TRAIN DRIVERS' FATIGUE & RECOVERY DURING EXTENDED RELAY OPERATIONS

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INTRODUCTION

In the past, extended (>2 day) relay operations in Australia have occurred mainly from the east to the west. More recently, the south-north track from Port Augusta to Darwin has been completed thereby increasing the number of train drivers exposed to relay work. Typically, both short (2 day) and extended (>2 day) relay operations in Australia require two crews work the train continuously during a round trip from one specified destination to another. The crews work alternating shifts where their sleep/duty times are opposite.

Typically, both short and extended relay operations involve irregular work hours – generally including day, night, morning and evening work. Workplace research, largely in the rail industry, has identified that the highest levels of sleepiness and fatigue are generally associated with early morning shifts and night shifts [1, 2]. As such, they exposed to increased levels of sleepiness and fatigue and hence an increased risk of accident and error. Environmental disturbances are known to impact negatively on sleep [3, 4] and the drivers have to sleep on the train in relay vans which are moving, vibrating and often noisy – and hence their fatigue levels whilst awake may be increased further.

While research suggests that the nature of relay work could potentially result in increased fatigue, the number of studies specifically investigating the effect of relay work on fatigue is limited. Past research has investigated train driver alertness during short relay operations (<48h) [5]. The relay from Adelaide-Melbourne takes approximately 40h – less than half of the time required for the Port Augusta to Darwin relay. The study assessed both subjective alertness and objective alertness (10-minute psychomotor vigilance task). The conclusions drawn indicated that, for short relay trips, when time away from home is restricted to about 40h, the impact of the irregular work schedule did not significantly impact on the drivers' alertness. The authors noted however, that sleep was restricted. Further investigation, focusing on the sleep of drivers during the Adelaide-Melbourne short relay operation, found that drivers, when sleeping in relay vans throughout the trip, obtained 5.8h sleep per 24h period [6].

It is evident that the sleep obtained in the relay vans was sufficient for maintenance of alertness across the 2-day trip. It is not known however, whether the same results can be applied to extended relay operations which span across 5-days. Laboratory studies have illustrated the cumulative effects of fatigue when sleep is restricted for a number of days[7-9]. While sleep restriction (5.8h per 24h) during the short relay trips did not seem to significantly affect alertness during the short trip, it might be reasonable to suggest that, over a 5-day trip, the cumulative effects will be more pronounced. This is especially likely when the sleep period prior to and following each trip is typically restricted, due to the timing of train departure and arrival. Levels of fatigue therefore, have the potential to accumulate significantly across the trip, making the amount of rostered time off (recovery) following each trip, of vital importance.

The introduction of the Port Augusta to Darwin extended relay operation has resulted in an increase in the number of drivers exposed to such work in Australia. Each return trip spans across 5 days and involves day, night, morning and evening shifts. In many cases, drivers are allocated the minimum time off (usually amounting to only 1 full night's sleep at home) before they embark on another 5 day trip. The aims of the present study were to determine levels of subjectively and objectively measured fatigue during the extended relay trips and also in the 'recovery' time between trips.

METHODS

Participant Recruitment

Participants were recruited from a pool of 27 train drivers working the Port Augusta to Darwin (return) relay operation for an Australian rail company. All drivers working the Port Augusta to Darwin relay were invited to attend one of three information sessions where information was provided about the project. Interested participants provided contact details and completed a general health questionnaire. In total 11 drivers attended the information sessions and expressed interest in the project. Another 2 drivers were unable to attend the sessions but expressed an interest also. Of the 13 interested participants 9 gave informed consent and participated in the study. Each participant volunteered to take part in the study twice (18 trips).

Participants

Participants (n=9) were aged between 42 and 63 years with a mean mean(±std) age of 51.3(±6.4). All drivers were male and one third of the participants were smokers. As a group they had an average of 27(±7.1) years experience as train drivers and 22.3(±11.7) years experience in relay driving. All had been working the Port Augusta to Darwin relay since completion of the northern part of the track in early 2004.

Materials

Objective Fatigue

A 5 minute Reaction Time (RT) task was used to assess reaction time performance before during and after each trip – as an objective measure of fatigue. The RT task was completed on a Palm Pilot using the PalmPVT program, developed by The Walter Reed Army Institute of Research. Palm Pilots are hand held devices and the program requires participants to react to a stimulus that appears on the screen of the Palm Pilot by pressing a designated button with the thumb on their dominant hand. Stimuli are presented at random intervals.

Subjective Fatigue

Subjective fatigue levels were assessed before during and after each trip. The scale used was the 7-point Samm-Pierelli fatigue scale, as shown below:

1. Fully alert, wide awake
2. Very lively, responsive, but not at peak
3. Okay, somewhat fresh
4. A little tired, less than fresh
5. Moderately tired, let down
6. Extremely tired, very difficult to concentrate
7. Completely exhausted, unable to function

Protocol

Baseline data for both the RT task and subjective fatigue were collected on the day prior to the train's departure. In all cases this was a rostered day off. Prior to each trip each participant had had at least 3 nights at home, at least one of which was a full night (i.e.

not preceded by a late/evening-shift or followed by an early morning shift). For 7 of the 11 trips, drivers had 2 full nights at home prior to the designated data collection trip.

A typical trip spanned across 5 days, taking approximately 40h (from Port Augusta to Darwin) followed by an overnight break in Darwin (between 8-14h) prior to return. Two crews, each consisting of 2 drivers, rotated every 8h giving each crew an 8h rest prior to each 8h working shift. There were 2 roster types 1) *working out* – where the first shift out of Port Augusta was a working-shift and 2) *resting-out* – where the first shift out of Port Augusta was a resting-shift. Those working-out, completed 3 (PD1, PD2, PD3) working shifts from Port Augusta to Darwin and 2 (DP1, DP2) working shifts on the return leg. For those resting-out, there were 2 (PD1, PD2) working shifts from Port Augusta to Darwin and 3 (DP1, DP2, DP3) on the return leg (see Figure 1). For each driver, RT and subjective fatigue ratings were assessed before and after each working shift.

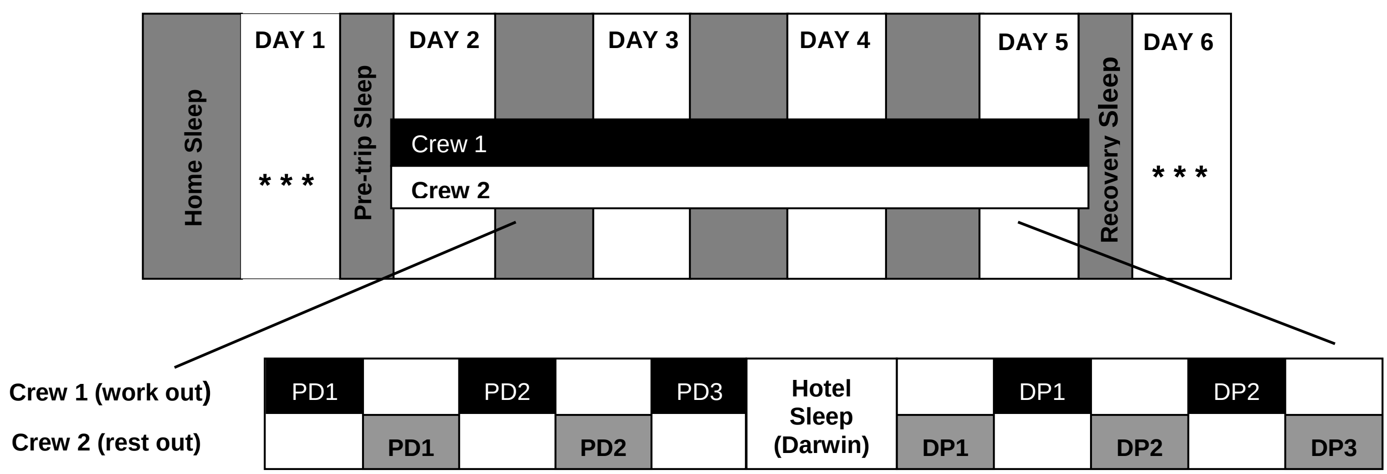

Fig 1. Typical structure of shifts for the two rosters - working-out and resting-out - during the 5 day Post Augusta- Darwin Relay Operation.

Recovery data was collected in the 2-3 days immediately following each trip. Participants completed the 5-minute RT task and fatigue ratings twice daily.

Statistical Analysis

All analyses were carried out using the statistical programme SPSS (version 11.5.0, SPSS Inc, USA). Changes in both subjective and objective fatigue across the trip and recovery were assessed using repeated measures analysis of variance (ANOVA). All data are expressed as a percentage change relative to the pre trip baseline. The pre trip baseline was taken as the lowest fatigue score of 3 on a rostered day off prior to the trip. The RT corresponding to this fatigue score was used as the pre tip baseline. In all cases this was the lowest mean RT. The two rosters; working-out and resting-out, were analysed separately. Planned comparisons were performed where relevant.

RESULTS

Subjective Fatigue

Pre trip baseline data was recorded on a rostered day off after at least 1 full night's sleep at home. Pre trip baseline was taken as the lowest reported level of fatigue. For those drivers working-out of Port Augusta had a mean(±std) minimum fatigue rating of 2.7(±0.5) and for those resting-out, the minimum fatigue rating on the baseline day was 3.2±(1.5).

Analysis (n=6) indicated that when working-out, fatigue ratings changed significantly across the trip [$F_{(1,13)}$= 5.327, p<.05)] as shown in Figure 2. Paired contrasts showed that fatigue ratings recorded *after* all shifts (post shift) except shift DP1 were between 75.0% and 86.7% greater than the pre trip baseline. During recovery, fatigue ratings were significantly (p<.05) elevated above the pre trip baseline during recovery day 1 (by 62.5%) but had returned to pre trip baseline levels for recovery days 2 and 3.

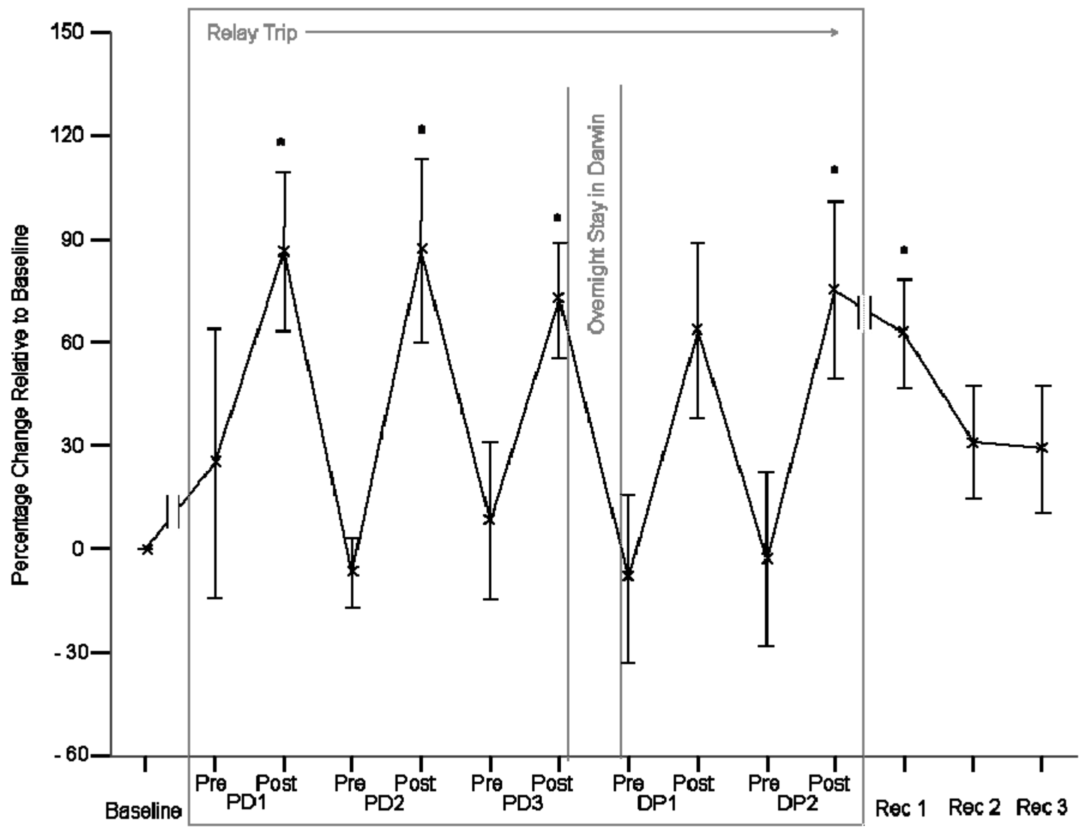

Fig 2. Mean±SEM subjective fatigue ratings throughout trip & recovery when working-out of Port Augusta. All values relative to baseline (n=6). *denotes significant (p<.05) difference compared to baseline.

Figure 3 (n=5) shows that, when resting-out showed that when resting-out, fatigue ratings did not change significantly across the trip [$F_{(1,13)}$= 2.692, p>.05)].

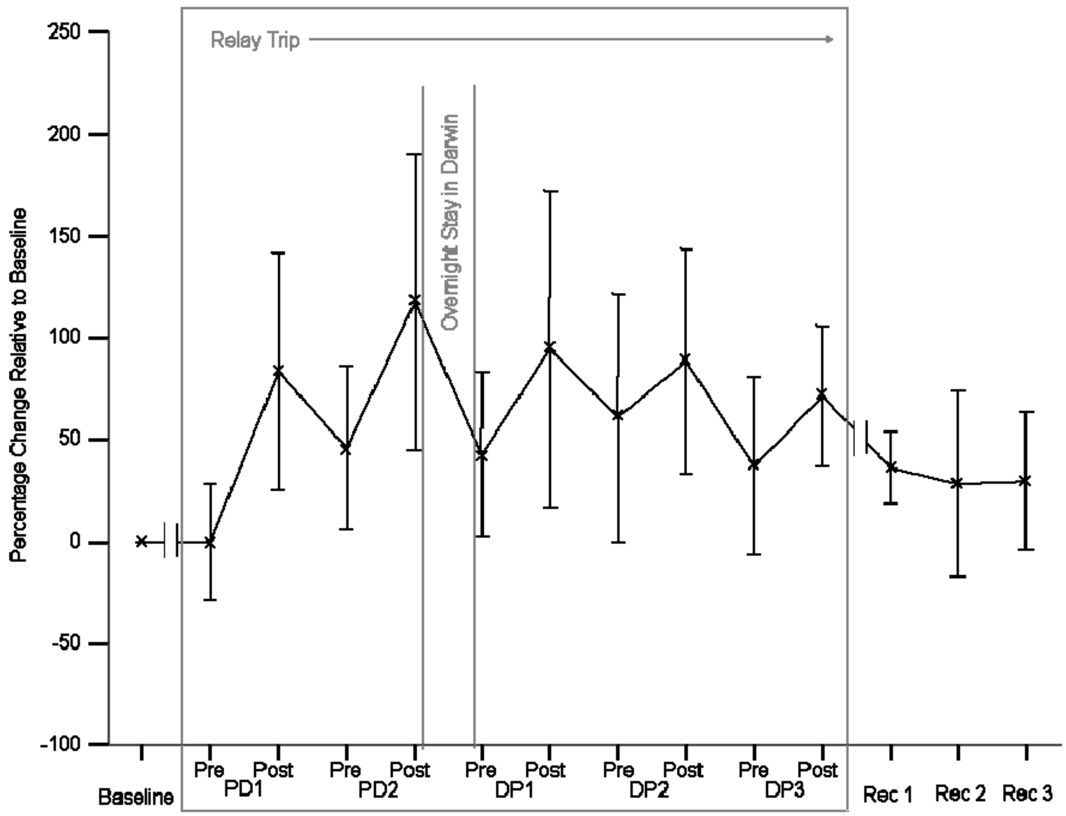

Fig 3. Mean±SEM Subjective fatigue ratings throughout the trip and recovery when resting-out of Port Augusta. All values relative to baseline (n=5).

Objective Fatigue – Reaction Time Performance on a Psychomotor Vigilance Task

Pre trip baseline data was recorded on a rostered day off after at least 1 full night's sleep at home. RT, mean(±std), for those on the working-out and resting-out rosters were 239.7(±21.0)ms and 238.1(±18.9)ms. respectively.

Analysis (n=6) showed that when working-out, fatigue ratings changed significantly across the trip [$F_{(1,13)}$= 2.462, p<.05)] as shown in Figure 4. Paired contrasts showed that fatigue ratings recorded *after* (post shift) shifts PD2 and PD3 were significantly elevated above baseline - by 16.5% and 9.6% respectively. During recovery, fatigue ratings were significantly (p<.05) elevated above baseline during recovery days 2 (by 9.6%) and 3 (by 10.7%) but not during recovery day 1. Analysis of the data (n=5) showed that when resting-out, mean RT scores did not change significantly across the trip [$F_{(1,13)}$= .940, p>.05)] as shown in Figure 5.

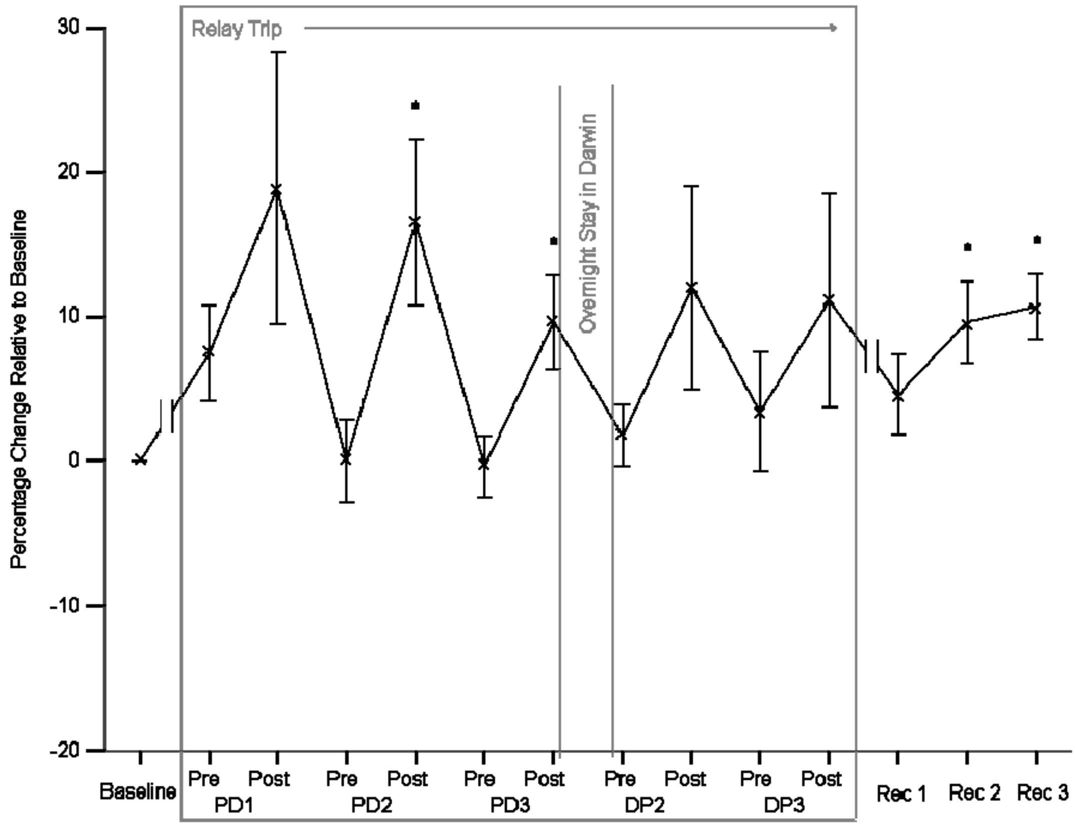

Fig 4. Mean±SEM RT scores throughout the trip and recovery when working-out of Port Augusta. All values relative to baseline (n=6). * denotes a significant ($p<0.05$) difference compared to baseline.

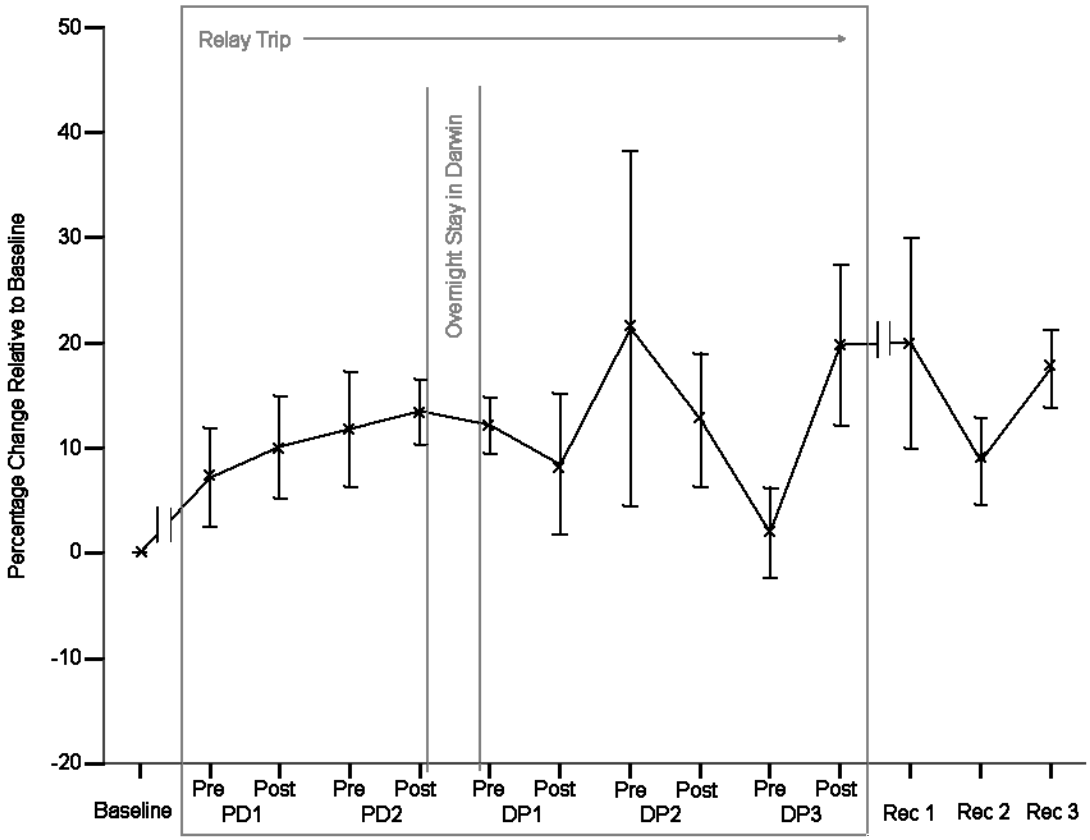

Fig 5. Mean±SEM RT scores throughout the trip and recovery when resting-out of Port Augusta. All values relative to baseline (n=5).

DISCUSSION

The main aims of this study were to determine the impact of extended (5-day) relay operations on the fatigue levels of Australian train drivers. Research investigating short (2-day) relay operations found that drivers were able to maintain alertness across these shorter trips [5]. It was not known however, whether the longer trips (5-day), would result in an accumulation of fatigue across the trip, therefore making drivers more susceptible to error and accident. Furthermore, recovery following a relay trip (whether long or short) has not previously been investigated. Both subjective and objective assessments of fatigue were examined to determine whether there are any cumulative effects of fatigue and the nature of 'recovery' following extended relay trips.

One of the main concerns associated with the extended relay operations, is the potential for fatigue to accumulate across the trip. When drivers were working-out of Port Augusta, fatigue did change significantly across the trip but did not accumulate. Not surprisingly, it tended to be greatest at the end of each 8h working shift. These increases in fatigue however, were relatively short-lived, with 8h resting shifts generally proving to be sufficient in reversing the impact of prior working shift and returning fatigue to pre trip baseline levels. Mean response time following working shifts PD2 and PD3 are about 10% greater compared to the pre trip baseline and, subjectively post shift fatigue increased up to 86.7% above baseline. These significant increases in fatigue, typically at the end of these working shifts is perhaps a cause for concern given that assessment of fatigue generally took place only 10-15 minutes following the working shift. While drivers were significantly more fatigued as shown by increased mean response times, it is difficult to determine exactly how this might translate into operational performance or risk.

It was predicted that the recovery time following each trip would be of particular importance if there was an accumulation of fatigue across the trip. With many drivers given only 1 or 2 full nights at home before embarking on another trip, the question was whether this minimum time off (as shown by fatigue ratings and RT scores on recovery day 2 – after 1 full night) is sufficient to see fatigue levels return to pre tip baseline. The first home sleep immediately after each trip is usually shortened – delayed due to the timing of arrival back into Port Augusta. Following this restricted sleep working-out drivers were not at pre trip baseline with subjective fatigue elevated above baseline. Objectively, during recovery days 2 and 3, RT performance also remained significantly above baseline. This might be due to the fact that the drivers are at home and, having been away from their family, friends and recreational activities for 5 days, began to prioritise these factors above their sleep. Whilst on the train, these factors are not present and do not therefore intrude into their sleep/rest time.

An interesting observation is that the level of both subjective and objective fatigue across the trip and recovery seems to depend on which roster is worked. When working out, there is a clear increase in fatigue following each working shift and a return to pre trip baseline levels following each resting shift. The data when resting out however, are quite different with no change in either reported fatigue or RT performance across the trip and recovery. The differences seen between the two rosters could be attributed to the departure time of the train from Port Augusta. Trains are scheduled to exit Port Augusta between 0330 and 0500 with book-on times usually 1-2 hours prior. Therefore, the first shift (PD1) for those drivers working-out is typically in the early morning. Research has shown that early morning shifts are generally, along with night-shifts, the most fatiguing[1, 2, 10]. The sleep period immediately prior to this early morning start is, for all drivers, curtailed. Those resting-out however, are able to go back to bed after they have booked on. Those drivers working-out not only have to work for 8h from the early morning but are then required to sleep/rest during the daytime prior to their next shift. The data suggest that the departure time might make the drivers more fatigued from the outset potentially therefore, making them more susceptible to increasing levels of fatigue across the trip.

It is interesting to note also that the first few 8h working shifts when working-out roster are also, seemingly more fatiguing than those in the in the Adelaide-Melbourne relay operation. In the Adelaide-Melbourne operation, alertness was maintained, yet, the data of the present study illustrate that, from the first shift, drivers are significantly more fatigued. Again, this might be due to the early morning departure time of the train. In the shorter operations, the book-on times were in the late afternoon (1730) or early evening

(1930), times where sleepiness and fatigue are not as prevalent compared to the early morning [1]

Central to the issue of workplace fatigue is sleep quality and quantity. Poor (through restriction for example) sleep has been associated with impairment in waking functions [7-9] and hence potentially dangerous workplace performance. Future research within the rail industry and extended relay operations should therefore focus on the measurement of sleep through either actigraphy or polysomography. This will enable true assessment of the quality of the rest/sleep during the resting shifts, providing information on the sleeping conditions of the relay vans and further contributors to train driver fatigue.

In conclusion, the data to date, suggest that while fatigue levels may increase after working shifts, the sleep/rest obtained during the 8h resting shifts are sufficient to see fatigue return to pre-trip baseline levels. During recovery however, in some cases, fatigue remains elevated. The working-out roster does appear to make the drivers more susceptible to increased levels of fatigue at the end of their shifts compared to the resting-out roster. This is possibly related to the early morning timing of the trains' departure out of Port Augusta. It is important to highlight however, that data collection is still in progress and that these results are still somewhat preliminary. Analysis of the complete data set may alter the final results.

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REFERENCES

1. Harma, M., Sallinen, M., Ranta, R., Mutanen, P., and Muller, K., *The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers.* Journal of Sleep Research, 11(p. 141-151;2002.
2. Ingre, M., Keckland, G., Akerstedt, T., and Keckland, L., *Variation in Sleepiness during early morning Shifts: A Mixed Model Approach to an Experimental Field Study of Train Drivers.* Chronobiology International, 21(6): p. 973-990;2004.
3. Thiis-Evenson, E., *Shift work and Health.* Industrial Medicine and Surgery, 27(p. 439;1958.
4. Knauth, P. and Rutenfranz, J., *The effects of noise on the sleep of night-workers*, in *Experimental studies of shiftwork.*, Colquhoun, P., S. Folkhard, P. Knauth, and J. Rutenfranz, Editors. 1975, Pladen: Westdeutscher Verlag.
5. Lamond, N., Darwent, D., and Dawson, D., *Train drivers' sleep and alertness during short relay operations.* Applied Ergonomics, 36(p. 313-318;2005.
6. Lamond, N., Darwent, D., and Dawson, D., *How Well Do Train Driver's Sleep in Relay Vans?* Industrial Health, 43(p. 98-104;2005.
7. Van Dongen, H. P., Maislin, G., Mullington, J. M., and Dinges, D. F., *The Cumulative cost of Additional Wakefulness: Dose-response Effects on Neurobehavioural Functions and Sleep Physiology From Chronic Sleep Restriction and Total Sleep Deprivation.* Sleep, 26(2): p. 117-126;2003.
8. Dinges, D. F., Pack, F., Williams, K., Gillen, K. A., Powell, J. W., Ott, G. E., Aptowicz, C., and Pack, A. I., *Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night.* Sleep, 20(4): p. 267-7.;1997.
9. Belenky, G., Wesensten, N. J., Thorne, D. R., Thomas, M. L., Sing, H. C., Redmond, D. P., Russo, M. B., and Balkin, T. J., *Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study*. J Sleep Res, 12(1): p. 1-12;2003.
10. Dawson, D., Roach, G. D., Reid, K. J., and Baker, A., *Australian Railroads Shiftwork and Workload Study.* 1998, The Centre for Sleep Research: Adelaide, Australia.