined effects of shift length (8 versus 12 hours) and night-to-morning-shift changeover time (0600 versus 0700) on retrospective on-shift alertness ratings.

Methods An abridged version of the Standard Shiftwork Index, which included retrospective alertness ratings, was completed by 4 groups of industrial shift workers. Two groups worked 8-hour shift systems and started their morning shifts at either 0600 or 0700; the other 2 groups worked 12-hour systems, starting their day shifts at either 0600 or 0700.

Results The 8-hour workers reported considerably higher levels of alertness in the afternoon, while the 12-hour workers were more alert than the 8-hour workers in the morning and at 2200. Workers who started their shift around 0600 were less alert during the morning than those who started around 0700. The data suggested that the combined effects of working 8-hour shifts and starting the morning shift at around 0600 have particularly deleterious effects upon alertness.

Conclusions Effects on alertness can be explained in terms of differences in elapsed time on duty, sleep duration, sleep disruption, and chronic fatigue. The findings of this study appear to contradict previous research demonstrating that the major deleterious effects of extended shifts and delayed changeovers upon alertness occur at night. However, it is acknowledged that the absence of a difference in alertness at night may have been due to floor effects. Nevertheless, the implications of the alertness ratings for performance and safety, particularly during the afternoon, should not be ignored.

Key terms safety, shift systems, shift timing, 12-hour shifts.

Many serious incidents have been caused or exacerbated by human error at times when sleepiness is high and performance capabilities are depleted. Decreased alertness towards the end of a 12-hour shift can be a major concern, particularly when the job being worked is highly monotonous and sedentary, such as monitoring screens, or requires continuous heavy physical activity. Decrements in performance and alertness have been observed in the last hours of extended work shifts (1). Declines in alertness are the most apparent at night, when lowered circadian arousal adds to fatigue resulting from extended hours of work (2, 3). However, in their comparison of 8- and 12-hour systems, Tucker et al (4) report that the greatest differences in alertness exhibited by workers on the 2 systems occurred in the afternoon, when the 8-hour workers had just begun their afternoon shift and the 12-hour workers were in the second half of their day shift.

Several studies have examined performance on mental or psychomotor tests administered at regular intervals

over the duration of 8- and 12-hour shifts. These studies have also tended to report detrimental effects on performance from working extended shifts, especially on night shifts (5, 6). However, a study of computer operators found no apparent costs, in terms of productivity, of a change from 8-hour to 12-hour shifts (7). Even under conditions of high physical work load, a study of mine workers found no differences in levels of fatigue between workers on 8- and 12-hour shifts (8). Another study observed improved performance following the introduction of 12-hour shifts; this was attributed to improved shift hand-overs (ie, when the workers at the end of a shift hand over their duties to their replacements), decreased turnover, and better employee attitudes and communications (9).

Thus, while there is a great deal of interest in the desirability of extended shifts, there is a lack of consensus over their potential detrimental impact. Moreover, there is no published research on how shift length interacts

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with differences in night-to-morning-shift changeover time. The current study examines these 2 aspects of shift-system design in combination.

Subjects and methods

A questionnaire was distributed to volunteers in 17 manufacturing and engineering companies. The sample of respondents comprised 2 groups of workers who started their morning or day shifts at 0600 and worked either 8-hour (N=171) or 12-hour (N=335) shift systems and 2 groups who started at 0700, working either 8-hour (N=89) or 12-hour (N=267) systems. The shift systems examined were all rapidly rotating continuous systems, usually involving 4 teams. Virtually all of the 8-hour systems were advancing or delaying 2—2—3 systems. The 12-hour systems all involved 2 successive day shifts followed by 2 successive nights. For about one-third of the volunteers, the 2 shifts were separated by 2 days of rest. For the remainder, the 1st night shift started 24 hours after the end of the 2nd day shift. Ninety-eight percent of the sample were men, and 89% were married or living with a partner.

The respondents completed a set of retrospective alertness rating scales (10), which were incorporated into a revised version of the Standard Shiftwork Index (SSI) (11) called the Survey of Shiftwork (SOS). The SOS also incorporated items measuring sleep duration and disruption, chronic fatigue (defined as “a general persistent tiredness and lack of energy irrespective of whether an individual has had enough sleep or has been working hard, and which persists even on rest days and holidays”), health and well-being, and biographic information. The results of the analysis of the data relating to health and

well-being have been reported elsewhere (12). The retrospective alertness rating scales required the respondents to indicate how alert or sleepy they *normally* felt at 2 hourly intervals before, during, and after each of the shifts on which they normally worked (only on-shift data are reported). All the ratings were made at a single sitting. For night shifts they were asked to make the rating with respect to their second and subsequent successive night shifts rather than their first, so that any potential difference on the first night shift from the typically longer period of prior wakefulness would be avoided. The respondents rated how alert they felt at 2 hourly intervals on a 9-point rating scale, 1 being equal to “very sleepy” (fighting sleep) and 9 being equal to “very alert” [after Akerstedt & Gillberg (13)].

Data relating to on-shift alertness, sleep duration, sleep disruption, and chronic fatigue were subject to both an analysis of variance (ANOVA) and an analysis of covariance (ANCOVA). Potential covariates were identified by comparing the 4 groups of respondents in terms of individual differences and biographic information, as measured by the SOS. Any of the potential covariates could, in theory, impinge on any of the outcome variables, and so a significant main or interaction effect in any of these analyses resulted in the dependent variable in question being used as a covariate in the ANCOVA (table 1). In the analysis of each outcome variable, the results of the relevant ANOVA and ANCOVA were compared, and where a difference between the 2 sets of results was observed, the latter was used. This method optimizes the sensitivity of the analysis while controlling for confounding factors where appropriate (14).

The effects of shift length (8-hour versus 12-hour), time of night-to-morning changeover (0600 versus 0700) and time of day (0000 to 2200) upon on-shift alertness

Table 1. Individual difference and biographic information, as functions of shift changeover time and shift length. (SEM = standard error of the mean)

	Changeover time								Use as a covariate in the analysis of the outcome variable
	Early (morning start 0600)				Late (morning start 0700)				
	8-hour shift		12-hour shift		8-hour shift		12-hour shift		
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	
Age (years)	40.32	0.70	41.34	0.53	42.86	0.98	41.19	0.58	Yes
Number of dependents	1.24	0.09	1.43	0.06	1.10	0.12	1.29	0.07	Yes
Shiftwork experience (years)	17.57	0.71	15.03	0.53	18.50	0.98	16.88	0.58	Yes
Work experience (years)	24.22	0.76	24.92	0.57	26.33	1.06	24.70	0.62	Yes
Present rota experience (years)	10.51	0.56	6.46	0.42	13.42	0.77	11.52	0.46	Yes
Actual workhours	45.39	0.53	47.05	0.40	44.49	0.75	45.05	0.44	Yes
Average commuting time (minutes)	19.93	1.12	17.53	0.84	19.42	1.55	19.04	0.92	No
Average perceived work load	3.40	0.05	3.44	0.07	3.25	0.04	3.54	0.04	Yes
Work pace	2.70	0.09	3.08	0.07	2.88	0.13	3.09	0.08	Yes
Flexibility	5.01	0.21	5.09	0.16	4.69	0.30	4.67	0.18	No
Morningness	4.22	0.18	4.66	0.13	4.64	0.24	4.65	0.14	No
Perceived sleep need (hours)	7.50	0.09	7.04	0.06	7.37	0.12	7.31	0.07	Yes

were examined. Where there was an overlap in the data of ratings obtained from workers who were at the end of one shift and those who were at the beginning of the next (ie, at the point of shift changeover), the analysis used only ratings obtained from the latter. A separate analysis examined the effects of shift length and changeover time upon sleep duration, sleep disruption, and chronic fatigue. Post hoc analyses of significant interactions were conducted by way of additional analyses of variance, at each level of the factor under investigation. These analyses incorporated adjustments of the familywise error rate, such that criteria were adjusted for the number of multiple comparisons made within the analysis of a particular interaction (15). All post hoc analyses adopted a significance criterion of $P < 0.05$. A large proportion of the data relating to the measure of sleep disruption after the last night was found to be missing, and therefore this item was dropped from the reported analyses.

Results

In the analysis of the alertness data, there was no main effect of either shift length [$F(1, 684) = 0.12, P > 0.05$] or changeover time [$F(1, 684) = 1.58, P > 0.05$], but there was a reliable effect of time of day [$F(11, 7524) = 272.63, P < 0.001$]. There was a reliable interaction between shift length and changeover time [means (and standard errors): 8-hour early changeover = 6.16 (0.10), 8-hour late changeover = 6.49 (0.14), 12-hour early changeover = 6.33 (0.07), 12-hour late changeover = 6.25 (0.08); $F(1, 684) = 3.97, P < 0.05$], although the effect did not reach significance in the associated analysis of covariance [$F(1, 592) = 2.92, P > 0.05$]. The interaction between shift length and time of day was highly reliable [$F(11, 7524) = 27.21, P < 0.001$]. The post hoc analysis of this significant interaction indicated that the 12-hour shift workers were more alert than the 8-hour workers between 0800 and 1200 [$F(1, 687) = 10.64, P < 0.05$; $F(1, 686) = 18.19, P < 0.05$; and $F(1, 686) = 13.87, P < 0.05$, respectively] and also at 2200 [$F(1, 686) = 17.17, P < 0.05$]. However, superior levels of alertness were reported by the 8-hour workers at 1400 and 1600 [$F(1, 686) = 36.19, P < 0.05$; and $F(1, 686) = 107.47, P < 0.05$, respectively]. (See figure 1.)

There was also a highly significant interaction between changeover time and time of day [$F(11, 7524) = 21.67, P < 0.001$]. The post hoc analysis of this interaction indicated that the early changeover group was more alert at 0600 [$F(1, 686) = 56.69, P < 0.05$] and at 1800 [$F(1, 686) = 25.69, P < 0.05$], while the late changeover group was more alert from 0800 to 1200 [$F(1, 686) = 18.69, P < 0.05$; $F(1, 686) = 21.42, P < 0.05$; and $F(1, 686) = 16.76, P < 0.05$, respectively]. (See figure 2.)

Finally, there was a significant 3-way interaction between shift length, shift changeover time, and time of day [$F(11, 7524) = 6.98, P < 0.001$]. Post hoc analyses indicated that there was a significant effect of shift length at

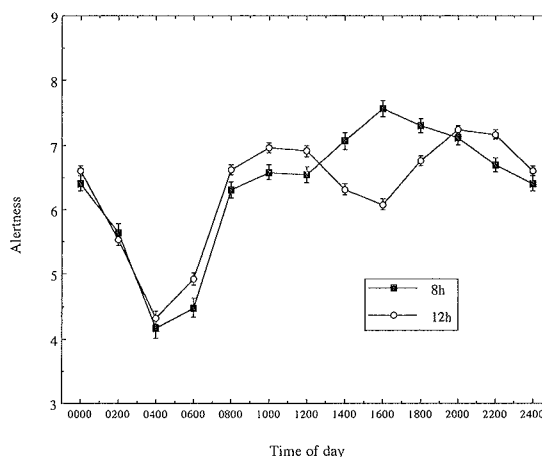


Figure 1. Alertness as a function of time of day — 8-hour versus 12-hour shift systems (means and their standard errors).

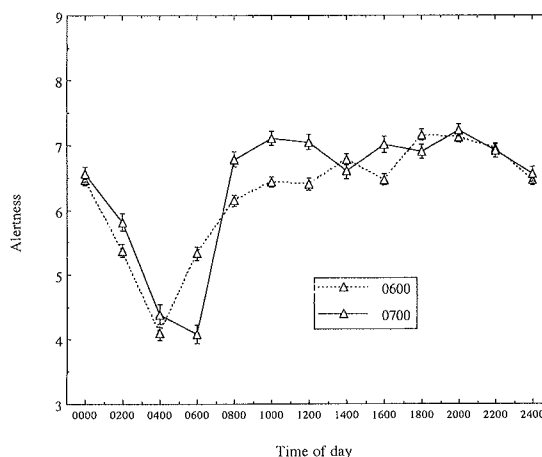


Figure 2. Alertness as a function of time of day — shift systems with early versus late changeovers (means and their standard errors).

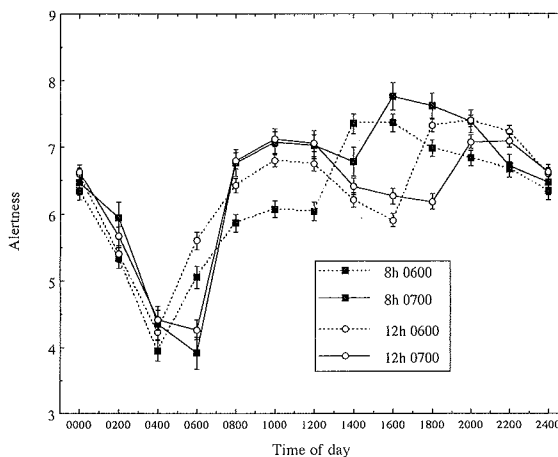


Figure 3. Alertness as a function of time of day — 8-hour versus 12-hour shift systems and early versus late changeovers (adjusted means and their standard errors).

both levels of changeover time. Figure 3 illustrates that, although the previously observed effect of shift length upon alertness in the afternoon held for both changeover times, it was shifted later in the late changeover group. Thus the difference associated with shift length occurred at 1400 [$F(1, 417) = 39.50, P < 0.05$] and 1600 [$F(1, 417) = 67.67, P < 0.05$] in the early changeover groups (the dotted lines), but at 1600 [$F(1, 267) = 46.66, P < 0.05$] and 1800 [$F(1, 267) = 40.34, P < 0.05$] in the late changeover groups (the solid lines). The post hoc analysis also indicated that there were effects of shift length that were only observed in the early changeover group between 0800 and 1200 [$F(1, 417) = 9.97, P < 0.05$; $F(1, 417) = 17.17, P < 0.05$; and $F(1, 417) = 13.20, P < 0.05$, respectively], at 2000 [$F(1, 417) = 14.50, P < 0.05$] and at 2200 [$F(1, 417) = 13.91, P < 0.05$].

Full details of the analyses of the dependent variables relating to sleep and fatigue are given in table 2. Interactions in the analyses of sleep duration suggested that the effect of early starts upon sleep duration before the first night shift was strongest among the 8-hour workers and that, while delaying changeover time has the effect

of increasing the sleep duration reported by 12-hour workers on days, it reduces the sleep duration among the 8-hour workers on the afternoon shift.

Discussion

The findings appear to contradict the widely held view that the most deleterious effects of extended shifts upon alertness are observed at night [eg, Rosa (2)], although they are in accordance with our own previous research findings on the effects of shift length (4). It should be noted that these effects were observed despite control for a wide range of variables related to individual differences, biographic details, and job context information. Nevertheless, it is possible that these findings reflect the fact that the current study examined systems which incorporated fewer consecutive shifts in a workweek than is often the case in some other countries. It seems unlikely that the direction of rotation of the 8-hour shifts has any bearing upon the results. The 8-hour sample was

Table 2. Sleep duration, sleep disruption, and chronic fatigue as a function of shift length and shift changeover time. (SEM = Standard error of the mean, df = degrees of freedom)

	Shift length								Changeover time (morning start)								Interaction	
	8-hour		12-hour		df 1	F ratio		Early (0600)		Late (0700)		df 1	F ratio		F ratio			
	Mean	SEM	Mean	SEM		Crude	Covariance	Mean	SEM	Mean	SEM		Crude	Covariance	Crude	Covariance		
Sleep duration																		
Morning versus day	5.98	0.08	6.30	0.05	759	12.08 ***	12.31 ***	5.80	0.06	6.49	0.07	759	55.19 ***	43.73 ***	2.98	2.24		
Afternoon versus day	8.23	0.08	6.30	0.05	767	423.78 ***	353.56 ***	7.46	0.06	7.08	0.07	767	16.13 ***	17.61 ***	93.70 ***	84.95 ***		
Afternoon (8-hour system only)	.	.	.	.	.	.	.	.	.	8.53	0.06	7.63	0.13	511	40.68 ***	46.88 ***		
Before 1st night	8.80	0.14	9.45	0.08	521	16.04 ***	13.78 ***	9.36	0.09	8.89	0.14	521	8.10 **	10.93 **	8.34 **	4.14 *		
Between nights	5.75	0.09	6.17	0.06	753	15.67 ***	19.06 ***	6.11	0.06	5.82	0.08	753	7.36 **	19.11 ***	0.90	0.07		
After last night	4.90	0.09	5.02	0.06	753	1.28	3.63	5.29	0.07	4.63	0.09	753	34.52 ***	37.59 ***	6.13 *	3.56		
Between rest days	8.89	0.08	8.84	0.05	737	0.35	0.37	8.98	0.06	8.75	0.07	737	6.41 *	7.95 **	3.41	0.38		
Sleep disruption																		
Morning versus day	3.15	0.05	3.03	0.03	813	3.77	1.50	3.25	0.04	2.94	0.05	813	26.24 ***	22.3 ***	1.33	0.41		
Afternoon versus day	2.40	0.05	3.03	0.03	814	120.57 ***	98.8 ***	2.80	0.04	2.64	0.04	814	7.23 **	4.48 *	2.28	2.22		
Afternoon (8-hour system only)	.	.	.	.	.	.	.	.	.	2.50	0.03	2.40	0.06	533	2.07	1.36		
Between nights	3.25	0.06	3.00	0.04	813	13.46 ***	7.53 **	3.02	0.04	3.23	0.05	813	9.88 **	11.18 **	0.40	0.12		
Between rest days	2.25	0.04	2.26	0.03	799	0.08	0.00	2.19	0.03	2.32	0.04	799	7.07 **	8.98 **	0.00	0.03		
Chronic fatigue	2.91	0.05	2.71	0.04	812	9.42 **	5.62 *	2.86	0.04	2.75	0.05	812	3.18	3.18	0.97	0.33		

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

split equally in terms of direction of rotation, and our analyses (not reported here) suggest that, while direction of rotation did have a significant effect on overall alertness levels (moderately, but significantly, favoring forward rotation), there was no interaction between direction and time of day. It is possible that the insensitivity of the measures to night-time alertness is due to the retrospective nature of the response, although such an explanation is not supported by previous research (10), which found similar effects in both concurrent and retrospective ratings of alertness.

The levels of alertness were lower among the 12-hour system workers between 1400 and 1800, but higher from 0800 to 1200 and at 2200. The difference in the afternoon coincides with the period at which there is the greatest difference between the 2 sets of workers in terms of elapsed time on the shift. In addition, the effects of differences in elapsed time on shift may have been compounded by the effects of differences in sleep disruption and duration, prior to the shift. Between successive afternoon shifts, markedly longer, less disrupted sleep was reported by the 8-hour workers than by 12-hour workers between successive day shifts. While it is true that there was relatively little difference in alertness levels between the 2 groups at night, despite smaller (but still significant) differences in the reported sleep length and disruption between successive night shifts, the differences in sleep disruption and duration between night shifts were far smaller than those on the day or afternoon shift. Moreover, differences between the 2 groups' alertness levels in the early hours of the morning may have been obscured by floor effects since the lowest overall levels of alertness occurred at this time. Workers may be reluctant to rate their alertness as being any lower than around 4 on the scale since it would constitute an admission of feeling sleepy during workhours. In other words, the range of responses may have been restricted by their proximity to a self-imposed minimum.

The difference in alertness in the afternoon has particularly important implications if an organization changes from using a 3-shift (8-hour) system to a 2-shift (12-hour) rota. Work loads should be distributed to account for critical time periods when fatigue is assumed to be high (2). Afternoons are often some of the busiest times of the day in industrial settings. Workers at the beginning of an 8-hour afternoon shift may be highly alert and fully capable of dealing with high work loads. However, our data suggest that, if a change is made to a 12-hour system, the work load should be redistributed across the

day so that workload demands are reduced in the afternoon to compensate for the lower levels of alertness among the workers.

The superior levels of alertness among the 12-hour workers in the morning and at 2200 are consistent with the difference in sleep duration that was reported by the workers on the 2 systems, when working the relevant shifts. Inspection of figure 3 indicates that the difference in alertness levels at these times is largely due to lower levels of alertness among the 8-hour workers on early changeovers, relative to their counterparts on 12-hour systems with early changeovers. The 8-hour workers on late changeovers reported levels of alertness in the morning that were equal to or higher than those reported by the 12-hour workers at that time.

Thus, while some of the largest effects of early shift changeovers were observed in the morning, the effects were greatest among the 8-hour workers at this time.³ It is suggested that this difference was due to the combined effects of early starts to morning shifts and the deleterious effects of working 8-hour shifts; the 8-hour workers experienced poorer morning shift sleep, as well as higher levels of chronic fatigue, than their 12-hour counterparts. The effects of late changeovers on night shift sleep, together with findings from previous studies (16), might have led us to expect a negative effect of late changeovers on nightshift alertness levels. Once again, the absence of such an effect on the night shift may have been due, in part, to a floor effect.

We must concede that our measures may have been insensitive to differences in alertness at night, effects which may be especially crucial since the effects of disrupted sleep may be compounded by the effects of being required to work through the circadian low point in arousal. Nevertheless, our evidence suggests that a change from 8- to 12-hour shift systems has potentially serious implications for alertness in the afternoon, a period that is traditionally one of the busiest times of day in industrial settings. In addition we have shown that, in terms of alertness, those working 8-hour shift systems are potentially at a disadvantage during the morning, as are workers who start their morning or day shift early (ie, around 0600).

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³ The differences at 0600 and 1800 were artifacts of the design. Six o'clock in the morning corresponds with the time at which the early changeover workers were at the beginning of their day or morning shift and the late changeover group was approaching the end of the night shift; similarly, 1800 corresponds with the changeover from the day shift to the night shift for the 12-hour workers.

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