The Impact of Extended Leave on Sleep and Alertness in the Australian Rail Industry

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Abstract: In the past, scientific studies have investigated the effects of shift timing and duration on sleep and alertness in the rail industry. To our knowledge no research has been conducted to determine the effects of extended break lengths (>48 h) on these factors. Hence, this study analyses the work and rest schedules of 304 Australian rail employees (mean age 41.3 yr, standard deviation 7.4 yr) to determine the effect of prior break lengths (12–169 h) on sleep and subjective alertness at work after periods of leave. Extended break periods (>48 h) were found to increase the length of the sleep prior to returning to work and reduce the total wake time to the end of the first shift, but did not influence levels of subjective alertness immediately prior to the commencement of the first shift. Research into the influence of longer break periods (>169 h) is needed in order to make definitive conclusions regarding sensible return to work policies after extended leave within the Australian rail industry.

Key words: Break length, Sleep, Alertness, Shiftwork, Rail

Introduction

On January 31 2003, a major train accident occurred near Sydney, Australia resulting in the death of 6 passengers and crew and serious injuries to 42 others. Subsequent investigations reported that fatigue may have played a causal role in this accident⁽¹⁾. Reviews of traditional factors which impact on fatigue and alertness were first carried out, indicating that working a series of night shifts (as was the case in this particular accident) may have contributed to decreased employee alertness. It was also questioned whether work related fatigue levels were further increased because the staff member had returned to a series of night shifts after a period of extended leave⁽¹⁾. It was recommended that further research be conducted to examine the effects returning to work from extended leave.

In general, working irregular shift schedules greatly impacts on sleep. Common complaints by shiftworkers include sleep disturbances and sleep loss caused by trying

to sleep at times traditionally spent awake^(2–4). This loss of sleep is compounded further by the need for many shiftworkers to fulfill their social and family responsibilities during their time off⁽⁵⁾. Generally, the quality of sleep experienced by shiftworkers working nights is poorer, and length much shorter, than those working during the day⁽⁶⁾. In addition, employees starting early in the morning experience shorter sleep lengths as their sleep is prematurely ended to rise for work in the morning⁽⁷⁾. Research indicates that many individuals find it difficult to shift their usual bed time (i.e. go to bed early) to counteract this problem, as the body is not programmed to sleep in the early evening⁽⁷⁾.

The government report on the causes of the January 31, 2003 train accident suggested that during a period of extended leave it was likely that the sleep/wake cycle of an employee would be ‘appropriate to being on holidays’⁽¹⁾. Specifically, evidence suggests that while on leave sleep onset times often become later at night and wake times generally become later in the morning⁽⁸⁾. This altered sleep schedule may exacerbate the sleep and fatigue problems typically experienced by shiftworkers upon return to work. Specifically, an individual

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may be unable to easily readjust their sleep patterns prior to returning to work, meaning that sleep may be further truncated or disrupted by shiftwork^{6, 8–10}. The degree of this disruption depends on which type of shift the employee is returning.

Research has shown that if returning to work early in the morning, sleep is truncated by up to three hours by the early start⁷. If an individual has shifted their sleep/wake schedule while on leave, and find it difficult to readjust to an early bedtime, then the reduction in sleep length may be even larger. This later sleep/wake cycle employees adopt during periods of leave may also affect alertness levels upon return to a night shift. For example, if an employee lengthened their final night's sleep period rather than nap prior to the first night shift, the length of extended wakefulness may in some cases be more than 20 h. Recent research has shown that performance impairment during periods of extended wakefulness of 20–25 h is equivalent to the impairment seen when blood alcohol concentration reaches approximately 0.1%^{11, 12}. This highlights the negative effect shiftwork and in particular night work has on performance and alertness. Thus, sleep, performance and alertness at work may be negatively affected by extended leave periods when returning to either an early morning or night shift where sleep disruption occurs.

Conversely however, upon return to work following periods of extended leave employees may be less likely to be suffering from the effects of a cumulative sleep debt. Cumulative sleep debt occurs when sleep periods are shortened or truncated for one or more days. The total amount of cumulative sleep debt experienced is the reduced sleep duration subtracted from the average sleep duration. For example, consider an employee who usually averages 8 h of sleep per day but has only obtained 5 hours of sleep per day for the last four days. Their cumulative sleep debt is therefore 3 (8–5) h per night or 12 (3 × 4) h in total. From simple numerical examples such as these, it becomes clear that reasonably small deficits in sleep over a number of days or weeks can add up to be a substantial total deficit over time.

Only recently has the adverse effect of chronic partial sleep restriction on alertness and performance been quantified^{13–16}. These studies indicate that performance and alertness deteriorates steadily after sleep loss of as little as 2.5 h per night for more than a week¹⁴. The sleep of employees working irregular shift schedules is often reduced by this amount, resulting in cumulative sleep debt. It is only after periods of recovery that these debts in sleep are repaid and performance and alertness increase to baseline levels (i.e. levels of performance prior to cumulative sleep

debt occurring)¹⁵. Since employees who have undertaken periods of extended leave have a greater opportunity to obtain sufficient sleep, in general, they have a reduced chance of accumulating such a debt. In fact, their performance and alertness may be better upon return to work than they were prior to their leave.

While numerous studies have investigated the timing of work and breaks on sleep, they typically concentrate on shorter break periods (up to 48 h in length) and specifically address the problem of minimum break requirements^{17, 18}. These studies have found that the amount of sleep obtained within a break period is determined by the length of the break period, and the time of day at which the break occurs. As previously reported, these studies support the long held argument that working at night or beginning work early in the morning causes loss of sleep and decrements in alertness and performance during a shift^{4, 6, 8, 9, 19}.

Within the Australian rail industry, break lengths are generally only greater than 48 h if employees have taken i) recreational or long service leave, ii) sick leave or iii) have extended break periods between blocks of different shift types (for example in many job types employees will have four to five days off between a block of night shifts and a block of early morning shifts). It was therefore decided to define periods of extended leave to be breaks longer than two days. The aim of this analysis was to determine the impact on extended leave on sleep and alertness during the first day back at work.

Methods

Participants

A total of 269 locomotive engineers (265 male, 4 female) and 35 male terminal operators from sixteen Australian rail depots gave their informed consent to participate as volunteers after attending an information session. Participants were screened prior study commencement to ensure they did not take any medication which could interfere with sleep or suffered from pre-existing sleep disorders.

Participants had a mean ($\pm$ s.d.) age of 41.3 ($\pm$ 7.4) yr and had been doing shiftwork for an average of 17.6 ($\pm$ 8.2) yr. Participants did not receive any additional payment for participating in the study above their usual salary. This study was approved by the University of South Australia's Human Ethics Committee.

Work setting

The sixteen rail depots chosen were representative of the varied work settings in the Australian rail industry and thus

encompassed a wide range of working conditions and roster schedules. Participants drove electric or diesel locomotives; worked with another engineer or a conductor or drove alone; carried passengers, freight or coal; travelled on country or metropolitan tracks; and obtained rest at home or in barracks. Some participants worked predominantly day shift, some worked predominantly night shift, and others worked a combination of both. Work periods were typically 6–12 h in duration (average of 8.4 h). Depending on the depot, participants had between twelve hours and two weeks notice of their work schedule, which could be altered with as little as 2–4 h notice.

Procedure

Data were collected at each depot in a succession of studies conducted over a 9-yr period. Data regarding participants' self-rated alertness, sleep/wake patterns and work schedules were collected at each depot for a period of fourteen days. During that time, participants worked their normal roster patterns.

Wrist activity monitor

Objective assessments of sleep/wake were made using activity monitors (Gaehwiler Electronic, Hombrechtikon, Switzerland) and Actiware-sleep software (Cambridge Neurotechnology Ltd). Each activity monitor contained a piezo-electric accelerometer with a sensitivity of 0.1 g. The analogue sensor sampled movement every 125 ms and the information was stored in 1-min intervals for analysis. Employees were required to wear the activity monitor on their wrist for the two-week period. The activity monitor was only to be removed whilst taking a shower (or in any other situation where the device was likely to be damaged).

Sleep and work diaries

Employees were asked to provide detailed information about their sleep and work patterns for the two-week period. For each sleep period, including naps, they recorded the time of sleep onset, the final wake time and the number and length of awakenings during the sleep period. For each work period, employees recorded *actual* hours of work (rather than their planned or rostered work hours). In addition, they rated their level of alertness immediately before and after each work period using either the 7-point Samn-Perelli Fatigue Scale²⁰ (20% of participants used this method of self rating alertness) or a 100 mm non-numeric visual analog scale (VAS, 80% of participants used this method of self rating alertness).

To increase recall accuracy, employees were instructed

Fig. 1. Schematic diagram of factors used in the analysis.

to record the information as soon as practicable after waking/finishing their shift. As the distributions of the two alertness scales were found to be comparable from initial analysis, alertness scores were standardized prior to analysis and combined into one large database.

Measures and Statistical Analysis

Data from participants' activity monitors, in conjunction with sleep and work diaries, were used to determine the factors that could potentially impact on levels of alertness and sleep after periods of leave (Fig. 1):

- *Shift Duration (SD)* is the amount of time between the start and end of a work period.
- *Prior Sleep Length (PSL)* is the length of the main sleep period prior to the commencement of a work period. It is the amount of time from sleep onset to wake up, less awakenings. Participants were excluded from the current analysis if their sleep diaries indicated that they employed a napping or split sleep strategy prior to return to work.
- *Prior Wake Time (PWT)* is the length of the period from wake until the conclusion of the work period.
- *Prior Break Length (PBL)* is the length of the period from the end of one work period until the start of the next work period. As previously stated, in the Australian Rail Industry, break lengths are generally only greater than 48 h if employees have taken i) recreational or long service leave, ii) sick leave or iii) have extended break periods between blocks of different shift types. It was therefore decided to define periods of extended leave to be breaks longer than two days. Break lengths shorter than 24 h were defined as short breaks as only limited recovery is usually achieved during these periods. Those break lengths between 24 and 48 h were deemed medium break lengths

Fig. 2. Self-rated alertness levels at the start of shift.

as moderate recovery can usually be achieved during this time from multiple sleep periods.

- *Returning Shift Type (ST)* is the type of returning shift categorised into Day, Afternoon or Night, depending on the shift's start time. A work period was defined as a Day shift if it began between the hours of 0500 and 0900. The majority of these day shifts began between 0600 and 0700 h. It was defined as an Afternoon shift if it started between the hours of 1200 and 1900 and was defined as a Night shift if it started between 1900 and 0300.
- *Break Start Time (BST)* is the time at which the break period begins at the conclusion of the previous shift. This variable is included as recent literature suggests that both the length and timing of break periods affect recovery from work¹⁷⁾.

Mixed model analysis of variance (ANOVA) was used to statistically assess which scheduling-related factors affected subjective alertness, sleep and prior wake. Scheduling factors included: (1) shift length [<8 , 8–8.9, 9–9.9, 10–11, >11 h]; (2) shift type [Day, Afternoon or Night]; (3) break start time [00:00–03:59, 04:00–07:59, ..., 21:00–23:59], and (4) break length, [Short, 0–24 h (mean 15.61 ± 2.98); Medium, 25–48 h (33.50 ± 7.38) and Long, 49–168 h (mean 89.62 ± 34.63)]. The mixed model procedure used was of factorial design with main effects plus 2-, 3- and 4-way interactions tested. Where relevant, post hoc analyses were carried out to determine which points were significantly different. For all analyses significance was set at the 0.05

Fig. 3. Self-rated alertness levels at the end of shift.

level. The statistical program SPSS 11.5 (SPSS, Inc.) was used for all analyses.

Results

Subjective alertness

Analysis indicated that prior break length did not significantly impact on self-rated alertness scores either prior to or post work ($F_{2,679}=0.530$, $P=0.589$ and $F_{2,643}=1.121$, $P=0.372$ respectively). This implies that extended leave did not improve or worsen subjective alertness at the start of the first shift back.

The results did indicate however that shift type (Day, Afternoon or Night) affected both prior ($F_{2,585}=9.104$, $P=0.0005$) and post shift ($F_{2,547}=11.038$, $P=0.0005$) subjective alertness scores. Specifically, it was found that prior alertness levels were highest at the start of the afternoon shifts, significantly lower at the start of the morning shifts and lowest at the start of the night shift (Fig. 2). On the other hand, post hoc analysis indicated that the day shifts were associated with highest post shift alertness scores, followed by the night and afternoon shifts (Fig. 3).

Post shift self-rated alertness levels were also significantly influenced by shift length ($F_{5,508}=5.014$, $P=0.0005$). As expected, post hoc analysis indicated that the longer the shift the lower the subjective alertness at its conclusion (that is, the alertness scores at the conclusion of shifts longer than 10 h were significantly different than those scores obtained at the end of shorter shifts).

Fig. 4. Interaction between Break Start Time (BST) and Break Length on Prior Sleep Duration.

Break start time did not significantly influence either the prior or post alertness scores, nor did any lower order interaction effects.

Prior sleep duration

Prior break length was found to significantly affect the final sleep duration prior to commencement of work ($F_{2,988}=9.475$, $P=0.0005$). Specifically, greater sleep durations were found for longer break periods. Break lengths of less than 24 h resulted in significantly less sleep being obtained, especially prior to the afternoon and night shift; however this interaction did not reach significance.

Shift type ($F_{2,970}=30.512$, $P=0.0005$) and shift length ($F_{4,907}=3.762$, $P=0.005$) also significantly influenced the amount of prior sleep obtained. The shortest prior sleep duration was before a night shift, followed by afternoon and then morning, irrespective of prior break length. It was found that the longest shift length was associated with the longest prior sleep period, possibly in anticipation for the upcoming extended work period.

Break start time was found to significantly influence the total amount of sleep obtained prior to returning to work ($F_{5,922}=11.355$, $P=0.0005$). In particular those break periods starting between 0500 and 1200 h were found to result in significantly less sleep. The interaction between break start time and break length was also found to be significant ($F_{10,893}=8.049$, $P=0.002$, Fig. 4), specifically suggesting that shorter break periods (<24 h) starting during the early morning result in significantly reduced sleep.

The only other significant lower order effect was the interaction between shift type and shift length ($F_{8,869}=2.720$,

$P=0.006$). In particular, more sleep was obtained prior to shorter morning shifts (<10 h) than longer night shifts (>10 h).

Prior wake

Prior Wake Time (PWT) was significantly influenced by the prior break length ($F_{2,970}=9.203$, $P=0.0005$). Breaks of 24–48 h were associated with significantly longer wake times compared to shorter (<24 h) and longer (>48 h) break periods.

Shift type ($F_{2,948}=72.338$, $P=0.0005$) and shift length ($F_{4,879}=41.500$, $P=0.0005$) also significantly impacted on prior wake time. In particular, prior wake times were significantly longer at the conclusion of an afternoon or night shift, especially those of longer duration.

Further, break start time was also found to significantly influence the prior wake time at the end of the shift ($F_{5,922}=17.40$, $P=0.032$), as was the interaction between break start time and break length ($F_{10,891}=7.428$, $P=0.0005$, Fig. 5). This interaction indicates that the prior wake time for short break periods beginning between 0900 and 1600 h is significantly less than breaks greater than 24 h in length.

The only other significant lower order effect was the interaction between shift type and shift length ($F_{8,873}=2.027$, $P=0.041$). In particular, post hoc analysis indicated that longer afternoon and day shifts (>10 h) resulted in significantly higher total wake time at the end of the shift.

Discussion

This study investigated the effects of prior break length on alertness and sleep within the Australian rail industry.

Fig. 5. Interaction between Break Start Time (BST) and Break Length on Prior Wake at the end of the shift.

The break lengths included in this analysis ranged from 12 to 169 h in length, representing both the short turnaround shifts and periods of extended leave often experienced by rail employees in Australia. The results of this study indicate that prior break length does not significantly influence the subjective alertness ratings of employees at either the start or end of the first shift back after the break. This suggests that even if employees had adapted to 'being in holiday mode', any potential changes in their sleep patterns during the period of extended leave did not further exacerbate decreases in alertness that are typically associated with irregular work hours.

Rather, in line with previous findings, it was found that subjective alertness ratings varied as a function of both the shift type and the length of the shift to be worked^(21, 22) and the timing of these break periods⁽¹⁷⁾. Results of the current study indicated that subjective alertness was highest prior to the afternoon shift and lowest prior to the night shift. Not surprisingly, post shift alertness scores indicated that employees were more alert at the end of day shifts. This supports numerous findings previously published which indicate that alertness ratings follow a 24-h rhythm⁽²³⁻²⁵⁾, and is typically highest during the day and lowest at night.

Analysis of the post shift self-rated alertness levels indicated that the longer the shift the lower the subjective alertness at its conclusion. Specifically, it was found that alertness scores at the conclusion of shifts longer than 10 hours were significantly lower than those scores obtained at the end of shorter shifts. These findings closely replicate a number of published studies stating that systems of extended

work hours can lead to an increased potential for fatigue, reduced performance and increased accident risk^(26, 27).

It is interesting to note that during this study prior break length did not significantly impact on subjective alertness levels both prior to work and at its completion. A possible reason for this result is that the alertness scales used (Samn-Perelli and Visual Analogue Scales) may not have been sensitive enough to detect changes in alertness caused by the prior break length. However, recent publications have reported subjective estimates to have moderate to strong correlations with objective performance, especially at the end of a testing period^(28, 29), refuting this argument.

The reported lack of significance may instead be caused by limited testing opportunity. These studies only requested participants to rate their alertness at the beginning and end of each shift. These scores may have been 'masked' by 'non-work' related contextual factors. For example, our results may show how participants felt just prior to starting work, but these subjective alertness ratings may have changed dramatically moments later when work began.

Furthermore, participants were asked to rate their alertness at the conclusion of their shift. The participants' true feelings of alertness may have been masked by an 'end-of-shift' effect which has been observed in other studies^(21, 29). This is evident when comparing the post shift alertness levels for the afternoon and night shifts in Fig. 3. This graph indicates that participants rated themselves more alert at the end of the afternoon shift, which contradicts previous findings in the literature⁽⁹⁾. A possible reason for this discrepancy is that the night shift results showed a greater 'end-of-shift'

effect than the afternoon shift.

Possible solutions for these experimental design flaws are to request participants rate their alertness' levels at frequent intervals during their shift. Masking effects may also be minimised if participants are required to sit still for one minute with their eyes closed in order to eliminate transient activation³⁰.

The results of this study indicate that prior break length significantly impacted on the main sleep period prior to returning to work. Specifically, sleep obtained during short breaks (<24 h) and medium (24–48 h) was shorter in duration than sleep obtained during extended (>48 h) break periods. It is not altogether surprising that employees obtained less sleep per period during shorter length breaks. It is highly probable that this was the case because they had less opportunity in general to attend to family and social (and other) commitments and to obtain sufficient sleep than during periods of extended leave. Furthermore, employees may actually obtain more sleep during short breaks (<24 h) than they do during medium length breaks as there may not be enough time for commitments other than sleep during these periods. On the other hand, it is possible that employees with medium length breaks choose to truncate their sleep period and extend their wake period prior to work in order to fulfil social and family obligations. Certainly, this suggestion is in line with the finding that total wake time was significantly longer for employees who returned to work after a medium length break period (24–48 h).

Prior wake time was also significantly influenced by break start time. It was found that a break start time between 0900 and 1600 h resulted in significantly less prior wake time for short breaks compared to longer periods of leave. As previously mentioned, employees with short turnaround breaks may choose to postpone family and social obligations more readily until a longer break opportunity arises. This would enable the employees to obtain sufficient sleep and therefore recovery prior to their next shift and still commit to family and social obligations at a later date.

Similarly, longer breaks were associated with longer sleep periods. Unlike short breaks, longer breaks would have allowed employees time to spend time with family and friends (etc), without sacrificing their sleep. Furthermore, it is possible that employees who return to work after longer break periods have had more chance to relax and unwind from their previous schedule and have had more time for social and family responsibilities. This could mean that employees returning after a longer break are more relaxed and therefore more able to sleep prior to returning to work and have more sleep opportunity during the break. Finally,

the fact that employees obtained more sleep following long breaks may also reflect the fact that they had adapted to longer sleep opportunities during their break, which may cause problems re-adapting to a different schedule upon return to work.

It was also found that break periods starting between 0500 and 1200 h were found to result in significantly less sleep. This is in line with previous shift work literature which states that sleep periods beginning during this time period are shorter and of lower quality than sleep periods starting late in the evening¹⁷. The interaction between break start time and break length was also found to be significant, specifically suggesting that shorter break periods (<24 h) starting during the early morning result in significantly reduced sleep, again supporting previous research^{17, 18}.

Surprisingly, the longest prior sleep duration was seen prior to morning shifts rather than night shifts as expected. This is not intuitive when considering previous literature on shift work^{4, 7}. One possible explanation for this is that participants may have stayed up later the night prior to a night shift hoping to nap during the afternoon. As naps were not included in this present analysis, it is not possible to determine whether this sleep debt was accounted for through napping prior to commencement of work. A further direction for this research is therefore to determine the effects napping may have on alertness levels and sleep prior to returning to work and also to determine the proportion of subjects who actually employ this sleep strategy.

This study does not include data relating to potential or actual sleep debt experienced by the participants in the days leading up to the break period. Further research stemming from our current work should therefore include analysis of schedules prior to starting a break, rather than just the break start time as is the case in this study. This would allow the potential performance and alertness deficits caused by a high sleep debt to be accounted for in the analysis.

The key to understanding the current problem and determining a plausible solution is to realise that employees do not work in isolation of each other. In fact, each employee's actions, responses and work hours impact appreciably on those of their colleagues. For example, when an employee takes leave due to illness, other employees are sometimes called upon to cover these shifts in order for operations to continue to run smoothly. This change in schedule can be defined in terms of opportunity cost.

Opportunity cost is a term used in economics, to mean *the cost of something in terms of an opportunity foregone* (and the benefits that could be received from that opportunity), or *the most valuable forgone alternative*. So

considering the previous example, possible opportunity costs associated with an employee taking unexpected sick leave could include calling in other employees to cover these shifts through overtime. This opportunity cost can be in terms of monetary loss (e.g. the cost to the organisation for the extra employees covering the shifts through overtime) or an increase in fatigue risk (e.g. if the relief employee has to work overtime to cover the unexpected leave then the increase risk of fatigue could be the opportunity cost).

Finally, it is possible that the results of this study could be different if longer prior break lengths were considered. For example, the government report questioned the relationship between a break of five weeks and the sleep and alertness of rail employees¹⁾. Further research is needed investigating this question before any definitive conclusions can be made regarding the affect of prior break length on alertness and sleep. However appropriate training of managers to consider the broader problem of opportunity cost rather than just the fatigue of rested employees may solve this issue.

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