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Tolerance to shift work—how does it relate to sleep and wakefulness?

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Abstract ***Objectives***: There is limited knowledge as to why some individuals tolerate shift work and others do not. As a consequence of their intolerance, many individuals develop dissatisfaction with their shift schedule. To evaluate if dissatisfaction with one's shift system was related to alterations of the daily pattern of sleep and sleepiness, we followed two groups of shift workers that were either highly satisfied or dissatisfied with their shift schedule, during an entire shift cycle. ***Methods***: Thirty-six male and 20 female shift workers were selected according to their satisfaction with their shift schedule. The shift cycle included seven work periods (“triads” of shifts; night shift—afternoon shift—morning shift), with only 8–9 hours off (quick returns) between shifts, but followed by a day off. ***Results***: Sleep length was reduced after night shifts (4.8 h) and afternoon shifts (5.4 h). Sleepiness was increased during all shifts, particularly night shifts. Sleepiness did not accumulate across the shift cycle even though sleepiness was slightly increased directly after the last triad of shifts. There were few significant gender differences. Dissatisfied shift workers reached much higher levels of sleepiness and reported less sufficient sleep, but not objectively poorer or shorter sleep. Amongst dissatisfied workers, this resulted in an increase of sleepiness problems across shifts within the triad of shifts. Dissatisfied workers also had more performance lapses at the end of the night shift. ***Conclusions***: Satisfaction with the shift schedule seems to reflect how well the shift workers were coping with the schedule. It is suggested that the increase of sleep/wake problems within the work period for the dissatisfied shift workers is related to increased sensitivity to curtailed and displaced sleep.

Keywords Shift work · Quick returns · Satisfaction · Gender · Partial sleep deprivation

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Introduction

Shiftwork is associated with several health-related problems, in particular disturbed sleep and fatigue [2]. However, problems are not uniform among shift workers, and some suffer while others thrive. It is likely that suffering will be related to turnover, absenteeism and productivity [8, 26, 32]. In addition, the degree of suffering will be reflected in the attitude, i.e. satisfaction, to the present work hours, and this is evidenced in several studies of satisfaction in relation to individual factors, organizational issues, social/family life, free time, health problems, sleepiness, sleep disturbances, sleep flexibility and the ability to overcome drowsiness [12, 14, 21, 22, 24, 29, 31, 34, 35].

In the studies above, overall, problems are, as expected, related to dissatisfaction, but there are only two studies that have tried to tease out in a multivariate fashion which major shift-related factors determine satisfaction [18, 21]. The first study included only a few sleep characteristics and individual factors [18], while the second found that sleepiness was the only significant predictor of dissatisfaction with the shift schedule [21]. Presumably, knowledge about what aspects of the schedule that explain dissatisfaction may indicate where improvements can be instituted. Similar gains may be made from knowledge about the characteristics of those resistant to the difficulties of shift work.

In a recent study we selected satisfied and dissatisfied individuals and used a multiple logistic regression analysis of the major predictors of “satisfaction with their work hours" (J. Axelsson, T. Åkerstedt, G. Kecklund, A. Lowden, manuscript submitted). The results show that general sleep quality and global anxiety/depression symptoms were the major determinants among a large set of predictors (age, gender, marriage status, body mass index, diurnal type, sleep flexibility, health problems, sufficient time for social activities, etc.). However, it was also found that a key factor behind both may be the lack of sleep in-between shifts.

The present paper constitutes an in-depth analysis of exactly what phase of the shift cycle is related to the differences in satisfaction and, specifically, the problems of sleep and fatigue (or sleepiness). The study was intended to maximize the presumed difficulties, and we therefore selected an extremely rapidly rotating shift system with only 8 h between the night, evening and morning shifts. Such quick returns (only 8 h off between shifts) are known to limit recovery [5, 23, 27]. In the present case, we had two quick returns in 36 h. Furthermore, the shift cycle extended across 28 days, making accumulation of sleepiness/fatigue probable. A particular effort was made to control for gender effects.

Subjects and methods

Of 368 full-time shift workers working at a paper and pulp factory, 317 filled out a questionnaire concerning background (age, gender, etc.), work situation, health symptoms (including sleep items) and well being [19]. Sleep items in the present study included "diurnal type " (1 = pronounced evening type to 4 = pronounced morning type [33]); habitual sleep need, phrased "how much sleep do you need per night?" (hours and minutes); sleep flexibility, phrased "I can sleep at any time"; ease in overcoming sleepiness, "I never worry about my sleep"; and "I can handle short sleep"; the latter four with a scale ranging from 1–4 (1 = I disagree completely to 4 = I agree completely). They also rated their satisfaction with their work hours, phrased "How satisfied are you with your present work hours?" (1 = very dissatisfied, 2 = dissatisfied, 3 = neither dissatisfied nor satisfied, 4 = satisfied, 5 = very satisfied). These ratings were used to divide the shift workers into two groups; those with a rating of 3 or lower were considered as "dissatisfied" (DIS) and those with "4" or higher were considered "satisfied" (SAT).

Of the 317 full-time shift workers (control room operators, shift engineers, machinists and shift supervisors), 100 were invited to participate in the diary/actigraphy study. This invitation was sent to those with the highest (5) and lowest (1–3) satisfaction, respectively. To obtain a sufficiently large group of satisfied women, we had to include some women who rated 4. Thirty-six were excluded [chose not to participate (11 subjects), changed to day work, changed employment, were on long-term sick leave or became pregnant]. Unfortunately, there are no data on why the 11 subjects abstained from participation. Of the remaining 64 subjects, another eight were excluded from the analysis because of incomplete data or too many deviations from the shift schedule. Thus, the groups in the present study were: 31 satisfied shift workers, of whom 11 were women [men with a mean age of 43, with a standard error (SE) of 2 years; women 38 ± 3] and 25 dissatisfied shift workers, of whom nine were women (mean age, men = 39 ± 2, women = 44 ± 4 years). The limited group sizes and the few women were due to the low number of women working full time (48 all together) and to few shift workers being dissatisfied with their work hours (only 8% rated 2 or lower).

The resulting satisfaction scores between satisfied and dissatisfied shift workers were SAT = 4.8 ± 0.1 vs DIS = 2.5 ± 0.1. There was no significant difference in satisfaction with respect to gender (men = 3.9 ± 0.2 vs women = 3.6 ± 0.3, $F = 1.1$, $df = 1/53$) and no interaction between satisfaction and gender ($F = 0.9$, $df = 1/53$).

All participants gave their informed consent prior to their inclusion in the study. They were instructed to adhere to their normal behaviour during the entire shift cycle and were not paid to participate. The participants were also subjected to a health examination and measurements of biological stress markers. These results will be presented elsewhere. The study was approved by the local ethical committee at the Karolinska Institute.

The shift cycle (comprising 35 days and five shift teams) was extremely rapidly rotating and included seven work periods (triads) and 1 week off. The shift schedule was as follows: *N* A M + N A *M* + N A M + N *A M* + N A M + *N A* M + N A M + + + + + + + +. Where N = night shift (21:00–06:00), A = afternoon shift (14:00–21:00), M = morning shift (06:00–14:00), + = day off, and in italics = weekend. A "triad" consisted of three shifts over 4 days (N A M +), with only 8 h off between the night shift and afternoon shift, and 9 h off between the afternoon shift and morning shift. The data from the first and the seventh triad and the first 4 days of the week off are presented in this paper. Half of the shift workers started the study when entering the first triad, while the rest started with the seventh triad. The shift system had been in use for more than 20 years when the study was carried out. The participants were instructed to adhere to their normal behaviour during the entire shift cycle.

The measurements used were the Karolinska Sleep Diary [4], a wake diary, actigraphy, and a single-choice reaction time test. The diaries were filled out daily during the entire shift cycle (35 days). The sleep diary was filled out after each main sleep period and after each nap; it contained questions about bed times, rising times, sleep latency, sleep quality, ease of falling asleep, calm sleep, sleeping throughout, ease of awakening, sufficient sleep and feeling well rested. A sleep quality index (SQI) was calculated using the items "sleep quality" (phrased "how was your sleep?"), "ease falling asleep", "calm sleep" and "slept throughout". The response alternatives ranged from 1 ("problems" or "very poor") to 5 ("no problems at all" or "very good"). In the wake diary the subjects were instructed to rate their sleepiness on the Karolinska Sleepiness Scale (KSS [3]) every second hour awake, during both work and free time. The KSS is a 9-point verbally anchored scale that ranges from 1 ("very alert") to 9 ("very sleepy, fighting sleep, an effort to keep awake"). The sleepiness analyses included the ratings between the following time points: N-shifts 22:00–04:00; A-shifts 14:00–20:00; M-shifts 06:00–12:00; and days off 12:00–18:00 (when compared to ratings at work); the analyses including only days off, also contain the ratings at 10:00, 20:00 and 22:00.

Activity was measured with an actigraph (Ambulatory Monitoring), which detects acceleration and sums the number of accelerations per minute. Sleep periods were analysed with an automatic sleep-scoring program (Action 1.24 [9]). The actigraph was worn during the first and seventh triads and the first 3 days of the week off. The shift workers were instructed to press an event button at lights out and when rising. The actigraph was worn on the non-dominant wrist at all times, except when the shift workers were exercising or showering.

The shift workers also carried out a simple serial reaction time test (RT) at the beginning and end of the night, evening and morning shifts, during the first and seventh triads. The test was based on similar tests developed by Lisper and Kjellberg [25] and Wilkinson and Houghton [36]. The test (length 6 min) was presented on a handheld computer (PSION LZ, Psion, London, UK) and was carried out in the normal work environment. Sixteen signals per minute were presented at random intervals (with an inter-stimulus interval of 2–7 s). The analysis presented was based on reactions after transformation of the raw reaction-time data (1/x) to counteract difference in variance or skewness [10]. For clarity, the mean values were transformed back (1/x) to be presented in milliseconds. A reaction time longer than 0.5 s was considered to be a performance lapse [11].

The data were analysed with a repeated measures analysis of variance (ANOVA) with two between-group factors and one, two or three within-group factors. Independent variables were "satisfaction with the shift schedule" (satisfied versus dissatisfied), "gender" (men versus women), "shift type" (night shift, afternoon shift, morning shift, and, when appropriate, day off), "shift sequence" (first and seventh triad), and, when appropriate, "time of day". For RT, work tasks sometimes interfered with tests, and the factor "triad" had to be dropped. Instead, a mean for each time point was calculated across the two triads. For repeated measures the Greenhouse–Geisser epsilon correction was used. The lowest N for any analysis, including all workers, was 50. The relatively stringent significance level was set to 0.01, due to the many tests conducted and to reduce the risk of any type 1 errors being made. Also, significances at the 0.001 level are reported for clarity. Analyses with a P value lower than 0.05 are reported as trends in the tables. The statistical packages used were Statview 5.0.1 and superANOVA 1.11.

Results

Background data and sleep characteristics of the shift workers with respect to satisfaction and gender are presented in Table 1. The only significant characteristics found were that dissatisfied shift workers rated themselves as having a higher habitual sleep need and a lower sleep flexibility than satisfied workers. There were no significant gender differences or interactions between gender and satisfaction, with the exception of a lower BMI amongst women.

Sleep

Actigraphy data and sleep diary ratings are presented in Table 2. The most central sleep data with respect to satisfaction and shift are also presented in Fig. 1 (with means across the two triads and gender). There were no significant effects with respect to triad or gender. Between-shift effects differed significantly with respect to all sleep variables, except for objective sleep efficiency (actigraphy data) and subjective sleep quality. The obvious differences in timing of sleep, according to shift type, were highly significant; bed and rise times were for sleep between night shifts and afternoon shifts 06:24–11:24 h; for sleep between afternoon shifts and morning shifts 22:43–04:42 h; and for recovery sleep 23:13–07:55 h ($F=7566$, $P<0.001$, $df=2/104$; $F=922$, $P<0.001$, $df=2/104$; respectively). Also, total sleep time (TST) and subjective ratings of sleep sufficiency and difficulties rising showed a significant variation across shifts, with shortest/worst sleep during the short recovery periods between shifts.

Also, napping behaviour differed according to type of shift; it was more common for workers to take a nap in connection with the night shift (before or during the shift) than after the morning shift (44 ± 5 vs 30 ± 4%; $F=7.4$, $P<0.01$, $df=2/104$); no naps were taken in connection with the afternoon shift.

A sleep sufficiency index (SSI = sleep time/habitual sleep need × 100) showed that the shift workers only had managed to get between 53 and 68% (on a group level) of their sleep need (mean sleep need for all workers = 8.0 ± 0.2 h) between the night shift and the afternoon shift, and between 65 and 80% between the afternoon shift and the morning shift, while recovery sleep rendered between 101 and 118%. There were no significant gender differences, even though there was a tendency for women to have less sufficient sleep. Dissatisfied workers rated less sufficient sleep than satisfied workers and a tendency for greater difficulties in arising from sleep.

There were two interactions. The first, between shift and satisfaction, showed that the differences between dissatisfied and satisfied workers with respect to ratings of sleep sufficiency disappeared after recovery sleep ($F=5.9$, $P<0.01$, $df=2/104$). The other interaction, between satisfaction and gender, showed that dissatisfied shift workers had poorer sleep quality than satisfied shift

Table 1 Background data and sleep characteristics (presented as means, SE or percentages) by ANOVA or chi-square analysis. Degrees of freedom (all ANOVAs) = 1/52. For both chi-square analyses $n=56$. *I* interaction, *NA* not applicable, *BMI* body mass index (weight/height^2)

Parameter	Mean ± SE				F values		
	Satisfied		Dissatisfied		Satisfaction	Gender	I
	Men	Women	Men	Women			
Age (years)	44 ± 2	39 ± 3	40 ± 2	45 ± 4	0.1	0.0	5.3[a]
BMI (kg/m^2)	26 ± 1	23 ± 1	25 ± 1	24 ± 1	0.0	7.6*	0.2
Married/cohabiting (%, chi-square)	86	56	55	78	0.8	0.4	NA
Subjects with young children (%, chi-square)	21	36	19	0	1.8	0.0	NA
Diurnal type (1–4 = morning person)	2.6 ± 0.2	2.3 ± 0.3	2.3 ± 0.3	2.1 ± 0.3	0.6	0.9	0.0
Habitual sleep need (h)	7.2 ± 0.2	8.2 ± 0.3	8.3 ± 0.3	8.8 ± 0.5	7.4*	6.0[a]	0.7
Sleep flexibility (1–4 = agree completely)	3.4 ± 0.1	2.6 ± 0.2	2.4 ± 0.2	2.2 ± 0.3	15**	6.1[a]	2.8
I always sleep at regular times (1–4 = agree completely)	2.3 ± 0.2	2.5 ± 0.2	2.9 ± 0.2	2.4 ± 0.2	1.2	0.4	2.3
Easy to overcome sleepiness (1–4 = agree completely)	3.4 ± 0.1	3.4 ± 0.2	3.1 ± 0.2	3.0 ± 0.2	3.9	0.3	0.0
I never worry about my sleep (1–4 = agree completely)	3.3 ± 0.2	3.3 ± 0.3	2.6 ± 0.2	3.0 ± 0.2	3.5	0.6	0.7
I can handle short sleep times (1–4 = agree completely)	3.1 ± 0.1	2.5 ± 0.2	2.4 ± 0.1	2.2 ± 0.3	6.1[a]	5.6[a]	1.4

*Significance level = $P<0.01$
**Significance level = $P<0.001$
[a]Trends set as $P<0.05$

Table 2 Means, SE and ANOVA results for actigraphy data and diary ratings of sleep

Parameter	Mean ± SE								F values			
	First triad				Seventh triad							
	Satisfied		Dissatisfied		Satisfied		Dissatisfied		Triad	Shift	Satisfaction	Gender
Actigraph data	Men	Women	Men	Women	Men	Women	Men	Women				
TST (hh.hh)									0.1	235**	1.6	0.1
Sleep between N and A shifts	5.0 ± 0.2	4.4 ± 0.3	5.1 ± 0.3	4.8 ± 0.3	4.9 ± 0.2	4.8 ± 0.3	4.8 ± 0.4	4.7 ± 0.5				
Sleep between A and M shifts	5.4 ± 0.2	5.6 ± 0.1	5.7 ± 0.2	6.0 ± 0.2	5.6 ± 0.2	5.7 ± 0.2	5.8 ± 0.2	5.7 ± 0.3				
Recovery sleep between M shift and day off	8.3 ± 0.2	8.5 ± 0.3	8.9 ± 0.5	8.8 ± 0.7	8.4 ± 0.3	8.8 ± 0.3	8.9 ± 0.6	8.9 ± 0.7				
SSI of work sleep and recovery sleep (%)									0.3	202**	2.3	5.6[a]
Sleep between N and A shifts	68 ± 3	55 ± 4	63 ± 3	55 ± 4	68 ± 3	60 ± 5	60 ± 5	53 ± 6				
Sleep between A and M shifts	79 ± 4	71 ± 3	71 ± 4	67 ± 3	80 ± 4	71 ± 3	69 ± 3	65 ± 6				
Recovery sleep between M shift and day off	116 ± 4	104 ± 3	110 ± 8	102 ± 10	118 ± 5	108 ± 4	112 ± 9	101 ± 8				
Sleep efficiency (%)									1.0	1.5	0.2	1.1
Sleep between N and A shift	85 ± 4	93 ± 1	91 ± 3	89 ± 6	91 ± 2	95 ± 1	93 ± 2	87 ± 7				
Sleep between A and M shifts	84 ± 6	96 ± 1	87 ± 3	89 ± 3	89 ± 4	88 ± 9	93 ± 1	93 ± 3				
Recovery sleep between M shift and day off	86 ± 5	97 ± 1	91 ± 2	93 ± 3	87 ± 3	98 ± 1	94 ± 2	93 ± 2				
Sleep quality index (1–5 = good)									0.3	0.9	2.6	0.7
Sleep between N and A shifts	4.4 ± 0.1	4.4 ± 0.2	4.0 ± 0.3	4.1 ± 0.3	4.4 ± 0.1	4.3 ± 0.2	4.0 ± 0.2	4.3 ± 0.3				
Sleep between A and M shifts	4.5 ± 0.1	4.0 ± 0.2	3.7 ± 0.2	4.3 ± 0.3	4.4 ± 0.1	4.4 ± 0.1	3.6 ± 0.2	4.6 ± 0.1				
Recovery sleep between M shift and day off	4.6 ± 0.1	4.0 ± 0.3	4.3 ± 0.1	4.5 ± 0.2	4.4 ± 0.1	4.2 ± 0.2	4.3 ± 0.2	4.2 ± 0.1				
Sufficient sleep (1–5 = good)									3.1	32**	17**	0.3
Sleep between N and A shifts	3.6 ± 0.1	3.3 ± 0.3	3.1 ± 0.3	3.0 ± 0.3	3.6 ± 0.1	3.3 ± 0.3	2.6 ± 0.2	2.8 ± 0.3				
Sleep between A and M shifts	3.4 ± 0.1	3.1 ± 0.2	2.4 ± 0.2	2.3 ± 0.4	3.4 ± 0.2	3.1 ± 0.3	2.1 ± 0.3	2.7 ± 0.4				
Recovery sleep between M shift and day off	4.1 ± 0.1	3.6 ± 0.3	3.9 ± 0.2	4.3 ± 0.2	3.9 ± 0.2	3.8 ± 0.2	3.6 ± 0.3	3.8 ± 0.3				
Easy to rise (1–5 = good)									0.0	16**	6.9[a]	4.2[a]
Sleep between N and A shifts	3.8 ± 0.2	2.9 ± 0.3	3.6 ± 0.3	2.3 ± 0.3	3.6 ± 0.2	3.4 ± 0.4	2.8 ± 0.2	2.7 ± 0.3				
Sleep between A and M shifts	3.5 ± 0.2	2.9 ± 0.3	2.8 ± 0.2	2.2 ± 0.3	3.6 ± 0.2	3.3 ± 0.3	3.0 ± 0.2	2.4 ± 0.4				
Recovery sleep between M shift and day off	4.1 ± 0.2	3.3 ± 0.5	3.4 ± 0.2	3.9 ± 0.3	3.9 ± 0.2	3.5 ± 0.3	3.1 ± 0.1	3.3 ± 0.3				

**Significance level = $P < 0.001$

[a]Trends set as $P < 0.05$

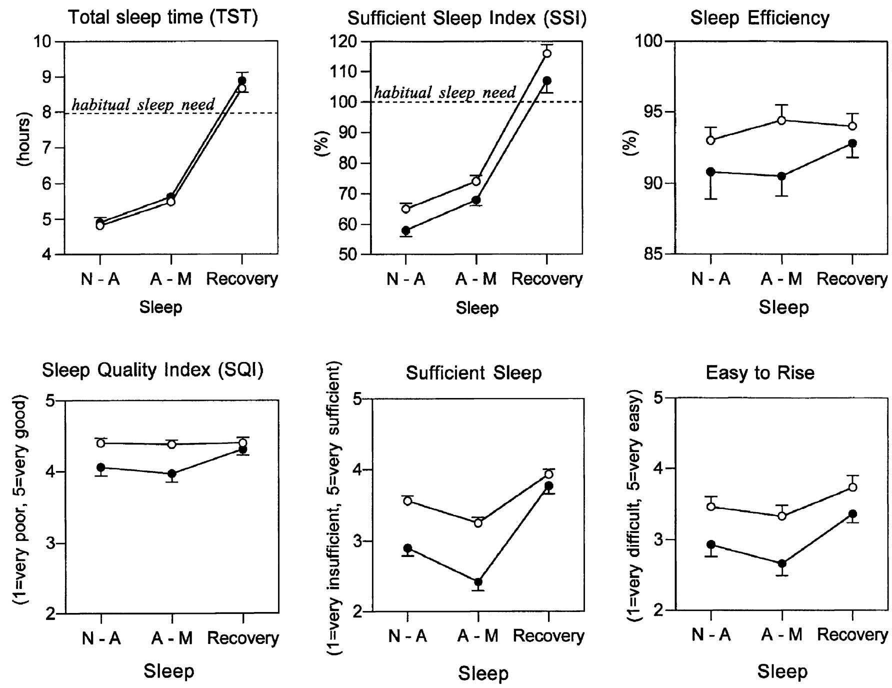

Fig. 1 Sleep data for satisfied and dissatisfied shift workers across the triad of shifts (mean for triads 1 and 7; and gender). *Closed circles* represent dissatisfied shift workers and *open circles* represent satisfied shift workers. *N-A* sleep between night shift and afternoon shifts, *A-M* sleep between afternoon and morning shifts, *Recovery* sleep after the morning shift to the day off. *Top left* illustration of how total sleep times (TST, actigraphy data) are shortened by quick returns and increased during recovery sleep. *Top middle* illustration of how sufficient the different sleep episodes are across the triad of shifts (the sufficient sleep index = TST/habitual sleep need = how much sleep obtained in relation to the individual's sleep need). *Top right* shows sleep efficiency (actigraphy data) (TST/time in bed = how much sleep obtained of the time spent in bed in percent) across the triad of shifts. *Bottom left* illustration of changes of subjective sleep quality across triads. *Bottom middle* illustration of how ratings of sufficient sleep develop across triads. *Bottom right* describes how easy it is to rise from different sleep periods

workers, but this was only true in men ($F=7.9$, $P<0.01$, $df=1/52$).

Sleepiness

Sleepiness ratings and significance levels during work and recovery days are presented in Fig. 2 and in Table 3, respectively. There were no main effects for sleepiness with respect to shift sequence or gender. However, sleepiness differed clearly between shifts, night shifts being most affected, followed, in order, by morning shifts, afternoon shifts and recovery days. There were also significant main effects for time—more sleepiness was reported at the end of shifts (except for the morning shift)—and for satisfaction, dissatisfied workers experiencing more sleepiness during work than their satisfied counterparts.

There were several significant interactions. The first showed that sleepiness developed differently according to type of shift ($F=53$, $P<0.001$, $df=9/441$). This was mainly due to the particularly high levels of sleepiness experienced at the end of the night shift and, to a lesser extent, at the beginning of the morning shift. Secondly, the differences between dissatisfied and satisfied workers were larger for afternoon and morning shifts than for night shifts, but disappeared after recovery sleep ($F=4.3$, $P<0.01$, $df=3/147$). Thirdly, dissatisfied shift workers were exceptionally sleepy at the end of the shifts ($F=5.5$, $P<0.01$, $df=3/147$).

We calculated a set of ANOVAs to obtain an understanding of how sleepiness varied over recovery days. The only significant effect we found when comparing the first recovery days—after the first triad with the first recovery day after the seventh triad—was that sleepiness varied across the day. The ANOVA calculated for the four rest days after the seventh, and last, triad showed no main effects for satisfaction, gender or day. A significant interaction between satisfaction and gender showed that dissatisfied men (mean 4.3 ± 0.1) were sleepier than dissatisfied women (mean 3.7 ± 0.1; $F=7.4$, $P<0.01$, $df=1/49$). In addition, a significant interaction between day and time of day suggested that morning sleepiness decreased across days off ($F=2.7$, $P<0.01$, $df=18/828$). An analysis comparing only the first and fourth recovery days on the week off, found a tendency for sleepiness to be lower after 4 days of recovery ($F=4.1$, $P<0.05$, $df=1/47$).

Performance

Figure 3 and Table 3 show that there were no main effects for either reaction times or lapses with respect to shift, time, satisfaction or gender. A significant interac-

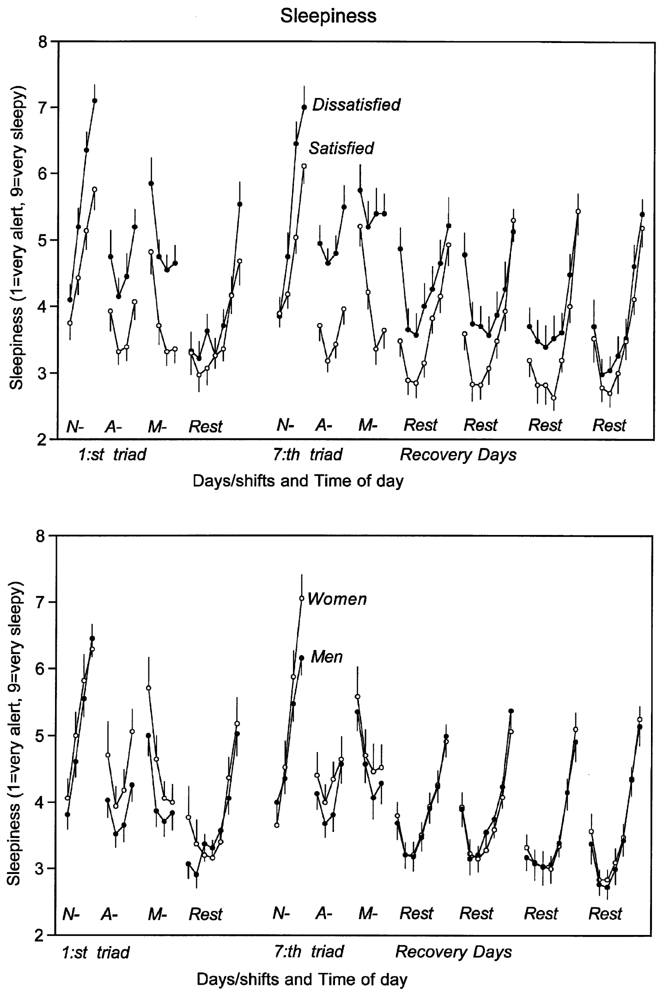

Fig 2 Sleepiness and standard error bars for night, afternoon and morning shifts and days off during the first and seventh triads. The first days of the week off are also presented. *Top* satisfied (*open circles*) and dissatisfied (*closed circles*) shift workers. *Bottom* men (*closed circles*) and women (*open circles*). The analysis comparing "days off" with work includes the ratings at 12:00 h, 14:00 h, 16:00 h and 18:00 h during days off. The ratings at 10:00 h, 20:00 h and 22:00 h are also included when only days off are analysed

tion between shift and time on shift showed that reaction times deteriorated more across night shifts than other shifts ($F=24$, $P<0.001$, df = 2/104). A similar trend was shown for lapses. There was also a significant interaction between shift, time on shift and gender, which showed that women had particularly long reaction times at the end of shifts, but only during night shifts ($F=5.8$, $P<0.01$, df = 2/104).

In an attempt to derive a global measure and understanding of how the present shift cycle affected the shift workers, we calculated the mean sleepiness level (diary ratings) across the entire shift cycle during both work and free time. The ratings were first averaged across the waking span of each day and then averaged across the entire shift cycle as well as for work days and days off (all sleepiness ratings from the start of the night shift until bed time after the morning shift were considered as belonging to the work period; all other times were calculated as free time). The mean sleepiness level for all shift workers across the entire shift cycle was 4.6 ± 0.1 (1–9 = very sleepy). The mean level of sleepiness during the working period was 5.1 ± 0.1 and 4.0 ± 0.1 during days off. Dissatisfied shift workers were more sleepy than satisfied ones during the working period (5.6 ± 0.1 vs 4.8 ± 0.1; $F=15.3$, $P<0.001$, df = 1/52), but not during days off ($F=2.3$, $P=0.13$, df = 1/52). There were no significant differences in sleepiness between men and women for working time ($F=1.1$, $P=0.29$, df = 1/52) or days off ($F=0.0$, $P=0.90$, df = 1/52). A significant interaction between attitude and gender showed that dissatisfied men were worse off than dissatisfied women during days off ($F=7.7$, $P<0.01$, df = 1/52).

Discussion

This study supports previous findings of shortened sleep in connection with quick returns [23, 27]. However, this is the first study that evaluates two consecutive quick returns. The quick returns seriously curtailed sleep to 4.8 h between the night shift and afternoon shift and 5.5 h between the afternoon and morning shifts, instead of two full 8-h sleep periods. The recovery sleep after the morning shift was 8.6 h, which was somewhat extended when compared with the stated sleep need (8.0 h). Sleepiness ratings showed the expected pattern, with most problems occurring during night shifts, followed by morning shifts, afternoon shifts and recovery days. There were no changes between triads, even though there were some tendencies for sleepiness to be somewhat increased during the first recovery day, after the shift cycle, as sleepiness gradually decreased over the oncoming 4 days. Thus, there was no major support for sleepiness to accumulate across the shift cycle.

Those that were dissatisfied with the shift schedule had far more problems with sleep and sleepiness, even though it was not manifested in worse performance. The major difference concerned sleepiness—to some extent during night work, but in particular during afternoon and morning shifts. Yet, there was no significant difference in the amount or objective quality of sleep preceding these shifts. However, the dissatisfied workers rated the sleep periods as considerably more insufficient and, in addition, reported a longer sleep need than satisfied workers. Interestingly, sleepiness levels gradually returned to normal during days off, when normal night sleep was taken. These observations suggested that the dissatisfied group was more sensitive to curtailed sleep. This was further supported by the fact that the dissatisfied workers in the questionnaire rated themselves as having more problems in overcoming the effects of short sleep periods (J. Axelsson, T. Åkerstedt, G. Kecklund, A. Lowden, manuscript submitted). In addition, the dissatisfied workers also rated themselves as having lower sleep flexibility than satisfied workers, which

Table 3 F values and significance levels for Figs. 2a,b and 3a–d. Results from the ANOVA for sleepiness ratings and performance data (reaction times and lapses). Work period (Triad/T), shift/day (Shift/S), time of day/shift (ToD), satisfaction (Sat), – category not applicable. Reaction times (mean for the first and seventh triad). Sleepiness at work (mean across the shift/day). Sleepiness on the first recovery days compares the recovery day in the first and seventh triad. Days off = the first 4 days on the week off. Degrees of freedom for sleepiness at work + first day off: T = 1/49, S = 3/147, ToD = 3/147, Sat = 1/49, G = 1/49; sleepiness on days off (first day off after the first and seventh triad, respectively): T = 1/49, ToD = 6/249, Sat = 1/49, G = 1/49; sleepiness on days off (day 1–4 on the week off) S = 3/138, ToD = 6/276, Sat = 1/46, G = 1/46; reaction times and lapses S = 2/104, ToD = 1/52, Sat = 1/52, G = 1/52

Parameter	F values				
	Triad	Shift/day	Time of day	Satisfaction	Gender
Sleepiness ratings					
Sleepiness at work + first day off	2.6	63**	38**	17**	1.8
Sleepiness on the first recovery days	0.9	–	27**	1.4	0.2
Sleepiness on days off (the first 4 days on the week off)	–	1.5	54**	2.7	0.0
Performance					
Reaction times	–	1.0	6.9[a]	0.1	0.6
Lapses	–	0.4	0.5	0.1	0.0

**Significance level $= P < 0.001$
[a]Trends set as $P < 0.05$

supports earlier research [16]. However, again, no objective measures supported this difference, and other individual sleep-related factors such as age, diurnal type, how much they worried about their sleep, or problems in overcoming sleepiness did not differ between groups.

The fact that the dissatisfied workers had more problems with sufficiency of sleep, but not with objective (actigraphy) and subjective measures of sleep quality, suggests that it is the total recuperative value that is impaired, rather than the quality of sleep. This vulnerability to short recovery periods, caused by the quick returns, could be related to less efficient sleep, but this needs to be determined through polysomnographic measures. The similar sleepiness levels in dissatisfied and satisfied shift workers at the start of the work period, as well as on days off, indicate that the differences in sleep sufficiency probably are transient effects of displaced and curtailed sleep. The diary ratings of sleep quality also confirmed transient effects on sleep. Overall sleep quality is obviously not the best predictor of satisfaction with the shift schedule (J. Axelsson, T. Åkerstedt, G. Kecklund, A. Lowden, manuscript submitted). From our data it seems reasonable to believe that other sleep variables should be of greater significance for satisfaction with the shift schedule, i.e. sufficiency of sleep. On the other hand, it is possible that general sleep quality in a questionnaire comprises a "full scale" evaluation of most sleep quality aspects. And insufficient work sleep would, obviously, have a great impact, as it constitutes a large part of all sleep periods.

It is notable that there were no differences in napping behaviour between dissatisfied and satisfied workers. Hence, it was not napping that helped the satisfied workers to overcome possible problems or that the dissatisfied workers used prophylactic naps.

Apparently, the two successive quick returns resulted in an accumulating sleep debt; the shift workers received only 53–68% (on a group level) of their sleep need between the night shift and the afternoon shift and between 65 and 80% between the afternoon shift and the morning shift. That the dissatisfied shift workers rated those short sleep periods as less sufficient than satisfied shift workers was probably due to their longer sleep need.

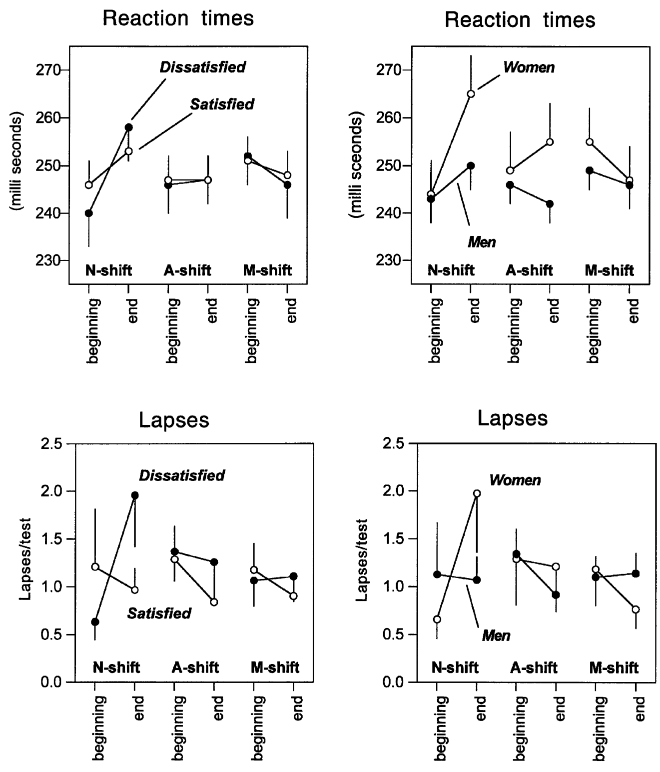

Fig. 3 Performance data (reaction times and lapses), with standard error bars, are presented for satisfied (*open circles*) and dissatisfied (*closed circles*) workers, and men (*open circles*) and women (*closed circles*), for both reaction times and lapses. *Top left* reaction times in satisfied and dissatisfied workers. *Top right* reaction times in men and women. *Bottom left* lapses amongst satisfied and dissatisfied workers. *Bottom right* lapses in men and women

The development of sleepiness across shifts confirms earlier studies, with worst sleepiness during the end of night shifts and, to a lesser extent, on morning shifts [1, 21]. Notably, one was sleepier during all shifts, even afternoon shifts, than during recovery days. Even though it seemed as if one recovery sleep was sufficient to recover and restore alertness levels, further reduction in sleepiness was seen after an additional 4 recovery days.

There was no evidence of an accumulation of sleepiness across the shift cycle. This suggests that 55 h of recovery time (between the triads) was sufficient for most workers to recover completely. However, morning sleepiness during the first days off after the seventh triad was slightly elevated. The difference between the first and the fourth day off (after seven triads) was a gradual elimination of morning sleepiness. The lack of accumulation during work may be related to a "ceiling effect", since sleepiness was already high during the first triad. However, situational factors such as physical activity, social contacts and mental stress could have prevented latent sleepiness to become manifest. Furthermore, another reason for the increased morning sleepiness could be a delay of the circadian phase, caused by the seven work periods. However, this was not supported by increasing evening alertness or altered sleep times.

The virtual absence of differences between men and women supports earlier findings [6, 7, 15], but also contrasts with studies showing more problems amongst women [13, 30]. It is possible that the lack of agreement derives from work-related issues or social responsibilities [6]. It should also be noted that stress research in general describes women as more likely to experience and report more problems in response to stressors [17]. The lack of differences reported in our study could also be related to the fact that the gender groups were not randomly chosen; the groups were chosen to maximize differences in satisfaction towards the shift schedule and, hence, to leave out the "intermediates". Consequently, it is possible that we have underestimated gender differences in the population.

Unexpectedly, and in contrast to prior experience, the (few) interactions between gender and satisfaction showed that the differences in sleepiness and disturbed sleep between dissatisfied and satisfied workers were larger amongst men than women. The larger differences amongst men could also be due to the fact that the groups (dissatisfied and satisfied) were chosen to maximize variation and that there were more men (269) than women (48) at this work site. Hence, it is possible that the male "dissatisfied" and "satisfied" groups were more "extreme" than the female ones, even if their satisfaction scores were similar.

The few performance differences found were somewhat unexpected. The lack of any main effects between shifts (for example impaired performance on night shifts) was due to the good performance at the beginning of the night shift. Instead, there was an interaction between time on shift and type of shift, caused by the deteriorating performance within night shifts but not during the other shift types. This is in line with several studies showing deteriorating performance towards the end of the night [28].

The results from the present study clearly demonstrate that quick returns seriously shorten sleep. The consequence was more sleepiness on the following afternoon and morning shifts. On the other hand, the workers seemed to be almost fully restored after only one recovery sleep. The fast recovery was probably a result of the undisturbed recovery and the fact that there was no need for circadian readjustment, since any tendencies to delay after the night shift would have been counteracted by the final morning shift. Hence, this particular schedule seemed to be characterized by more problems with sleep and sleepiness within the work period and probably by fewer problems during leisure time. This supports earlier findings that quick returns inflict acute effects. Thus, workers would probably benefit from changing to a schedule without quick returns [27]. In addition, it is notable that a large majority (more than 70%) of the workers was satisfied with the shift system and reported relatively minor problems with poor sleep and sleepiness.

In summary, the short rest time between shifts caused insufficient sleep, whereas the subjective and objective sleep quality was unaffected. Workers dissatisfied with their work hours were more vulnerable to the short rest periods and had more sleep and sleepiness problems. The differences between satisfied and dissatisfied subjects seemed to increase across shifts within the triad. However, the differences in sleepiness between satisfied and dissatisfied workers disappeared after recovery sleep. The latter suggests that the differences are due to short-term states, presumably related to lack of sleep and to displaced sleep, rather than long-term, enduring individual traits. Sleepiness during work did not increase across the shift cycle. Few gender differences were found.

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