Effects of direction of rotation in continuous and discontinuous 8 hour shift systems

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Abstract
***Objectives*—Previous research has produced conflicting evidence on the relative merits of advancing and delaying shift systems. The current study assessed the effects of the direction of shift rotation within 8 hour systems, upon a range of measures including sleep, on shift alertness, physical health, and psychological wellbeing.**
***Methods*—An abridged version of the standard shiftwork index which included retrospective alertness ratings was completed by four groups of industrial shiftworkers on relatively rapidly rotating 8 hour systems (n=611). Two groups worked continuous systems that were either advancing or delaying; the other two groups worked discontinuous systems that were either advancing or delaying.**
***Results*—Few effects were found of direction of rotation on chronic measures of health and wellbeing, even when the systems incorporated "quick returns" (a break of only 8 hours when changing from one shift to another). This was despite the use of measures previously shown to be sensitive to the effects of a broad range of features of shift systems. However, advancing continuous systems seemed to be associated with marginally steeper declines in alertness across the shift (F (3,1080)=2.87, $p<0.05$). They were also associated with shorter sleeps between morning shifts (F (1,404)=4.01, $p<0.05$), but longer sleeps between afternoons (F (1,424)=4.16, $p<0.05$).**
***Conclusions*—The absence of negative effects of advancing shifts upon the chronic outcome measures accorded with previous evidence that advancing shifts may not be as harmful as early research indicated. However, this interpretation is tempered by the possibility that difficult shift systems self select those workers most able to cope with their deleterious effects. The presence of quick returns in advancing continuous systems seemed to impact upon some of the acute measures such as duration of sleep, although the associated effects on alertness seemed to be marginal.**
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Shift systems can be distinguished by the direction of shift rotation involved when the worker changes from one block of shifts to the next. Thus a so called forward rotating system involves changing from morning shifts to afternoon shifts, and then from afternoons to nights. So called backward rotating systems involve changes in the opposite direction—that is, from morning shifts to night shifts, etc. Forward rotating systems are also known as delaying shift systems. They are so called because the change from one shift to the next involves delaying the phase of the body clock—that is, effectively extending the day by remaining awake for longer.

It has been commonly suggested that delaying the phase of the rhythm is more compatible with the natural endogenous rhythm of the body clock. This suggestion was based upon early research findings that the endogenous rhythm runs with a period of around 25 hours,[1] although recent research has indicated that the period may be closer to 24 hours than was previously thought.[2] In accordance with the earlier findings, it has previously been suggested that delaying systems are preferable to advancing (backward rotating) systems.[3 4] This view was confirmed by early research on the topic which found that delaying systems were associated with fewer physical, social, and psychological problems, reduced fatigue, improved sleep quality,[5–7] and were viewed more favourably by workers who had experienced both systems.[8] In a similar vein, there is some evidence to suggest that air travellers adjust more quickly to westward flights which require a delay of the body clock, than to eastward ones requiring advance.[9]

In a cross sectional comparison of delaying and advancing systems, Barton and Folkard[10] found advancing systems to be associated with poorer physical and psychological wellbeing and higher levels of chronic fatigue. However, further analyses indicated that these differences were only significant when considering advancing systems that included quick returns (a break of only 8 hours when changing from one shift to another). Advancing systems with quick returns were also associated with the highest levels of disruption to social and domestic life and the lowest levels of job satisfaction. Measures of sleep disturbance tended to favour delaying systems, although the effects were mostly non-significant. In their suggested explanation of the absence of strong effects, Barton and Folkard cited previous research findings[11] which indicated that, while the timing of the work period may be delayed, sleep onset times remain unaffected by the direction of shift rotation, as people have a choice of when to go to sleep. Thus, during a complete rotation between three shifts, the timing of sleep will be phase advanced once, phase delayed once, and not shifted once, regardless of whether or not workers are on an advancing or delaying shift system. Barton and Folkard concluded that direction of rotation may be less critical than the combination of direction of rotation and the duration of break when changing from one shift to another.

Barton *et al*[12] reported a longitudinal study of the effects of changing from a delaying to an advancing system. They found an increase in sleep difficulties between successive afternoon shifts which they attributed to undesired adaptation to working nights immediately before working afternoons. Few differences between the two types of system were found in health and wellbeing, and it was concluded that advancing shifts may not be as harmful as originally suggested. The main implications of their findings related to acute effects, although it was conceded that the 6 months over which the study was conducted may not have been sufficient time for the build up of health related problems. A further caveat to their results was that the systems under study were discontinuous and did not include any quick returns. The results of the two studies by Barton *et al* taken together suggest that further research into the deleterious effects of advancing systems should focus upon those systems which include quick returns.

We are unaware of any published work that has examined the effects of direction of rotation on shift alertness. Nevertheless, we have already found that advancing systems, and particularly those which incorporate quick returns, are associated with higher levels of chronic fatigue and more disruption of sleep, as described by Barton and Folkard.[10] Barton *et al*[12] concluded that the main implications of a change from a delaying to an advancing system related to acute negative effects, which included increased sleep difficulties between successive afternoon shifts. Thus it seems possible that advancing systems, particularly those which incorporate quick returns, may be associated with lower levels of alertness. However, there is some recent evidence which indirectly counters this prediction. Macdonald *et al*[13] found only slight evidence of a detrimental effect of the presence of quick returns within a shift schedule, on accident rates in the steel industry.

Previous research has produced inconsistent findings about the relative merits and demerits of delaying and advancing shift systems. The objective of the current study was to shed new light on this conflict, by assessing the effects of the direction of rotation within 8 hour systems, on a range of acute and chronic measures including sleep, on shift alertness, physical health, and psychological wellbeing. Alertness does not seem to have previously been examined relative to direction of rotation, and is especially salient in the light of previous suggestions that the effects of rotation are primarily acute in nature. Also, our study aims to provide a focus on the effects of quick returns. The study incorporates data from workers on both 8 hour continuous and discontinuous systems. Continuity of 8 hour systems is rarely studied in this context, as the choice of whether to implement either a continuous or discontinuous system will nearly always be based on economic considerations, rather than ergonomic ones. However, certain features of shift systems, such as the duration of rest breaks, are usually jointly determined by both the direction of rotation and by whether or not the system is continuous. Therefore it is of interest to ascertain whether continuity of a system moderates the effects of direction of rotation on outcome variables.

Methods

PARTICIPANTS AND SHIFT SYSTEMS

The participant organisations were all manufacturing companies—for example, steel, chemicals, oil, aluminium, chipboard, glassfibre, food, and metal containers. The sample comprised four groups of workers on 8 hour shifts systems, either working delaying continuous systems (n=133); advancing continuous systems (n=143); delaying discontinuous systems (n=65); or advancing discontinuous systems (n=270). All but two of the continuous systems were advancing or delaying 2-2-3 combination of mornings, afternoons, and nights (the exceptions were similar 2-2-2 systems). In this type of system, rotation is between blocks of either 2 (or 3) shifts of each type, with the block of three shifts alternating between mornings, afternoons, nights, and rest days on each cycle of the rota. The discontinuous systems were weekly rotating, involving 5 days (or 4 nights) on a given shift, followed by the weekend off. The continuous and discontinuous shift systems examined involved four and three teams, respectively. The four main types of system (including both the 2-2-3 and 2-2-2 versions of the continuous systems) are illustrated in table 1. Ninety eight per cent of the sample were men and 84% were married or living with a partner.

MEASURES

A questionnaire was distributed to volunteers at 15 United Kingdom companies which had agreed to participate in the study, through health and safety officers, personnel services managers, or occupational health doctors or nurses. It was not possible to determine the precise response rates as these were subject to the number of questionnaires that the health and safety officers, etc, chose to give out. Questionnaires were returned directly to the authors in prepaid postage envelopes.

A revised version of the standard shiftwork index (SSI) called the survey of shiftwork (SOS) was used. The major revisions included the omission of items and scales from the SSI that related to individual differences, on the basis of psychometric criteria, as well as the inclusion of new scales. This resulted in a shorter battery of scales aimed at increasing compliance and response rates. The SOS comprised a set of items and scales specifically selected for use in shiftwork research. The psychometric properties of the scales have been established as generally highly satisfactory.[14 15]

A full description of the original SSI measures, their psychometric properties, and

Table 1 Shift rotas worked by the four groups (including both 2-2-3 and 2-2-2 versions of the continuous systems), over a 28 day period

	Day																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
8h (2-2-3) Advancing continuous	M	M	N	N	A	A	A	–	–	M	M	N	N	N	A	A	–	–	M	M	M	N	N	A	A	–	–	–
8h (2-2-2) Advancing continuous	M	M	N	N	A	A	–	–	M	M	N	N	A	A	–	–	M	M	A	A	N	N	–	–	M	M	A	A
8h (2-2-3) Delaying continuous	M	M	A	A	N	N	N	–	–	M	M	A	A	A	N	N	–	–	M	M	M	A	A	N	N	–	–	–
8h (2-2-2) Delaying continuous	M	M	A	A	N	N	–	–	M	M	A	A	N	N	–	–	M	M	A	A	N	N	–	–	M	M	A	A
8h Advancing discontinuous	N	N	N	N	–	–	–	A	A	A	A	A	–	–	M	M	M	M	M	–	–	N	N	N	N	–	–	–
8h Delaying discontinuous	M	M	M	M	M	–	–	A	A	A	A	A	–	–	N	N	N	N	–	–	–	M	M	M	M	M	–	–

D=day shift; N=night shift; M=morning shift; A= afternoon shift; –=rest day.

the development of the battery were provided by Barton *et al*.[16] The composition of the battery was founded on the research evidence that the nature of the shift schedule worked can impact on both the biological and social rhythms of the shiftworker. The disturbance of biological and social rhythms may result in various problems for many shiftworkers. The most common problems can be broadly classified as acute (sleep disturbances and difficulties in maintaining alertness) and chronic (increased fatigue; impairment of physical and psychological health, and disruption to family and social life).

Acute measures used

Sleep duration—These were calculated for each shift and gave an indication of normal sleep onset and wake up times relative to the respondents' shifts and rest days. Naps were not included.

Sleep disturbance scales—These scales each comprised five items. The items asked the respondent what they thought about the amount of sleep they normally had, how well they slept, how rested they felt after sleep, whether they ever woke earlier than intended, and whether they had difficulty falling sleep. Sleep disturbance measures were obtained for morning shifts; afternoon shifts; night shifts; and rest days.

Retrospective alertness rating scales—A measure developed by Folkard *et al*.[15] It was an additional measure which was not included in the original SSI. Respondents were asked to indicate how alert or sleepy they normally felt at 2 hourly intervals before, during, and after the shifts that they normally worked. In the case of the night shift they were asked to do this for their second and subsequent successive night shifts rather than their first. This was to avoid any potential difference on the first night shift that might result from the typically longer period of wakefulness beforehand. Respondents rated how alert they felt at 2 hourly intervals on a nine point rating scale, 1 being equal to very alert and 9 being equal to very sleepy (fighting sleep). For the analyses the scales were reverse scored so that higher scores were indicative of greater alertness.

Chronic measures used

Chronic fatigue—This three item scale measured a general persistent tiredness and lack of energy irrespective of whether a person has had enough sleep or has been working hard, and which persists even on rest days and holidays.

Psychological wellbeing—The 12 item version of the general health questionnaire[17] was used. The items variously referred to the respondents emotional state and coping ability. This is a standardised screening test for detecting minor psychiatric disorders in the general population. In the current study, it was used as a single measure of mental health over the past few weeks which was computed by adding individual scores on the 12 items.[18]

Neuroticism—This was a six item scale extracted from the 12 item Eysenck personality inventory.[19] Neuroticism has been found to act as an outcome variable in previous shiftwork research.[20 21]

Physical health questionnaire—Two subscales, each of eight items, measured the incidence of symptoms of digestive problems and symptoms that may be associated with cardiovascular disease, and there was a single item which measured susceptibility to minor infectious diseases. Also, four items indexed the experience of musculoskeletal pain in different parts of the body.

Social and domestic disruption—Three independent items were used to measure the degree of interference of the shift system in social life, domestic life, and non-domestic life—for example going to the doctor, dentist, or bank.

Shift system advantages—This single item asked the question "Do you feel that overall the advantages of your shift system outweigh the disadvantages?" It was scored on a five point Likert scale so that higher scores were associated with more negative attitudes towards their shift system.

As well as these outcome variables, the questionnaire also tapped a set of moderator variables.

Moderator variables

Biographical information—This included questions on age, sex, marital status, numbers of dependants, duration of experience of work, shiftwork, and their current rota, contracted and actual work hours, shift changeover time, and time taken to travel to and from work for each shift.

Workload scale—A single item measure of perceived workload on each shift.

Table 2 Individual difference and biographical information, as functions of direction of rotation and continuity (adjusted means)

	Continuous				*Discontinuous*							
	Delaying		*Advancing*		*Delaying*		*Advancing*					
	mean	*SEM*	*mean*	*SEM*	*mean*	*SEM*	*mean*	*SEM*	*df*	*F* Direction	*F* Continuity	*F* Interaction
Age (y)	41.69	0.88	40.99	0.85	40.36	1.30	37.90	0.73	1,523	2.69	5.24*	0.823
Number of dependants	1.12	0.10	1.32	0.10	1.13	0.15	1.21	0.08	1,508	1.55	0.19	0.35
Shiftwork experience (y)	18.56	0.89	17.17	0.86	15.84	1.29	11.83	0.74	1,528	7.80**	17.41***	1.83
Work experience (y)	25.57	0.94	24.73	0.90	24.00	1.41	20.66	0.78	1,521	4.05*	7.41**	1.46
Present rota experience (y)	13.22	0.72	9.79	0.69	9.98	1.04	7.39	0.59	1,527	15.04***	13.20***	0.29
Actual work hours	45.29	0.61	44.89	0.58	45.80	0.86	42.19	0.50	1,515	9.40**	2.82	6.05*
Contracted work hours	38.47	0.28	40.32	0.26	40.56	0.40	38.12	0.22	1,525	0.96	0.04	52.06***
Average commuting time (mins)	19.52	1.50	19.82	1.44	24.00	2.17	19.26	1.23	1,531	1.87	1.45	2.40
Perceived workload:												
Morning	3.69	0.07	3.58	0.06	3.68	0.10	3.47	0.06	1,522	4.66*	0.79	0.43
Afternoon	3.43	0.06	3.47	0.06	3.53	0.10	3.33	0.05	1,521	1.47	0.06	3.32
Night	3.07	0.07	3.33	0.06	3.45	0.10	3.18	0.06	1,518	0.02	2.51	13.24***
Work pace	2.83	0.11	2.73	0.10	2.98	0.16	2.92	0.09	1,521	0.48	2.08	0.03
Flexibility	4.95	0.25	4.97	0.24	4.56	0.36	5.16	0.21	1,531	1.35	0.14	1.14
Morningness	4.50	0.22	4.36	0.21	5.25	0.31	4.78	0.18	1,528	1.70	6.26*	0.52
Perceived sleep need (h)	7.42	0.10	7.43	0.10	7.28	0.15	7.18	0.08	1,526	0.19	3.22	0.26
Shift changeover time (night to morning)	06:37	2 min	05:55	2 min	05:59	3 min	06:00	2 min	1,524	70.56***	43.40***	76.09***

*p<0.05; **p<0.01; ***p<0.001.

Job pacing scale—A single item measure of the level of control an individual has over the pacing of her or his work.

Morningness scale—A single item measure, which gave a measure of individual preferences or predisposition towards greater activity earlier or later in the day.

Sleep flexibility scale—This was a single item measure, derived from the circadian type inventory.[22] It measured the ability to sleep at unusual times and in unusual places.

Sleep need—A single item which provided an indication of the duration of sleep an individual perceived herself or himself to need each day irrespective of which shift they were working.

Despite the efforts made to reduce the length of the questionnaire compared with the original SSI, the SOS would exact a cost in effort and time to complete. Thus, as expected with such a large sample, there were data missing across the full range of SOS scales. This inevitably affects the numbers on which the following results are based.

ANALYSES

A series of two way analyses of covariance (ANCOVA) were conducted on the outcome variables derived from the SOS measures to examine differences between the four groups. Each analysis examined the factors between groups direction of rotation (delaying versus advancing) and continuity of system (continuous versus discontinuous). As well as the two factors between groups, the analysis of the alertness data also incorporated the factor time of day (12 levels) within groups. Covariates were included in the analysis to avoid confounding the effects of direction of rotation with other factors—such as differences in work environment between the participant organisations—as well as individual differences. The list of covariates was derived from the moderator variables already described. Virtually any of the potential confounders could, in theory, impinge on any of the outcome variables. Therefore, as a general rule, all covariates were included in the analysis of each outcome variable. Two exceptions were made to this rule. Firstly, contracted work hours were excluded in favour of actual work hours, which was deemed more salient. Secondly, the analyses of duration of sleep and sleep disturbance on a particular shift only incorporated the relevant measures of perceived work load as covariates, rather than incorporating all three work load measures.

Later analyses of significant interactions between groups were conducted by additional analyses of covariance, at each level of the factor under investigation. These incorporated adjustments of the familywise error rate (the probability that a set of multiple comparisons will contain at least one type I error), such that criteria were adjusted for the number of multiple comparisons made within the analysis of a particular interaction.[23] All later analyses adopt a significance criterion of $p<0.05$. Unless stated otherwise, higher scores are associated with experiencing more of the problem being measured. Reanalyses of the data excluding the 2% of women in the original sample produced only minor changes in the patterns of results reported.

Analyses of variance (ANOVA) were conducted to compare the groups in terms of the moderator variables. The results of these analyses are summarised in table 2. The delaying group had longer experience of working ($F_{(1,521)}=4.05$, $p<0.05$), shiftworking in general ($F_{(1,528)}=7.80$, $p<0.01$), and of their present rota in particular ($F_{(1,527)}=15.04$, $p<0.001$). The delaying group also worked longer actual hours ($F_{(1,515)}=9.40$, $p<0.01$). The delaying group reported higher levels of perceived work load on the morning shift ($F_{(1,522)}=4.66$, $p<0.05$). The delaying group had a later night to morning shift changeover ($F_{(1,524)}=70.56$, $p<0.001$). The mean age of the continuous group was higher than that of the discontinuous group ($F_{(1,523)}=5.24$, $p<0.05$). The continuous group also had greater work experience ($F_{(1,521)}=7.41$, $p<0.01$), longer experience of shiftworking ($F_{(1,528)}=17.41$, $p<0.001$), and longer experience of the current rota ($F_{(1,527)}=13.20$, $p<0.001$). They reported a lower mean level of morningness ($F_{(1,528)}=6.26$, $p<0.05$). They also reported a later mean night to morning shift changeover time (F

Table 3 Summary of the analysis of the effects of direction of rotation and continuity of system on the sleep measures (adjusted means)

	Continuous				Discontinuous							
	Delaying		Advancing		Delaying		Advancing					
	mean	SEM	mean	SEM	mean	SEM	mean	SEM	df	$F_{Direction}$	$F_{Continuity}$	$F_{Interaction}$
Sleep duration (h):												
Morning	6.13	0.13	5.55	0.11	6.26	0.19	6.24	0.10	1,404	4.66*	8.49**	4.01*
Afternoon	8.22	0.12	8.81	0.12	8.14	0.17	8.19	0.10	1,424	5.71*	7.24**	4.16*
Before 1st night	8.89	0.20	9.18	0.15	9.20	0.25	9.03	0.14	1,286	0.10	0.16	1.42
Night	5.78	0.14	6.05	0.12	6.61	0.19	6.47	0.11	1,421	0.19	18.41***	1.92
After last night	4.87	0.17	5.17	0.15	5.53	0.24	5.62	0.14	1,413	1.20	9.17**	0.35
Rest	9.00	0.14	8.90	0.12	9.06	0.20	9.18	0.12	1,392	0.01	1.23	0.54
Sleep disturbance:												
Morning	3.14	0.08	3.24	0.07	3.01	0.10	3.12	0.06	1,440	1.84	2.48	0.00
Afternoon	2.37	0.07	2.45	0.06	2.43	0.09	2.58	0.05	1,440	2.70	1.90	0.31
Night	3.28	0.08	3.05	0.07	2.96	0.10	3.24	0.06	1,440	0.06	0.66	9.44**
After last night	3.54	0.16	3.64	0.10	3.32	0.13	3.44	0.08	1,240	0.80	3.04	0.00
Rest	2.29	0.06	2.13	0.06	2.22	0.08	2.13	0.05	1,427	1.08	0.32	0.28

*=p<0.05; **p<0.01; ***p<0.001.

(1,524)=43.40, p<0.001), although a significant interaction between direction of rotation and continuity (*F* (1,524)=76.09, p<0.001) indicated that this was only true for the continuous group. Also, there were significant interactions between direction of rotation and continuity in the number of actual work hours (*F* (1,515)=6.05, p<0.05), the number of contracted work hours (*F* (1,525)=52.06, p<0.001), and in the levels of perceived work load on the night shift (*F* (1,518)=13.24, p<0.001).

Results

ACUTE MEASURES

The results of the analyses of the sleep measures are summarised in table 3. Workers on advancing systems reported shorter sleeps between successive morning shifts (*F* (1,404)= 4.66, p<0.05), but longer sleeps between successive afternoons (*F* (1,424)=5.71, p<0.05). However, analysis of the interactions between continuity and direction of rotation indicated that these effects of direction of rotation were only present within the sample of continuous workers (*F* (1,404)=4.01, p<0.05; and F (1,424)=4.16, p<0.05, respectively). By comparison with the other three subgroups in the analysis, those working advancing continuous systems achieved less sleep between successive morning shifts, but longer sleeps between afternoon shifts.

Continuous systems were associated with shorter sleeps between successive morning shifts (*F* (1,404)=8.49, p<0.05) and longer sleeps between successive afternoon shifts (*F* (1,424)=7.24, p<0.01) (but note the interactions described above). Also, continuous systems were associated with shorter sleeps between successive night shifts (*F* (1,421)=18.41, p<0.001) and after the last night shift (*F* (1,413)=9.17, p<0.01). Another interaction suggested that those working either delaying continuous or advancing discontinuous systems experienced greater sleep disruption between successive night shifts than the other two groups (*F* (1,440)=9.44, p<0.01).

The results of a four way analyses of the retrospective alertness ratings as a function of time on shift, shift, direction of rotation, and continuity are reported in table 4. There was a significant main effect of shift (*F* (2,720)=4.52, p<0.05) and a significant interaction between time on shift and shift (*F* (6,2160)=3.78, p<0.05), as illustrated in figure 1.

There was also a marginally significant three way interaction between time on shift, direction of rotation, and continuity, such that the most rapid decline, to the lowest level of alertness was found over duration of shift among the advancing continuous group (*F* (3,1080)=2.87, p<0.05), as illustrated in figure 2.

Table 4 Retrospectively rated alertness as a function of time on shift; analysis of covariance, examining direction of rotation and continuity

	df	F
Effects between groups:		
Direction	1,360	1.24
Continuity	1,360	0.24
Direction×continuity	1,360	0.89
Effects within groups:		
Shift	2,720	4.52*
Shift×direction	2,720	1.91
Shift×continuity	2,720	0.16
Shift×direction×continuity	2,720	1.27
Time on shift	3,1080	2.41
Time on shift×direction	3,1080	0.65
Time on shift×continuity	3,1080	0.74
Time on shift×direction×continuity	3,1080	2.87*
Shift×time on shift	6,2160	3.78**
Shift×time on shift×direction	6,2160	0.25
Shift×time on shift×continuity	6,2160	0.46
Shift×time on shift×direction×continuity	6,2160	0.12

*p<0.05; **p<0.01.

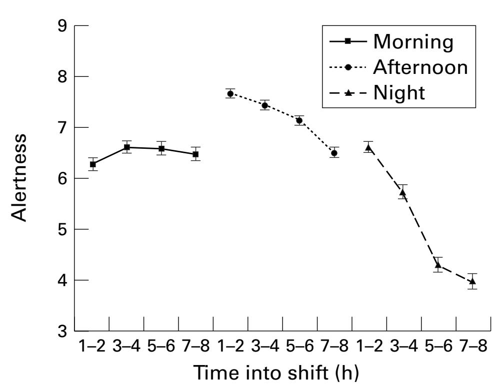

Figure 1 Adjusted mean levels of retrospectively rated alertness as a function of shift and time into shift; vertical lines depict the SEMs.

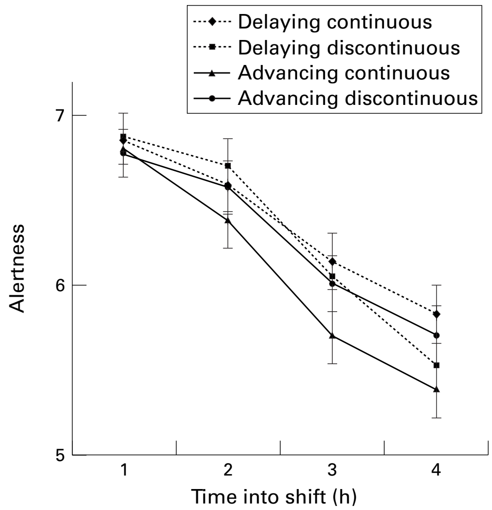

Figure 2 Adjusted mean levels of retrospectively rated alertness as a function of shift system and time into shift; vertical lines depict the SEMs.

CHRONIC MEASURES

There was no effect of direction of rotation on any of the chronic outcome measures. The discontinuous workers reported greater incidence of musculoskeletal pain (F (1,435)=6.19, p<0.05). They also reported higher levels of interference with their domestic life (F (1,434)=6.81, p<0.01) and they rated themselves as less satisfied that the advantages of their system outweighed the disadvantages (F (1,431)=19.09, p<0.05, table 5).

Discussion

The findings seem to be generally supportive of the conclusions reached by Barton *et al*,[10 12] that the effects of direction of rotation are primarily acute in nature, and act in combination with the effects of the duration of the break when changing from one shift to another. As has already been noted, it is rare that ergonomic considerations play a significant part in the choice of whether to implement either a continuous or discontinuous system, and so discussion of continuity will be limited to the manner in which this factor moderates the effects associated with direction of rotation.

Interactions were found in the analyses of the data on duration of sleep which indicated that observed differences between advancing and delaying systems were only significant when the systems in question were continuous. Similarly, there was some evidence from the retrospectively rated alertness data which suggested that the advancing continuous group showed the most rapid decline in alertness levels over the duration of the shift, to the lowest level of alertness that was found among the four groups. However, the size of this effect was marginal.

There was more than one difference between the features of the continuous and discontinuous systems (the speed of rotation, the duration of a break when changing from one shift to the next). This is potentially problematic when attempting to explain the interactions between continuity and direction of rotation found in the acute measures. Nevertheless, there was compelling evidence to suggest that the unique presence of quick returns within the advancing continuous systems was responsible for the negative impact on at least some of the acute measures within this group. By comparison with the other three subgroups, the workers on this system reported longer sleeps between afternoon shifts, but shorter sleeps between successive morning shifts. Quick returns were most likely to feature in the change from night to afternoon shifts, and so the long sleeps between afternoon shifts can be attributed to the need to recover from this shift changeover. This conclusion is supported by the fact that the sleeps between afternoon shifts were longer than the amount of sleep that respondents said that they would ideally need, under normal circumstances.

The shorter sleeps between successive morning shifts may be associated with circadian adaptation, after the prolonged recovery sleeps that are associated with the afternoon shift. Phase delay of the sleep-wake cycle is associated with both later sleep onset times and later waking times. Even if the changeover from afternoon to morning shift does not involve a quick return, it is still quite likely that any phase delay of the sleep-wake cycle that is facilitated by prolonged recovery sleeps while working afternoons, could easily be carried through intervening rest days. The consequence of sleeping longer and waking later when working afternoons, would therefore be increased difficulty in advancing sleep onset to prepare for an early starting morning shift.

Table 5 Summary of the analysis of the effects of direction of rotation and continuity of system on the chronic outcome measures (adjusted means)

	Continuous				*Discontinuous*							
	Delaying		*Advancing*		*Delaying*		*Advancing*					
	mean	*SEM*	*mean*	*SEM*	*mean*	*SEM*	*mean*	*SEM*	*df*	$F_{Direction}$	$F_{Continuity}$	$F_{Interaction}$
Chronic fatigue	2.93	0.10	2.97	0.08	2.88	0.12	2.84	0.07	1,434	0.00	0.83	0.14
GHQ (mental health)	11.00	0.55	11.28	0.46	11.01	0.71	11.84	0.42	1,427	0.98	0.26	0.24
Neuroticism	2.12	0.06	2.02	0.05	1.91	0.08	2.01	0.05	1,435	0.00	2.82	2.28
Digestive problems	13.74	0.54	14.11	0.45	14.51	0.69	15.37	0.41	1,435	1.28	3.41	0.20
Cardiovascular problems	10.42	0.40	10.84	0.34	10.66	0.52	11.49	0.31	1,435	2.33	1.17	0.24
Infectious diseases	1.98	0.08	1.91	0.07	2.00	0.11	1.96	0.06	1,435	0.36	0.18	0.03
Pain	1.84	0.08	1.85	0.06	2.05	0.10	2.03	0.06	1,435	0.00	6.19*	0.06
Leisure interference	3.42	0.12	3.58	0.10	3.68	0.16	3.47	0.10	1,434	0.02	0.33	2.19
Domestic interference	3.07	0.13	3.19	0.11	3.47	0.17	3.49	0.10	1,434	0.28	6.81**	0.14
Non-domestic interference	2.09	0.14	1.99	0.12	2.25	0.18	2.33	0.10	1,434	0.00	3.13	0.42
Advantages outweigh disadvantages?	2.84	0.14	2.85	0.12	3.58	0.18	3.34	0.10	1,431	0.66	19.09***	0.86

*p<0.05; **p<0.01; ***p<0.001.

The current findings fail to support those earlier studies—for example, Barton and Folkard[10]—which have indicated that advancing systems are associated with poorer health and wellbeing, particularly when the systems incorporate quick returns. It is worth pointing out that the current results were obtained with measures which have previously been shown to be sensitive to the effects of a broad range of features of shift systems. It could be argued that the necessity of including many covariates in the analysis will have reduced the sensitivity of the comparisons. Although this point must be conceded, it should be noted that additional unreported analyses that we have undertaken suggest that the inclusion of the covariates had little overall impact on the general pattern of results.

Taken in conjunction with recent evidence that the intrinsic period of the human circadian pacemaker may be closer to 24 hours than had previously been thought,[2] the current findings seem to lend support to the conclusion reached by Barton *et al*[12] that advancing shifts in themselves may not be as harmful as originally suggested. Moreover, unlike the earlier longitudinal study, the absence of chronic effects are unlikely to simply reflect the participants' limited experience of advancing systems. However, we must concede that the cross sectional nature of the study introduces other methodological difficulties which may have obscured long term effects. For example, workers with adverse reactions to a particular shift schedule could have left jobs that require that schedule and thus we must remain cautious of the apparent absence of chronic effects.

In conclusion, there were relatively few effects of direction of rotation upon chronic measures of health and wellbeing. It is suggested that the effects found in the analysis of the acute measures derived from the combined effects of direction of rotation and the presence of quick returns in the advancing continuous system.

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