TP 13035E

A 36-Hour Recovery Period for Truck Drivers:

Synopsis of Current Scientific Knowledge

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NOTICE

TP 13035E

A 36-HOUR RECOVERY PERIOD FOR TRUCK DRIVERS: SYNOPSIS OF CURRENT SCIENTIFIC KNOWLEDGE

Prepared for

Transportation Development Centre
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Transport Canada

by

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16. Abstract

This report presents a broad review of the scientific literature on rest and recovery requirements from acute and cumulative fatigue due to extended hours of work during the day and across several days. Many articles were found which dealt with the impact of length of shift, time of day, and sleep deprivation effects on driver performance and accident rates. Very few studies were found that looked at crash risk or performance in terms of number of days worked in sequence or number of hours worked since the last period of days off. The literature is also reviewed from the perspective of assessing the potential adequacy of a 36-hour off-duty period as a reset time for rest and recovery of commercial drivers from the current weekly maximums on driving and on-duty hours in the Canadian hours-of-service regulations. Although the overall body of knowledge offers guidance on this issue, only one study was found that specifically dealt with an operational schedule that would be permitted under a 36-hour reset scenario. This is mainly because such a short reset period would result in schedules that would exceed current hours-of-work regulations in most countries. Finally, areas of potential future research addressing driver performance and recovery are presented.

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16. Résumé

Ce rapport présente les résultats d'une recherche documentaire approfondie sur le repos et la récupération nécessaires pour éliminer la fatigue aiguë et la fatigue accumulée attribuables à de longues heures de travail et à de longues séquences de jours travaillés. Nombre d'articles répertoriés traitent du rôle de facteurs comme le nombre d'heures de travail consécutives, la période du jour travaillée et le manque de sommeil sur la performance au volant et le taux d'accidents. Mais très peu de chercheurs se sont penchés sur le risque de collisions ou la performance au volant en regard du nombre de jours de travail consécutifs ou du nombre d'heures travaillées depuis la dernière période de congé. La recherche documentaire visait en outre à établir si une période de 36 heures, dite «de récupération», est suffisante pour permettre à des conducteurs de véhicules utilitaires de se reposer suffisamment après avoir atteint le nombre maximal d'heures de service hebdomadaires autorisé par la réglementation canadienne sur les heures de service. Dans l'ensemble, les études recensées fournissent certaines indications sur cette question. Mais une seule évoque précisément un horaire de travail dans lequel a pu être intercalée une période de récupération de 36 heures : c'est que l'insertion, dans les horaires, d'une période de repos aussi courte entraînerait un dépassement du nombre maximal d'heures de service autorisé par la réglementation de la plupart des pays. Le rapport propose finalement des axes de recherche future sur la performance au volant et la récupération.

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SUMMARY

This report presents a broad review of the scientific on rest and recovery requirements from acute and cumulative fatigue due to extended hours of work during the day and across several days. The literature was also reviewed from the perspective of assessing the potential adequacy of a 36-hour off-duty period as a reset time for rest and recovery of commercial drivers from the current weekly maximums for driving and on-duty hours in the Canadian hours-of-service regulations.

Many articles were found which dealt with the impact of length of shift, time of day, and sleep deprivation effects on driver performance and accident rates. Very few studies were found that looked at crash risk or performance in terms of number of days worked in sequence or number of hours worked since the last period of days off. Even fewer studies were found that looked at the recuperative value of rest periods and time off.

Overall, based on the studies cited in the literature review and the data from the recovery study by Wylie et al. (1997), it is clear that further research is necessary to evaluate the recuperative value associated with prescribed time off. There are few studies pertaining to this problem and most do not specifically address the issue. Therefore, the conclusions drawn from the literature lack a strong scientific foundation and are based on generalizations from studies not directly assessing the problem of a 36-hr reset. The recovery study by Wylie et al. (1997) was the most direct evidence on this issue. However, conclusions from these data are more suggestive rather than conclusive since the number of subjects was small and sleep during the recovery periods was not fully recorded. Nevertheless, although the available research is sparse, it is sufficient to raise concerns about a 36-hour reset that would allow drivers to accumulate up to 92 hours on-duty within a seven-day period, particularly for night driving. It is also clear that there is insufficient scientific foundation on which to base prescriptive solutions for appropriate rest periods.

Currently, regulations prohibit on-duty time exceeding 60 hours in most countries. Consequently there are no studies which address accident risk associated with a 92-hour week, as would be possible with the 36 hour reset rule. The only data relative to crash risk associated with working in excess of current hours comes from a study by Jones and Stein (1987) showing that drivers with logbook violations have a higher risk of crashes. However, whether this is due to extended driving in a single shift or cumulative fatigue from several days of driving is not known.

The study by Jovanis and Kaneko (1990) indicates increased accident risk for night drivers after 3 to 4 days of driving. The NTSB (1995) study indicated that driving at night with a sleep deficit is far more critical in terms of predicting fatigue-related accidents than simply nighttime driving. The Jovanis and Kaneko (1991) study indicates less concern for daytime drivers with respect to a crash immediately following a 3 to 4 day period of driving. However, the study by Linklater indicates lower accident risk for drivers who typically drive less than 55 hours per week. This is corroborated by Jones and Stein who showed that drivers with logbook violations have a higher risk of crashes. Nevertheless, the evidence concerning extended hours of work and likely crash risk is not conclusive.

Sleep deprivation is known to interfere with performance of vigilance tasks (Wilkinson et al, 1966, Rutenfranz et al, 1973). A number of studies (Wylie et al., 1996; Wylie et al., 1997; Rhodes et al., 1995; Donderi, Smiley and Kawaja, 1993; Rutenfranz et al., 1972; Hertz, 1988) have shown that drivers, night workers and shiftworkers obtain insufficient sleep and can build up a large sleep debt over the shift cycle due to reduced sleep.A driver who would commence a 60 hour period of work after a single day off would start a heavy schedule (60 hours in 4 days) in a fatigued state, with little chance of recovery during the work cycle because of the limited daily time off (e.g., 8 hours off after 15 hours on-duty).

Arguably the most important study on recovery in the general literature is by Lille (1967). Her results suggest that a single day off is insufficient for night workers to recover after an accumulated sleep debt from 5 days of work. A recent Ontario Hydro study (Malette, 1994) suggested that 3 days rest was superior to 2 days rest after three 12-hour night shifts were worked. A study of railroad locomotive drivers (Hildebrandt, Rohmert and Rutenfranz, 1975) indicates an advantage of a 2 day (and even 3 days), as opposed to a 1 day rest period in terms of reduced automatic brakings. In a review of the literature, Johnson and Naitoh (1974) argued that following protracted periods of sleep loss, 2 nights of recovery sleep is usually sufficient to allow near full recovery. This conclusion is still widely regarded as correct. However, the degree to which it may be true for partial sleep loss over extended periods is unknown.

The study by Wylie et al. (1997) provided the most direct, though limited (because of the few subjects involved), evidence on whether 36 hours off-duty provides sufficient time for drivers to recover after accumulating 60 hours on-duty. The study examined a number of rest periods following 4 consecutive 15-hr day or night on-duty periods (13 hours of driving in each period). Measures analyzed included EEG, face video recordings, vehicle lane tracking, and computerized performance tests. The authors concluded that there was no objective evidence of driver recovery from the 36 hours of time off. In terms of sleep duration, the 36-hour off-duty period appeared to impact the day and night drivers differently. For drivers starting their shift by day, some increase was observed in the amount of sleep obtained during the 36 hours of time off. On the other hand, the one workday (36 hours) off appears to have resulted in less sleep for drivers starting their shifts at night. In all likelihood, these drivers resumed day shift sleep-wake patterns on their time off, even through the time off was insufficient for accomodation.

The general literature and the Wylie et al. study (1997) suggest several important factors that must be considered when examining performance and rest requirements of commercial drivers. These involve recognizing that circadian factors strongly influence work performance and the restorative potential of sleep, and that there is an interaction between work demands and the required duration of rest periods.

Areas for further research are identified that include: further analysis of the data collected by Wylie et al. (1997); epidemiological assessments and surveys on the effectiveness of rest periods; experimental studies on the recuperative value of sleep and rest; napping studies to maximize sleep benefits; exploration of hypnotics and other sleep inducing strategies; and, education and awareness training.

SOMMAIRE

Ce rapport présente les résultats d'une recherche documentaire approfondie sur le repos et la récupération nécessaires pour éliminer la fatigue aiguë et la fatigue accumulée attribuables à de longues heures de travail et à de longues séquences de jours travaillés. La recherche documentaire visait en outre à établir le bien-fondé d'une période dite «de récupération» de 36 heures pour permettre aux conducteurs de véhicules utilitaires de se reposer et de récupérer après avoir atteint le nombre maximal d'heures de service hebdomadaires présentement autorisé par la réglementation canadienne sur les heures de service.

Nombre des articles répertoriés traitent du rôle de facteurs comme le nombre d'heures de travail consécutives, la période du jour travaillée et le manque de sommeil sur la performance au volant et le taux d'accidents. Mais très peu de chercheurs se sont penchés sur le risque de collisions ou la performance au volant en regard du nombre de jours de travail consécutifs ou du nombre d'heures travaillées depuis la dernière période de congé. Encore plus rares sont celles qui se sont penchées sur les pouvoirs reconstituants des périodes de repos et des jours de congé.

De façon générale, les études visées par la recherche documentaire et les résultats de l'étude sur la récupération menée par Wylie et coll. (1997) pointent clairement vers la nécessité de mener d'autres études pour être en mesure d'apprécier les pouvoirs reconstituants des périodes de repos prescrites. Peu d'études ont traité cette question et encore, la plupart l'ont fait indirectement. Les conclusions que l'on peut en tirer sont donc mal étayées sur le plan scientifique, car fondées sur des généralisations faites à partir d'études qui n'abordaient pas directement la question d'une période de récupération de 36 heures. L'étude de Wylie et coll. (1997) est la plus probante. Mais les conclusions auxquelles elle aboutit s'assimilent davantage à des suggestions qu'à des conclusions au sens strict, en raison du nombre limité de sujets et des lacunes dans la mesure du sommeil pendant les périodes de récupération. Mais, même rares, les études disponibles suffisent à soulever des doutes sur la capacité des conducteurs de récupérer suffisamment en 36 heures pour accumuler ensuite jusqu'à 92 heures de service en 7 jours, surtout s'ils travaillent de nuit. De plus, il ressort clairement qu'il existe peu de données scientifiques sur lesquels appuyer de nouvelles dispositions concernant les périodes de repos.

La réglementation présentement en vigueur dans la plupart des pays limite à 60 heures la durée des périodes de service. Il n'existe donc pas d'étude portant sur le risque d'accidents associé à la semaine de 92 heures, qui deviendrait possible si on appliquait la règle des 36 heures de récupération. Les seules données actuellement disponibles sur le risque d'accidents associé à des périodes de service de plus de 60 heures proviennent d'une étude de Jones et Stein (1987), qui montre un risque accru d'accidents chez les conducteurs dont le carnet de route révèle un dépassement des heures admissibles. Mais on ne sait s'il faut attribuer ce risque accru au nombre excessif d'heures de conduite pendant un quart de travail ou à la fatigue accumulée au cours de plusieurs jours consécutifs de conduite.

L'étude de Jovanis et Kaneko (1990) révèle un accroissement du risque d'accidents chez les conducteurs qui travaillent de nuit, au bout de 3 à 4 jours de travail. Une étude menée en 1995 par le

NTSB a par ailleurs montré que, plus que la simple conduite de nuit, la conduite de nuit avec déficit de sommeil constitue un facteur prédictif majeur des accidents dus à la fatigue. Selon une autre étude de Jovanis et Kaneko (1991) le risque d'accidents est moins élevé chez les conducteurs qui travaillent de jour, après une période de 3 à 4 jours de conduite. L'étude de Linklater révèle, par ailleurs, un risque d'accidents moindre chez les conducteurs qui conduisent normalement moins de 55 heures par semaine. Ce qui est corroboré par Jones et Stein, qui ont montré que les conducteurs qui dépassent les maximums permis courent davantage de risques d'avoir un accident. Mais le lien entre les heures prolongées de conduite pendant un même quart et la probabilité que survienne un accident n'est pas clairement établi.

Il est bien connu que le manque de sommeil diminue la performance et la vigilance (Wilkinson et coll., 1966, Rutenfranz et coll., 1973). Plusieurs études (Wylie et coll., 1996; Wylie et coll., 1997; Rhodes et coll., 1995; Donderi, Smiley et Zawaja, 1993; Rutenfranz et coll., 1972; Hertz, 1988) ont montré que les conducteurs professionnels, les travailleurs de nuit et les travailleurs par poste ne dorment pas assez et qu'ils peuvent accumuler, avec le temps, un lourd déficit de sommeil. On peut en effet penser qu'un conducteur qui entame, après une seule journée de repos, une période de 60 heures de conduite sur 4 jours, est encore fatigué et qu'il a peu de chance de récupérer pendant son cycle de travail, en raison du peu de temps hors service prévu dans son horaire (alternance de 8 heures de repos et de 15 heures de service).

L'étude de Lille (1967) est sans contredit la recherche la plus marquante sur la récupération. Les résultats de cette étude laissent entendre qu'une seule journée de repos n'est pas suffisante pour permettre à des travailleurs de nuit de compenser le déficit de sommeil accumulé pendant 5 jours de travail. D'après une étude récente de Ontario Hydro (Malette, 1994), 3 jours de repos seraient plus profitables que 2 jours de repos, à la suite de 3 quarts de nuit d'une durée de 12 heures. Une recherche portant sur les mécaniciens de locomotives (Hildebrandt, Rohmert et Rutenfranz, 1975) a démontré que les périodes de repos de 2 jours (voire de 3 jours) sont associées à moins de freinages automatiques que les périodes de repos de 1 jour seulement. Au terme d'une recherche documentaire, Johnson et Naitoh (1974) ont fait valoir qu'après une période prolongée de manque de sommeil, il suffit habituellement de 2 bonnes nuits pour récupérer complètement. Cette conclusion est encore aujourd'hui largement admise. On ne sait toutefois pas dans quelle mesure elle demeure valable lorsque le manque de sommeil s'étale sur une longue période.

L'étude de Wylie et coll. (1997) est celle qui apporte la réponse la plus directe, bien qu'à interpréter avec réserve (en raison du nombre restreint de sujets), à la question de savoir si une période de récupération de 36 heures est suffisante pour permettre aux conducteurs d'évacuer la fatigue accumulée au bout de 60 heures de service. L'étude a porté sur différentes périodes de repos prises à la suite d'une séquence de 4 périodes de 15 heures de service, de jour ou de nuit (chaque période comportant 13 heures de conduite). Les mesures soumises à l'analyse comprenaient des EEG, des enregistrements vidéo du visage, des enregistrements des déviations de trajectoires du véhicule et les résultats de tests de performances complémentaires informatisés. Les auteurs ont conclu que l'on ne pouvait établir une preuve objective de l'état de récupération des conducteurs au bout d'une période de repos de 36 heures. En ce qui a trait à la durée du sommeil, le repos de 36 heures semble avoir influé différemment sur les conducteurs, selon qu'ils travaillent de jour ou de nuit. Une certaine augmentation du temps de sommeil a été observée chez les conducteurs qui entament leur période de travail le jour. À l'inverse, il semble qu'un repos d'un jour (36 heures) ait entraîné une diminution des heures de sommeil chez les conducteurs dont le quart débute la nuit. Selon toute vraisemblance, ces conducteurs reprenaient, pendant leur période de congé, le cycle veille-sommeil caractéristique de leur période de travail de jour, même si leur période de congé n'était pas assez longue pour une adaptation naturelle.

Les études sur le sujet, et notamment celle de Wilie et coll. (1997) font ressortir plusieurs facteurs importants dont il y a lieu de tenir compte dans l'examen de la performance au volant et des besoins de repos des conducteurs de véhicules utilitaires. Il importe, entre autres, d'étudier l'effet considérable du rythme circadien sur la performance au travail et sur les pouvoirs reconstituants du sommeil, et les liens entre les exigences de la tâche et la durée que doivent avoir les périodes de repos.

Certains axes de recherche future sont proposés, soit : des analyses complémentaires des données colligées par Wylie et coll. (1997); des évaluations et des enquêtes épidémiologiques; des expériences sur les pouvoirs reconstituants du sommeil et du repos; des études sur les sommes en tant que catalyseurs des bienfaits du sommeil; l'exploration de l'hypnose et d'autres méthodes utilisées pour induire le sommeil; l'information et la sensibilisation des personnes concernées.

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SECTION 1. INTRODUCTION

BACKGROUND

The Ontario and the Canadian Trucking Associations have proposed a change to the hours of work legislation. Transport Canada and the Canadian Council of Motor Transport Administrators are considering how the safety of this proposed schedule might be examined in a scientific study.

Currently, the hours of work legislation allows a maximum of 13 hours of driving within a 15 hour period of duty before an 8 hour rest period is required and a maximum of 60 hours on-duty in a 7 day period or 70 hours on-duty in an 8 day period. There are no requirements for days off. The trucking associations are requesting regulations allowing a driver to complete his or her 60 hours of on-duty within a 4 day period followed by a mandatory 36 hours off. This would allow a driver to accumulate up to approximately 92 hours on-duty within a 7 day period, or 53% more than the current 60 hours. It is of interest to note that this exceeds the number of hours stipulated in the first hours of work legislation, the Federal Factory Act in Switzerland, passed in 1877 which stipulated 65 hours per week.

RESEARCH OBJECTIVES

The objectives of this research, and the mandate accorded to the investigators by Transport Canada's Transportation Development Centre (TDC), were as follows.

- To undertake a broad review of the scientific literature and report on current knowledge concerning the human's need - and strategies employed - for rest and recovery from acute and cumulative fatigue due to extended hours of work during the day and across several days, with particular emphasis on shift and night workers; and

- Based on current scientific knowledge, to discuss the adequacy of a 36-hour off-duty period as a reset time for rest and recovery of commercial motor vehicle drivers from the current weekly maximums on driving and on-duty hours in the Canadian 'Commercial Vehicle Drivers Hours of Service Regualations, 1994'; SOR/DORS/94-716, 15 November 1994. References to the scientific literature are to be provided in support of the discussion.

LITERATURE SEARCH CONDUCTED

A literature search was conducted of the Medline database (1966-1996), as well as the UTCat (University of Toronto Library Catalogue), Library of Congress catalogue (1968-1996) and Life Sciences and Bioengineering bibliographic index (1982-1994). Searches were carried out using keyword subject and title searches, alone and in combination. Key words used included: shift-work, driving, accidents(traffic), reaction time, motor skills, wakefulness, fatigue, sleep deprivation, work-rest tolerance, recovery, time factors, rest, work, and performance.

Various conference proceedings, including the 1994 International Society for Chronobiology XXI Conference proceedings, the 1995 International Symposium Shiftwork and Job Demands Abstracts, Truck Safety: Perceptions and Reality 1995 Conference Abstracts, were searched for relevant abstracts or papers.

Several issues of Shiftwork International Newsletter (Volume 12(1), 1995; Volume 12(2), 1995; Volume 11(1), 1994; Volume 11(2), 1994; Volume 10(2), 1993; Volume 7(2), 1990) were reviewed for information on work in progress.

The annotated bibliographies from "Effects of Circadian Rhythm Phase Alteration on Psychological Variables: Implications to Pilot Performance", 1981. (2084 entries) and from "Shift Scheduling and Overtime: A Critical Review of the Literature" carried out for the U.S. Nuclear Regulatory Commission were reviewed.

Several major reports and texts were reviewed, including "Driver Fatigue: Concepts, Measurements and Crash Countermeasures" (Haworth et al, 1988), "Recommendations for NRC Policy on Shift Scheduling and Overtime at Nuclear Power Plants" (Lewis, 1985), Fatigue, Safety and the Truck Driver (McDonald, 1984), Occupational Medicine: State of the Art Reviews (Shiftwork, 1990), Shiftwork and Biological Rhythms: Implications for the Worker (U.S. Office of Technology, 1991), Experimental Studies in Shift Work (Colquhoun, et al eds, 1975), Fitting the Task to the Man (Grandjean, 1988), and Effects of Hours of Service, Regularity of Schedules, and Cargo Loading on Truck and Bus Driver Fatigue (Mackie & Miller, 1978).

The literature search uncovered many articles which dealt with the impact of length of shift, time of day, and sleep deprivation effects on driver performance and accident rates. Very few studies have looked at crash risk or performance in terms of number of days worked in sequence or number of hours worked since the last period of days off. Except for a study by Wylie et al. (1997), none of these few studies considered a schedule such as that proposed, mainly because it exceeds current hours of work regulations in most countries.

SECTION 2. LITERATURE REVIEW

SLEEP DEBT AND CUMULATIVE HOURS/DAYS WORKED

Long shifts have been shown to result in sleep debts. A concern with increasing the number of days on which very long shifts can be worked in a week is that there will be inadequate recovery from these sleep debts.

One of the findings of the "Commercial Motor Vehicle Driver Fatigue and Alertness Study" (Wylie et al, 1996), conducted on behalf of FHWA and TDC, was that drivers were obtaining insufficient sleep. In that study, daytime drivers working 10 hour days were only averaging 5.5 hours of sleep whereas those drivers working 13 hour days were averaging about 5 hours of sleep. In contrast, drivers working 10 hour irregular shifts averaged less than 5 hours of sleep and drivers working 13 hour night shifts averaged just under 4 hours of sleep. The amount of sleep under all driving conditions was considerably less than the 7.5 to 8.0 hours sleep length considered to be normal for day workers.

Other studies of shiftworkers have also found that night workers build a large sleep debt over the shift cycle due to reduced sleep. For instance, in a survey carried out of air traffic controllers who worked 12 hour shifts, night workers estimated that they obtained only about 5 hours of sleep on average (Rhodes et al, 1995). In another study, sleep of controllers working 5 consecutive midnights was actually monitored. These controllers were found to average 4.3 hours of sleep on this shift (Rhodes et al, 1996). Another study examined the sleep of Canadian Coast Guard watchkeepers working 12 hours a day in two shifts. In the study, sleep was recorded on a hand-held computer but not monitored by EEG, for each of 56 days for 32 watchkeepers. Watchkeepers who worked mainly during daytime hours reported 5.5 hours sleep. Those working mainly during the night reported 5 hours of sleep (Donderi, Smiley and Kawaja, 1993).

Studies of marine watchkeepers who work odd shifts, show shorter total sleep and poorer performance are associated with split sleep (Rutenfranz et al, 1972). Even small reductions in sleep - by 2 hours - can result in measurable changes in performance on tests of vigilance (Wilkinson et al, 1966).

In summary, research indicates that sleep debts lead to poorer performance and contribute to accidents.

ACCIDENTS AND SLEEP DEBT

Sleep debts have been linked to accidents. An analysis of 107 single vehicle heavy truck accidents carried out by the National Transportation Safety Board Safety (NTSB, 1995) concluded that the most critical factors in predicting fatigue-related accidents were the duration of the most recent sleep period, the amount of sleep in the past 24 hours, and split sleep patterns. The truck drivers in fatigue-related accidents were found to have obtained an average of 5.5 hours sleep in the last sleep period prior to the accident. This was 2.5 hours less than the drivers involved in non-fatigue-related accidents (8.0 hours).

Many of the truck drivers who were involved in fatigue-related accidents did not recognize that they were in need of sleep and believed that they were rested when they were not. The authors note that "about 80 percent of the drivers involved in fatigue-related accidents rated the quality of their last sleep before the accident as good or excellent".

The authors conclude that the data from this study indicate that driving at night with a sleep deficit is far more critical in terms of predicting fatigue-related accidents than simply nighttime driving. Truck drivers with split sleep patterns obtained about 8 hours sleep in a 24-hour time period; however, they obtained it in small segments, on average of 4 hours at a time. Their concern about sleep deficits is further supported by Hertz (1988) who examined the impact of the use of sleeper berths on accident causation. She compared sleeper berth use by 418 fatally injured tractor-trailer drivers to that of 15,692 non-injured drivers involved in property damage accidents. Use of sleeper berths in two shifts increased the risk of a fatal crash by a factor of 3. Univariate analysis was used to identify confounding factors, and then logistic regression was used to adjust for these confounding factors. Hertz found that the risk of an accident associated with sleeper berth use was as high for drivers driving alone as for drivers driving in a team. In other words, the risk due to sleeper berth use does not appear to arise because of the disturbance of sleep due to the motion of the truck, but rather because of the splitting of sleep into two periods.

ACCIDENTS AND CUMULATIVE HOURS/DAYS WORKED

Only 2 articles were found which dealt with the issue of cumulative days or hours of driving and crash rates. Jovanis and Kaneko (1990) report on an analysis of carrier-supplied accident and non-accident data for a 6 month period in 1984. The data were obtained from a "pony express" type operation which operates coast to coast with no sleeper berths. Cluster analysis was used to identify 9 distinct patterns of driving hours over a 7 day period. The driving patterns of drivers who had an accident on the 8th day were compared to drivers who had no accident on the 8th day. These patterns reflected times of day of most frequent on-duty and driving time, the most frequent off-duty times, the mean and standard deviation of the total hours on-duty for the 7 days, the mean and standard deviation of consecutive hours driven per driver and the mean and standard deviation of the driving cycle. Unfortunately these authors did not include statistics on off-duty times in excess of 24 hours. They assumed that a substantial recovery occurs when a driver is off-duty in excess of 24 hours, after reaching the DOT limit of 60 hours in 7 days.

Accident risk on the eighth day is shown to be consistently higher for the 4 patterns involving infrequent driving the first 3-4 days followed by regular driving during the last 3-4 days, than the 4 patterns with the reverse arrangement. This suggests cumulative fatigue from driving over 3-4 days does occur, and leads to increased accident risk. When the patterns are examined in detail it appears that drivers who begin their trips near midnight and typically end them around 10:00 a.m. face a particularly increased crash risk after driving for several consecutive days. In contrast, drivers who typically drive a regular daytime schedule (10 a.m. to 6 p.m.) show little evidence of any effect due to continuous driving. Total hours of driving in a 7 day period varied between averages of 54 to 59 hours among the 9 patterns identified.

A study in Australia by Linklater (1980) collected self-report crash data from 612 truck drivers interviewed at truck stops. Of the total, 171 drivers reported one or more crashes within the preceding 2 year period. Linklater reported that there was an increase in crash risk for drivers who typically exceeded 55 hours per week. When the data were broken down further, the small groups of drivers reporting that they typically drove 75 or more hours per week actually reported lower crash risk. The authors attribute this counter intuitive result to the small sample sizes for the groups reporting the longest hours.

In addition to the evidence cited above relating hours of work and accidents, indirect evidence of a connection comes from a study by Jones and Stein (1987). This was a case control study which examined the relative risk associated with long hours of driving. For each large truck involved in a crash, three trucks were randomly selected from the traffic stream at the same time and place as the crash but one week later. A sample of 332 tractor-trailer crashes, each with 1, 2 or 3 case controls was extracted for analysis. For tractor-trailers, the authors found that the relative risk of crash involvement for drivers who reported a driving time in excess of 8 hours was almost twice that for drivers who had driven fewer hours. In addition, drivers who violate logbook regulations, drivers age 30 and under, and interstate carrier operations were associated with an increased risk of crash involvement.

We know from an extensive survey of 1249 drivers in four states (Braver et al, 1992) that many drivers violate hours-of-work regulations. Braver and his colleagues found that 73% of the interviewed tractor-trailer drivers were hours-of-service violators. Thirty-one percent reported driving more than the legal weekly limit (60 hours in 7 days, or 70 hours in 8 days). Over one quarter of the drivers reported working 100 hours or more per week. Nineteen percent of the tractor trailer drivers reported falling asleep at the wheel one or more times during the past month. Significantly more of the work-hour-rule violators than non-violators admitted to this problem. This suggests that extending hours of work will lead to increased incidents of drivers falling asleep at the wheel.

ACCIDENTS AND CIRCADIAN EFFECTS

Many of the studies cited above show greater performance decrements or greater evidence of crash risk during night work. In addition to these studies, two other studies of truck accidents and time of day effects make this link clear.

Mackie and Miller (1978) examined truck accident rates controlled for exposure. An accident involving a dozing driver was found to be 7 times more likely to occur during the hours of midnight to 8:00 a.m. than in the other hours of the day, with the highest risk occurring between 4:00 and 6:00 a.m.

A study in Sweden also controlled for number of vehicles on the road and found that, for trucks, the risk of a single vehicle accident increased during the night with a peak between 3:00 and 5:00 a.m. of 3.8 times the risk of an accident during the day (8:00 a.m. to 4:00 p.m.) (Kecklund and Akerstedt, 1995).

Despite findings that accidents are more prevalent in the early morning hours, hours of service regulations treat hours of the day as if they were interchangeable. It is as acceptable to drive for 13 hours starting late in the evening, reaching the end of the trip at the circadian low point of the day, as it is to drive 13 hours starting in the morning, despite the fact that the former schedule carries a much higher accident risk. The proposed 36 hour reset schedule also ignores these day-night differences in performance and accident risk.

PERFORMANCE AND CUMULATIVE HOURS/DAYS WORKED

TRUCK DRIVING

The classic study of the impact of hours worked on performance of truck drivers was carried out by Mackie and Miller in 1978. They measured behaviour, over a week long period, of a total of 12 truck drivers on regular and irregular schedules, involved in sleeper cab operations, and performing physical work in addition to driving. Their measures were multi-dimensional. They looked at vehicle control performance as measured by lane position control and levels of fine and coarse steering reversals. An accompanying experimenter kept track of critical incidents involving driver drowsiness. Physiological measures, namely adrenaline excretion rates, heart rate, percent theta and beta in the EEG, were used to determine stress and arousal levels. Subjective ratings of fatigue were also recorded. Finally, they looked at performance on a tracking task shown to be sensitive to impairment from other stressors such as alcohol.

This very thorough study indicated that the effects of fatigue were evident long before the limits in the hours of service regulations had been reached. Fatigue effects showed up as significantly greater feelings of fatigue during the second half of all standard length (9.5 hour) trips, and after 6 hours on irregularly scheduled trips. Significant changes in steering patterns and in lane position variability showed up after 8½ hours of driving on the regular schedule and after 4-5 hours during late night early morning trips on irregular schedules. Drivers engaged in sleeper operations showed earlier and/or greater signs of subjective fatigue and degraded performance as compared to drivers not so engaged.

In addition, Mackie and Miller examined cumulative effects of fatigue. They concluded that "some cumulative fatigue occurs during 6 consecutive days of relay operations, but time of day strongly affects how much will be seen." They offered the following evidence in support of this conclusion: "Significantly increased lane tracking variability for drivers on the regular schedule after 4 days of operation” and “significantly increased lane tracking variability for drivers on the irregular schedules after 4 days of operation." They also concluded that "there is some evidence of cumulative fatigue in sleeper driver operations though it is strongly affected by time of day and may be associated primarily with the moderate-work condition." One item of evidence provided for this conclusion is that the frequency of "critical incidents" involving driver sleepiness or inattentiveness was high for all drivers on the final day, regardless of whether they drove at night or during the day.

The second major study of performance and long distance truck driving was carried out in Australia (Williamson et al, 1994). This study involved 27 drivers driving 10-12 hour trips on

3 different schedules. The first of these was staged driving which involves a driver going halfway to the destination of the goods and exchanging loads with another driver who completes the trip. The advantage is that the driver is always returning to his own home, and therefore sleeps in familiar surroundings. The second schedule was a flexible one, in which drivers took rest and drove according to their own needs, regardless of working regulations. The third schedule involved drivers driving according to then current hours of work regulations.

Performance was assessed by means of test batteries evaluating drivers before driving, during the mid-trip break, and after driving. In addition, steering and speed variability measures were taken during the trip, and auditory reaction time was sampled every two hours. Subjective fatigue was measured using the Stanford Sleepiness Scale. Physiological fatigue was measured using heart rate and heart rate variability.

All three schedules showed greater subjective fatigue at the end of the trip as compared to the beginning. Because of operational constraints the staged trip was carried out first for most of the drivers, and took place after a week of work. Ratings of fatigue were higher both at the beginning and the end of the staged trip, as compared to ratings for the other two schedules tested, suggesting that if a driver starts a trip tired he is likely to be more tired at the end of the trip. The authors note that this underlines the need for adequate rest before starting trips. Changes in subjective ratings of fatigue were associated with changes in test performance.

OTHER INDUSTRIES

A classic study which clearly established time of day effects in performance was carried out using data collected over a 30 year period from 3 gas meter readers working rotating shifts (Bjerner, Holm, and Swenssen, 1955). In addition to examining time of day effects, this study also examined the impact on performance of a reduction in hours worked from 56 (7 8-hour shifts per week) to 48 (6 8-hour shifts per week). This drop in number of hours resulted in a 34% drop in the meter reading error rate.

Studies carried out during the First World War in British munitions factories examined the impact of working hours on productivity (Vernon, 1921). Shorter weekly hours were found to increase productivity per hour with the biggest improvement occurring when hours were reduced to 47.5 per week (169 units per hour) from 54.4 (131 units per hour). Productivity at 66 hours per week was lowest of all, at 108 units per hour.

In a report on recommendations for NRC policy on shift scheduling Lewis (1985) recommended that the number of hours worked in a 7-day period be limited. The basis of this recommendation was discussed in terms of other industries. "Federal regulations limit airline pilots and crew to 30 hours of duty aloft in a 7-day period and limit truck drivers to 60 hours of work in a 7-day period." Lewis cites Nicholson's work hours index (Nicholson, 1972) for airline pilots and crew which sets a limit of 55 hours of duty time (duty time = flight time + ground duty time). Nicholson’s index was based on data linking flight schedules with abnormal sleep. Lewis also cites a physiological index (Mohler, 1976) for airline pilots and crew which indicates that 56 hours in 7 days is a high load and that 84 hours in 7 days is far too many. Mohler’s index was based on observations of pilots on international flights. U.S. Air Force flight crews are limited to 125 hours of flight duty in 30 days, which is an average of 29 hours in 7-days.

RECOVERY REQUIREMENTS

RECOVERY AND SLEEP DEBT

In a review of the literature, Johnson and Naitoh (1974) argued that following protracted periods of sleep loss, 2 nights of recovery sleep is usually sufficient to allow near full recovery. This conclusion is still widely regarded as correct. However, the degree to which it may be true for partial sleep loss over extended periods is unknown. One study that did examine the impact of partial sleep loss on the need for recovery sleep comes from Haslam (1985). In that study Haslam had one group of subjects sleep for 4 hours per night for 6 nights. A second group of subjects slept for only 1.5 hours per night for 3 nights followed by 3 nights of total sleep deprivation. The group that obtained only 4 hours of sleep per night across the shift cycle slept for 12.83 hours of sleep when given the opportunity. This indicates the strong need for sleep following a protracted period of sleep restriction. The data from the other group are more problematic (since only half of the subjects entered into this group were successful in completing the protocol) but showed that this group slept for 16.75 hours when given a sleep opportunity.

One of the most important studies for understanding recovery in shiftworkers is that of Lille (1967). Lille (1967) carried out EEG recordings to determine the length of daytime sleep of 15 night-shiftworkers. The average length of sleep on days when a night shift was worked was 6 hours. On rest days the average varied from 8 to 12 hours, with the longer sleep on the second of the two rest days. Lille concluded that during the week the night workers accumulated a sleep debt, which was paid back on the days off. From the data it is clear that one day was not sufficient for this purpose.

A recent study suggests that shiftworkers may not be obtaining quite as much sleep on days off as reported by Lille for French shiftworkers in 1967 or as reported by Haslam (1985) in an experimental situation. Rhodes et al. (1995) reported that air traffic controllers on shiftwork, despite a significant sleep debt that had accumulated from reduced sleep during the work cycle, typically reported only 8-10 hours of sleep on days off. One could conclude from these data that many shiftworkers do not take advantage of their sleep opportunities sufficiently to promote recovery.

RECOVERY AND TIME OFF

The relationship between recovery and time off is generally studied in the context of short breaks or naps (two hours or less) and performance. Few studies were found dealing with the number of days off required for recovery of performance after a sequence of days worked.

Alluisi (1972) discusses 4 hour on-4 hour off schedules and effect on performance, over a continuous work period. He found that average performance dropped to 67% of baseline toward the end of a 48 hour period of continuous work. A 24 hour rest period was sufficient to permit recovery to 94-101% of baseline.

Hildebrandt, Rohmert and Rutenfranz (1975) investigated performance of 1000 locomotive drivers over a total of 6304 work hours. Performance was assessed with respect to an alerting device which requires a driver to hit a button in response to a light signal. If the driver does not respond within 2.5 seconds, a loud warning hooter is sounded; if there is still no response within the next 2.5 seconds, an emergency brake is applied. Analysis showed the frequency of sounding of the warning hooter to have peaks at 0300 and 1500, but it was noted that the visibility of the warning signal was considerably greater at night than during the day. The greater visibility at night would have made the nighttime detection task easier, and no doubt contributed to there being a greater time of day effect at 1500 than at 0300 (the reverse is usually the case). The authors did note that small increases in frequency at these two points were accompanied by a notable increase in frequency variability.

Further analysis was carried out to examine time on shift and recovery time after days off. Afternoon and night peaks in soundings of the hooter were more pronounced for drivers working during their 4th to 6th hour. After a recovery period from work of 24 hours or more, the authors note that "the daily course of sounding of the warning hooter was quite similar to the one found during the first 3 hours of the work shift".

The authors show the mean hourly frequency of sounding of the hooter plotted against the duration of the recovery period. As can be seen in Figure 1 the relationship is a complex one, with error rate increasing with increasing length of recovery period up to a first maximum at 10-16 hours. With longer durations error rate decreases reaching a minimum at 20-24 hours, followed by a second increase with a maximum at 48-72 hours.

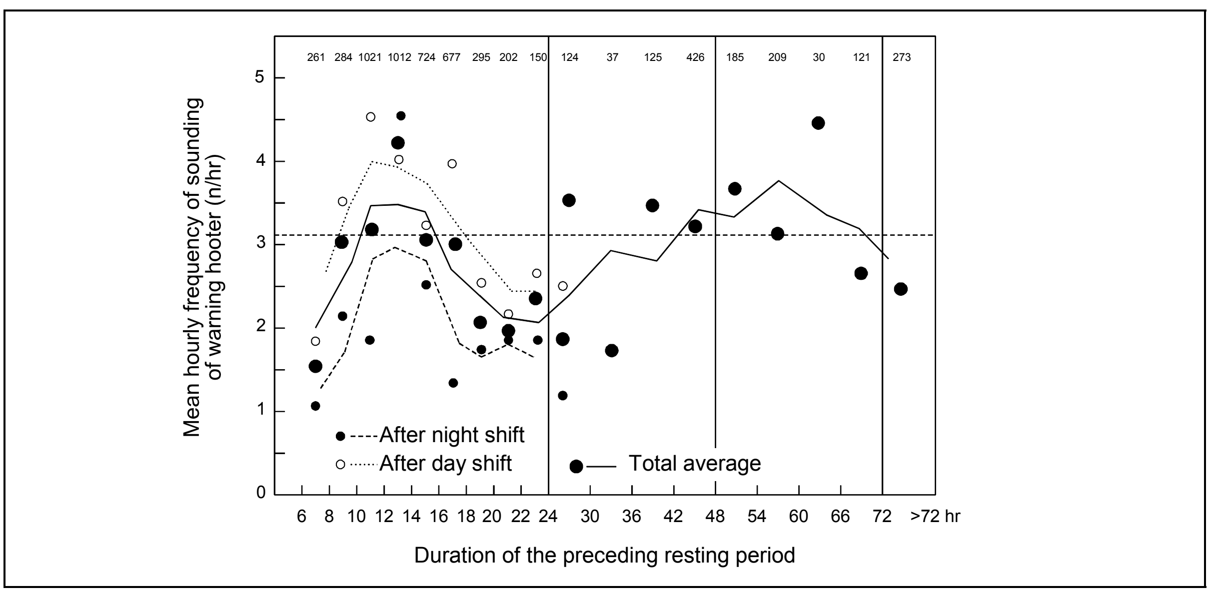

Figure 1. Mean hourly frequency of soundings of the warning hooter during the whole shift in relation to the duration of the preceding rest period. Up to a rest duration of 24 hours, separate averages for shifts following a night shift and a day shift are also shown. (Hildebrandt et al, 1975)

The authors also plot the relative frequency of automatic brakings against the duration of the preceding resting period. Here the relationship between performance and recovery is more straightforward, probably because fewer points are plotted. As can be seen from Figure 2, after a rest period of 24 hours, the relative frequency of automatic brakings was 35%. This declined to 17% after 42 hours rest. Rest periods longer than 42 hours up to 66 hours did not improve this performance. However, with 72 hours rest (3 days) relative frequency of automatic brakings declined to an average of 7.5%, indicating a benefit of 3 days as compared to 1 day of rest. The authors do not indicate the average number of hours worked before the recovery period.

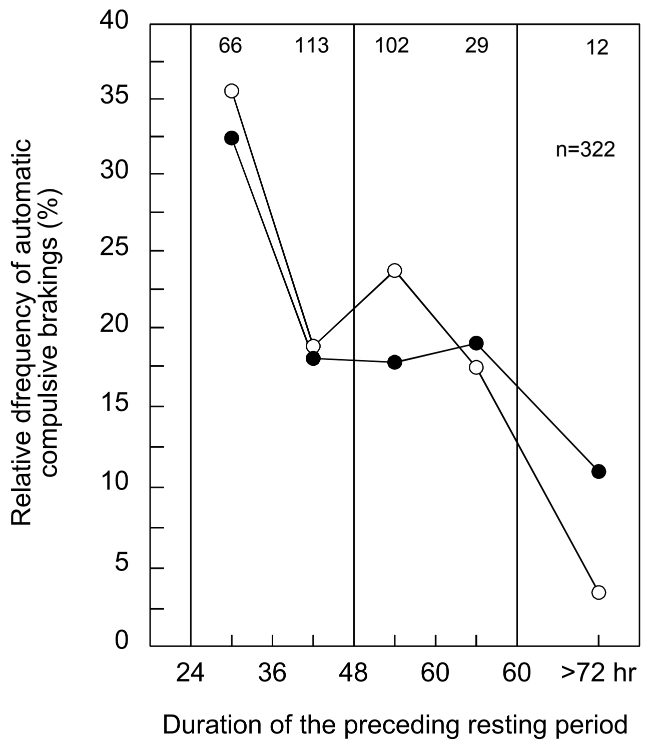

Figure 2. Relative frequency of automatic compulsive brakings caused by errors of omission by locomotive drivers in relation to the duration of the preceding rest period. The two curves were obtained from two different sets of data concerning the average frequency of rest periods of different duration on the German Federal Railways. Numbers in the upper part of the graph indicate the absolute frequencies of compulsive brakings. (Hildebrandt et al,1975)

In 1994, Dr. R. Mallette at Ontario Hydro (Molette, 1994) carried out a study assessing alertness of shiftworkers after a rest period of 48 hours as compared to 72 hours. Alertness was assessed using a psychophysical test, critical flicker fusion. Two representative shift crews worked three 12 hour night shifts followed by 48-hour or 72-hour rest periods before resuming work on day shifts. Alertness after 72 hours rest was found to be significantly higher than after 48 hours rest. The difference was equivalent to the difference in alertness at the start and at the end of an 8-hour day. The major drawback of using this difference as a point of reference is that there is no information as to whether flicker fusion varies according to circadian rhythm, or declines monotonically with number of hours worked.

STUDY BY WYLIE ET AL (1997), "CMV DRIVER REST PERIODS AND RECOVERY OF PERFORMANCE"

The most important study with regard to the degree of recovery afforded to truck drivers by rest periods is the Essex study conducted on behalf of TDC and CTRI entitled "Commercial Motor Vehicle Driver Rest Periods and Recovery of Performance" (Wylie et al, 1997). In this study, a group of 5 drivers who had driven for four 13-hr periods with night time starts were given a 36-hr period off and then returned for four more consecutive 13-hr night driving periods. This schedule allowed for an afternoon sleep following their last night's driving (which ended around 1:00 p.m.), a further nighttime sleep that night and an afternoon sleep the following day.

Another group of 20 drivers who had driven four 13-hr day trips (day time starts) were assigned to four different conditions. One group of 3 drivers was given no time off and worked an additional 5th day so they had only the usual sleep between shifts. A second group of 5 drivers was given a 36-hour period off and worked 4 additional days. A third group of 6 drivers was given 36 hours off and then worked an additional day. A fourth group of 6 drivers was given 48 hours off and then worked an additional day.

The number of drivers were small in all of these groups and this limits the strength of the conclusions that can be drawn. Nevertheless, these data provide the best available estimates of recovery or recuperative effects of time off for truck drivers under operational conditions. Below we consider the effects of these various rest periods after day and after night driving on measures of sleep and lane tracking.

For the night driving condition involving 4 days on, a 36-hr rest and another 4 days on, an increase in sleep time is seen across the initial 4 days and is particularly noticeable on the last day. These data suggest an increasing need for sleep which probably becomes more important than operational demands and their reduced ability to sleep because of the more difficult sleeping conditions (i.e., daytime sleeping).

During the 36-hr rest period, the second principal sleep period (afternoon sleep) prior to driving in the evening was markedly reduced to only about 2 hours of sleep. This is likely because the drivers had an extended off-duty night sleep in the 24-hour period immediately after going off-duty thereby reducing their ability to get sleep in the afternoon prior to their next work period. Previous data from other studies (e.g. Kogi 1985) are consistent with this explanation in that night workers who attempt to sleep in the afternoon only get about 2 hours of sleep. However, even with this reduced total sleep there was a 50% increase in the percentage of slow-wave sleep compared to the first sleep in the prior work cycle, suggesting drivers were still tired after the 36-hour recovery period. Subsequent sleep periods were then the same as were acquired during the first 4-day cycle, i.e., only about 4 hours of sleep.

For the day driving condition (i.e., for drivers starting their trips around noon on average), the second principal sleep which occured on the second night of the 36-hour recovery period (just before the first trip of the second work cycle) was the longest, indicating a need for recovery sleep. This sleep contained a comparable percentage of slow-wave sleep but a greater percentage of REM sleep

(70% more REM) compared to the first sleep in the first work cycle, again suggesting drivers were still tired after the recovery period. The total sleep over the remainder of the second work cycle was comparable to that of the first work cycle.

Without complete information on sleep in this 36-hr off-duty period other than the sleep recorded at the sleep centre, it is difficult to be more than speculative. However, the results from the Essex study do appear to show that the 36-hr reset period was differentially beneficial for the day and night drivers.

First, the night drivers' sleep prior to their first night shift after the 36 hours of time off was reduced compared to the day drivers. Despite this reduction, there was an increase in the amount of slow-wave sleep in this period compared to a similar period in the first work cycle. As slow-wave is often used as an indicator of need for recovery sleep, these data suggest that whatever sleep was obtained prior to this sleep was insufficient to promote full recovery. Of course with a reduced sleep period of 2 hours, less recovery would be possible and further sleep periods would be necessary for full recovery.

Second, for the day drivers, the first measured sleep of the second work cycle was longer than earlier sleep periods. However these earlier sleep periods had an equivalent amount of slow-wave sleep. This result would suggest that more slow-wave sleep was being acquired through longer sleep lengths. (Studies indicate that the first sleep following sleep deprivation contains more slow-wave sleep, with subsequent sleep periods containing more REM sleep than is the case in normal sleep structure.) The increase in the percentage of REM would suggest that recovery was incomplete at the start of the second work cycle.

Together these data suggest that neither day or night drivers were fully recovered though day drivers were more recovered than night drivers.

In terms of the other conditions, the day driving condition with no time off did not afford an opportunity for increased sleep and no increase in total sleep time was evident. There was, however, an increase in total sleep time following this work period. Those with either 36 or 48 hours off showed an increase in total sleep time during the time off although it was not greater than the baseline sleep prior to the first work cycle.

Another way of looking at these data is to examine the slow-wave sleep component of sleep across the sleep periods. For those who worked a 5th day with no time off, the next sleep period showed that slow-wave sleep increased by over 100%, compared to baseline, and by 50% during the first recovery sleep. For those with a 36 hours off, the first recovery sleep showed a 60% increase in slow-wave sleep but the slow-wave sleep during the next post-work sleep period was 250% greater. For those with 48 hours off, there was no increase in slow-wave sleep in the first measured sleep at the start of the second work cycle. These data suggest that 48 hours off may be sufficient for full recovery for daytime drivers.

Next, consider the lane tracking data. For the groups described above, the results were as follows. For the night drivers, there was a steady increase in variability of lane tracking during the last 3 nights of driving in the first work cycle. The same pattern occurred during the second work cycle except that the pattern was exaggerated; the first night was worse than during the first work cycle and the slope of the decay was greater during the second work cycle. In addition, variability in lane tracking for the night drivers was worse than that of the day drivers regardless of schedule.

For day drivers who worked two full cycles with a 36-hr reset, there was a progressive decline in lane tracking performance during the first work cycle. During the second work cycle, the first day was worse than the remaining periods, which is similar to the night drivers. However, the remaining 3 work periods were similar to each other but worse than all work periods during the first work cycle.

Contrasting these night and day drivers, it appears that the night drivers performed less well than the day drivers. There was a progressive decline in lane tracking performance across work periods for night drivers, especially in the second work cycle. The day drivers also performed worse in the second work cycle, but had reached a plateau of performance decline by the second shift in the second cycle. These data are somewhat consistent with the sleep data indicating that the night drivers were more impaired and that limited recovery was present in the night drivers.

For those with 0, 1 (36 hours), or 2 (48 hours) work cycles off on day driving, the results appear to be consistent with expectations. For the group with no time off, there was a large decline in performance between the 4th and 5th work period. For those with a 36-hr reset, the decline in lane tracking ability from the last day of the first cycle to the first day on the second cycle was somewhat smaller. For those with 2 work cycles off, the level of performance was within a range no different from the range of performance over the first work cycle.

Together these data suggest that for day drivers, 2 work cycles off are preferable to only 1 work cycle. Night drivers were only examined under one condition, the 36 hour reset. For this condition, day drivers seemed to fare better than night drivers. The data suggest that only partial recovery occurs after a 36-hr reset for both day and night drivers, and that working continuously after such a reset is only reducing the sleep debt to some degree.

These data are encouraging with respect to a solution but are largely based on a relatively small number of subjects in each condition and the prior experience of the different groups. What is needed is more systematic study of the circadian-based value of both recovery periods and previous workplace demands.

SECTION 3. OBSERVATIONS FROM THE LITERATURE ON THE RESTORATIVE NATURE OF REST

The general literature and the Wylie et al. (1997) study suggest several factors that must be considered when examining performance and rest requirements of commercial drivers. Included among these are the following:

The role of circadian factors on work performance: In terms of work periods, it is clear that the deterioration in performance across work cycles will be, in part, dependent on the placement of those work periods within the circadian cycle. It is well-recognized that working at night will generate greater performance deterioration within a shift and working consecutive night shifts will generate greater cumulative performance decay across a shift cycle.

The role of circadian factors on the normal restorative nature of sleep: In terms of sleep, the restorative value of sleep will be dependent on when that sleep is acquired. Since the restorative nature of sleep is largely dependent on the quantity and quality of sleep, sleeping at times that promote a longer, more contiguous sleep period will promote greater restoration. Thus, night sleep will be more restorative than day sleep, and particularly more restorative than "core" sleep taken in the afternoon.

The circadian interaction between work demands and restorative sleep potential: If workers are working night shifts, their performance is likely to be more deteriorated prior to the rest period than day workers and thus they more strongly require restoration from sleep during that rest period. However, if the sleep period occurs during the daytime then the potential restorative value of sleep will be diminished.

Work schedules and duration of rest periods: Rest periods must allow sufficient recuperation to carry a driver through the subsequent work cycle. The current data suggests that a 36-hour reset is inadequate although day drivers may acquire a greater degree of restoration than night drivers. The data from Lille (1967) and the Ontario Hydro report also suggest that a single day off is insufficient for complete recovery.

The need for further research: Currently available data from the literature should be considered suggestive. More directly targeted studies must be conducted to adequately address the question of the relationship between restorative rest periods and work demands if prescribed rest periods are to be implemented.

SECTION 4. CURRENT SCIENTIFIC KNOWLEDGE AND THE 36-HOUR RESET PROPOSAL

Overall, based on the studies cited in the literature review and the data from the recovery study by Wylie et al. (1997), it is clear that further research is necessary to evaluate the recuperative value associated with prescribed time off. There are few studies pertaining to this problem and most do not specifically address the issue. Therefore, the conclusions drawn from the literature lack a strong scientific foundation and are based on generalizations from studies not directly assessing the problem of a 36-hr reset. The recovery study by Wylie et al.(1997) was the most direct evidence on this issue. However, conclusions from these data are more suggestive rather than conclusive since the number of subjects was small and sleep during the recovery periods was not fully recorded. Nevertheless, although the available research is sparse, it is sufficient to raise concerns about a 36 hour reset that would allow drivers to accumulate up to 92 hours on-duty within a seven-day period, particularly for night driving. It is also clear that there is insufficient scientific foundation on which to base prescriptive solutions for appropriate rest periods.

Currently, regulations prohibit on-duty time exceeding 60 hours in most countries. Consequently there are no studies which address accident risk associated with a 92-hour week, as would be possible with the 36 hour reset rule. The only data relative to crash risk associated with working in excess of current hours comes from a study by Jones and Stein (1987) showing that drivers with logbook violations have a higher risk of crashes. However, whether this is due to extended driving in a single shift or cumulative fatigue from several days of driving is not known.

The study by Jovanis and Kaneko (1990) indicates increased accident risk for night drivers after 3 to 4 days of driving. The NTSB (1995) study indicated that driving at night with a sleep deficit is far more critical in terms of predicting fatigue-related accidents than simply nighttime driving. The Jovanis and Kaneko (1991) study indicates less concern for daytime drivers with respect to a crash immediately following a 3 to 4 day period of driving. However, the study by Linklater indicates lower accident risk for drivers who typically drove less than 55 hours per week. This is corroborated by Jones and Stein who showed that drivers with logbook violations have a higher risk of crashes. Nevertheless, the evidence concerning extended hours of work and likely crash risk is not conclusive.

Sleep deprivation is known to interfere with performance of vigilance tasks (Wilkinson et al, 1966, Rutenfranz et al, 1973). A number of studies (Wylie et al., 1996; Wylie et al., 1997; Rhodes et al., 1995; Donderi, Smiley and Kawaja, 1993; Rutenfranz et al., 1972; Hertz, 1988) have shown that drivers, night workers and shiftworkers obtain insufficient sleep and can build up a large sleep debt over the shift cycle due to reduced sleep.A driver who would commence a 60-hour period of work after a single day off would start a heavy schedule (60 hours in 4 days), likely in a fatigued state, with little chance of recovery during the work cycle because of the limited daily time off (e.g., 8 hours off after 15 hours on-duty).

Arguably the most important study on recovery in the general literature review is by Lille (1967). Her results suggest that a single day off is insufficient for night workers to recover after an accumulated sleep debt from 5 days of work. A recent Ontario Hydro study (Malette, 1994) suggested that 3 days rest was superior to 2 days rest after three 12 hour night shifts were worked. A study of railroad locomotive drivers (Hildebrandt, Rohmert and Rutenfranz, 1975) indicates an advantage of a 2 day (and even 3 days), as opposed to a 1 day rest period in terms of reduced automatic brakings. In a review of the literature, Johnson and Naitoh (1974) argued that following protracted periods of sleep loss, 2 nights of recovery sleep is usually sufficient to allow near full recovery. This conclusion is still widely regarded as correct. However, the degree to which it may be true for partial sleep loss over extended periods is unknown.

The recovery study by Wylie et al. (1997) provides the most direct, though limited, evidence on the estimates of degree of recovery possible with a 36-hr reset period, by examining varying rest periods following 4 consecutive 13-hr day or night driving periods. For the night driving condition, the initial four 13-hr work periods showed an increase in sleep time suggesting an increasing need for sleep. Even though the sleep following the 36-hr reset was not lengthened, possibly due to unrecorded sleep that may have been acquired during the reset period, there was a 50% increase in the percentage of slow-wave sleep compared to the first sleep in the prior work cycle. Since a preponderance of slow-wave sleep is generally thought to indicate recovery from sleep debt, these data suggest that the

36-hr reset was inadequate to pay off the sleep debt acquired during the first work cycle of night driving.

For day drivers following the same schedule, this sleep period following a 36-hr reset contained a greater percentage of REM sleep (70% more REM) compared to the first sleep in the first work cycle but slow-wave sleep percentage was comparable. Since REM sleep is well-known to be enhanced after REM deprivation and REM increases following sleep deprivation are a lower priority than slow-wave sleep increases, these results suggest that restoration may be incomplete but greater restoration has taken place than in the night driving condition.

A comparison of data for the day drivers having either 0, 1, or 2 work cycles off was also interesting. For those who worked a 5th shift with 0 work cycles off, slow-wave sleep increased by over 100% prior to this shift, compared to baseline, and by 50% during the first recovery sleep. For those in the 36-hr reset group, the first recovery sleep showed a 60% increase in slow-wave sleep but the slow-wave sleep during the next post-work sleep period was 250% greater. For those with 2 work cycles to recover (48 hours off), there was no increase in slow-wave sleep. These data suggest that 2 work cycles may be sufficient for full recovery but 36 hours is insufficient.

If one considers the lane tracking data, further conclusions regarding the proposed 36-hr reset period can be drawn. First, night drivers performed less well than day drivers in general and showed a steady decline in performance across the 4 day work cycle both before and after the 36-hour off-duty period. However, the decline after the 36 hours off was exaggerated with the slope of the decay was greater during the second work cycle. Second, day drivers showed worse performance after the 36 hours off-duty period, with performance being as poor as the worst performance prior to the 36 hours off. For day drivers who had 0, 1, or 2 work cycles off, performance declined most sharply with no recovery period but also showed a decline on work periods following the 36 hours off relative to the first 4 work periods. With 2 work cycles off, lane tracking performance was comparable to that during the first 4 work periods.

Like the sleep data, the lane tracking data suggest that 2 work cycles off promotes sufficient recovery in that sleep and lane tracking performance return to the levels found at the beginning of the first work cycle. However, with only 1 work cycle off (36-hr reset), both sleep and performance data suggest that restoration is incomplete and that performance will deteriorate at a more rapid rate with further work demands. In addition, this pattern seems to be exaggerated for night drivers who appear to be less restored by the 36-hr off-duty period than their day driving colleagues.

SECTION 5. RECOMMENDATIONS FOR FUTURE RESEARCH

The overall conclusion drawn from the current state of scientific knowledge is that sufficient information does not exist to determine the adequate length of a recovery period. The following sections highlight some research areas and strategies that could serve to maximize the performance of drivers, maximize the restorative nature of rest, maximize the health and safety of drivers in the industry, and minimize costs associated with accident/injury and lost productivity.

REVIEW THE RECOVERY STUDY BY WYLIE ET AL. (1997)

The most relevant data with regard to the restorative value of varying reset periods comes from the recovery study by Wylie et al. (1997). However, the data reported from that study is incomplete and may need further analysis. It appears that the complex relationships between various factors in this study were investigated only in a preliminary fashion. Further analysis of these data could provide stronger support for the conclusions drawn. For instance, heart rate data might prove useful in providing evidence for changing workload as a function of fatigue (similar to the use of such data in the CANALERT '95 project). Even though the number of subjects is too small for firm conclusions to be drawn, a more in-depth review of these data could be helpful. Valuable lessons from these already collected data may be learned and could assist in directing and focusing more expensive empirical efforts.

EPIDEMIOLOGICAL ASSESSMENTS AND SURVEYS

Epidemiological studies of the type described by Jones and Stein (1987) could be used to examine the impact of various rest periods on accident risk. These researchers used a case control approach where 3 matching non-accident involved drivers were identified for each accident-involved driver.

Another approach to the issues of fatigue countermeasures and the recuperative value associated with sleep and rest interventions would be to collect information on on-duty and off-duty activities of truck drivers (work- driving, work-on-duty, leisure, sleep) as well as assessments of alertness and sleep quality under different driving schedules. Such data might be collected over a one-month period. This would allow a comprehensive assessment of the impact of various schedules on the amount of sleep and perceived alertness, for drivers with various characteristics (e.g. age).

There are advantages to the driver and the employer for such logged data. For the driver, insight will be gained from the systematic assessment of work demands and sleep benefit that can be incorporated into practise. For the employer, systematic variation between workers, work schedules, and sleep requirements will lead to the ability to target interventions to promote/enhance driver effectiveness and increased productivity while retaining drivers longer under improved working conditions. Such data will also assist in identifying interventions more likely to be accepted by drivers and by managers.

EXPERIMENTAL STUDIES ON THE RECUPERATIVE VALUE OF SLEEP AND REST

It is clear from the earlier conclusions that systematic empirical work must be conducted into the restorative value of sleep. To be relevant, such work has to be carried out under conditions that are as real as possible with such work supplemented by laboratory work as needed to enhance control and precision.

The projected study should incorporate the essence of the recovery study by Wylie et al. (1997), but with more subjects. The previous study suggests that 4 consecutive 13-hr trips generates a significant decay in performance among drivers. This decay and the accompanying causes should be reexamined with sufficient precision to establish this suspicion. Sleep measures should be recorded through use of sleep diaries (perhaps implemented on a hand-held computer with a reminder alarm) both during the work cycle and during the recovery period. In lieu of intrusive physiological monitoring, performance measures that have been shown to be sensitive to sleep loss should be used. Wristwatch techniques (actiagraph, and heart rate monitors) might also be considered as non-intrusive methods of collecting workload and accurate sleep data.

In addition, driving specific measures such as lane tracking variability and speed variability should be monitored as well as driver attentiveness. This can be measured through latency to respond to a secondary task (such as the reset alerting device used by rail engineers). Missing a response to the secondary task would have no driving consequence but would be recorded as a failure of attention. In addition, imperative stimuli should be included such as responses to acknowledge dispatcher requests for information.

As in the Wylie et al. recovery study, 4 or 5 days of consecutive driving should be studied as this represents the standard within the industry. Subjective assessments should be used to ascertain driver state and acknowledge the importance of driver participation. Finally, physiological recording of sleep should be limited to a night at the beginning and at the end of the study to establish changes in sleep patterns. This also has the added benefit of reducing study cost. Overuse of such sleep measures, apart from diaries, can lead to poor cooperation and an artificial nature to the study.

Two conditions should be completed with 36 subjects in each of a day driving condition and a night driving condition. The day driving condition should be structured to start no earlier than 0800 in order to be completed by 2300 which is within the 13-hr driving and 15-hr day of drivers currently. In this way the protocol avoids an early start, which tends to lead to performance deterioration in its own right, and avoids the usual beginning of circadian based performance deterioration in the 2300-0100 period. If operational conditions suggest that most morning starts for drivers begin 1 hour or more before the proposed start time then a separate, partially (naturally) sleep-deprived group should be considered.

The night driving condition should incorporate the 0000-0700 period and start at 2000 and end by 1100. Performance on the secondary task described above could be monitored during the drive and used to determine when a trip should be discontinued because of safety concerns.

Following baseline comparisons to determine day and night performance sleep deficits that have developed as a function of the protocols, 36, 48, and 60 hour reset conditions should be investigated. Sleep timing, length and quality taken during these off-duty recovery periods should be fully recorded (this was not done in the Wylie et al. recovery study). For the 36-hour reset, both groups would send 12 subjects back on the same shift for one shift after this reset period. In other words, 12 day shift drivers would do one more day shift as would 12 night shift drivers do one further night shift. This comparison would allow a comparison across shifts of a 36-hr reset.

For the 48-hours reset, 12 day shift drivers would then go on to night shift for one shift and 12 night shift drivers would go on to day shift for one shift. This comparison would allow both an opportunity for an extended sleep opportunity following the previous shift schedule and allow a comparison of the performance of changing shift rotation.

For the 60-hr groups, if sufficient restoration of function has occurred as a result of the 60 hours off then the difference between both groups should not exceed the initial differences between the two groups during the previous work cycle. If night drivers have not responded as well to the time off as day drivers then the original difference between the groups will be exceeded.

Variations on this theme can be considered but the fundamental aim is to examine fundamental benefits associated with varying reset periods, particularly where drivers have the opportunity for night sleep.

NAPPING STUDIES TO MAXIMIZE SLEEP BENEFITS

The above studies centre on the existing rules and regulations for commercial trucking, not on the actual practise of truck drivers. For this reason, studies are proposed to examine the impact of napping on the performance of commercial drivers.

It is recognized throughout the industry that drivers take naps when fatigued. However, little is known about the value of naps to sustain driver performance, reduce sleep debt, and maintain continuous operations. Studies should be carried out in this regard. If such strategies reduce fatigue developed by drivers driving over night, then shorter reset periods for full restoration become possible.

As an initial study, varying length short-term naps would be provided to night drivers and the immediate and long-term (but within the single trip) benefit associated with such naps could be ascertained. Measures might include the alertness and imperative stimuli mentioned above, as well as perhaps actigraphy and heart rate measures. Night drivers are suggested as night driving is known to result in a greater deterioration in performance than day driving.

Such a study should examine not only the initial subjective and objective benefit of varying short-duration naps but also the long-term benefit of these varying naps across the circadian cycle. Data from such a study would allow drivers and the trucking industry to estimate the effects of short-duration naps. If such naps are beneficial to reduce the sleep debt accumulated as a function of night shifts, such strategies may be easily incorporated into company policy as a fatigue countermeasure. In addition, if the numbers of drivers in such a study are sufficient, then the differential benefit associated with differential fatigue at the onset of the nap (based on individual differences or perhaps previous workload effects) may be determined. From such data, individuals may be able to tailor the naps to their own level of fatigue.

Numerous studies related to other countermeasures, such as rest breaks, can be contemplated.

HYPNOTICS AND OTHER SLEEP INDUCING STRATEGIES

One of the problems that commercial truck drivers and night shift workers in general have with getting adequate restorative sleep is that it is difficult to fall asleep during the day. Many night workers find that they have difficulty getting to sleep and maintaining sleep. For this reason, biological aids for sleeping should be a subject of enquiry for research.

One of the most prominent hypnotics, or sleep-inducing substances, is the drug melatonin which is widely used in the U.S. because of its availability in health food stores. In Canada, it is not available over the counter or in health food stores because of the Health Protection Branch policy of considering melatonin to be a drug which therefore requires close scrutiny to production standards. Nevertheless, many studies are being conducted worldwide to examine the potential of melatonin as a natural hypnotic to promoted sleep.

Melatonin is a non-addictive hormone normally produced at night by the pineal gland in the brain and is intimately tied with sleep. Studies have shown little in the way of side-effects with pharmacological versions of melatonin and it seems to be an effective agent for the helping individuals initiate sleep at times when biologically this would be difficult. A recent study of 12 shiftworkers on 12 hour shifts (Sack, Blood and Lewy, 1995) showed that melatonin helped half of the group to shift phase more quickly. Since melatonin has a relatively short half life of about 30 minutes, it may be a suitable substance to study to help promote sleep. Since many drivers in the U.S. use melatonin regularly, the potential effects of melatonin should be studied with respect to driving performance.

Another potential non-addictive hormone that can be acquired through a variety of food products is tryptophan. Tryptophan is a precursor to melatonin and likely has many of the sleep-inducing qualities of melatonin. This naturally occurring substance should also be explored as a natural sleep-promoting substance.

EDUCATION AND AWARENESS TRAINING

Studies should be carried out on the effectiveness of education and awareness training associated with fatigue countermeasures both for drivers and for managers. It is likely that many drivers are unaware of the basics of circadian rhythms and sleep that influence their daily lives and routines. Knowledge of such factors can influence how drivers acknowledge and deal with problems of fatigue and alertness as well as issues with their partner, family and social connections. It is clear that a failure to adequately deal with family and social matters can influence job performance and sleep which in turn can further aggravate job performance and sleep. The vicious cycle continues and results in marital problems, domestic instability, and other consequences such as a higher degree of substance abuse and health problems in shift workers that exceed those rates in non-shift workers. Thus, education and awareness training should be conducted to aid shiftworkers to understand the issues they face as shiftworkers and become aware of strategies to manage their personal lives. Education and awareness training should also be given to managers so that they understand which schedules promote better rested drivers and decrease crash risk. Managers also need to recognize their responsibility in creating a work environment where drivers have the opportunity to obtain adequate rest. Education that is only directed at the drivers will be less effective than education for both managers and drivers.

An opportunity exists to develop and implement an education and awareness package for truck drivers, implement this package in some companies and not others, and develop outcome measures to determine whether such an educational and awareness intervention promotes behaviour change. Previous research, including the study by Wylie et al (1997), suggest that drivers do not use their time off appropriately for rest and recovery and may arrive for their first shift of a work cycle in a fatigued state. In fact, in the study by Wylie et al. (1997), it appeared that some drivers got better sleep during the work cycle even when on night shifts. Obviously, to benefit from any self-regulated or prescriptive remedies for reset periods, such periods must be used judiciously. If the culture in the trucking industry does not support appropriate use of off-duty time, no reset period will be long enough. For these reasons research into the behaviour change that can occur as a result of education and awareness training is suggested. Such research will maximize the benefits of prescribed rest periods or naps that research studies determine to be effective.

COMMENTS ON PROPOSED RESEARCH

The previous section outlined some of the potential areas for research. A multifaceted approach on a number of fronts is suggested. Many of these projects can be carried out in parallel. The level of effort can be adjusted to resources and to the availability of drivers. However, it is recommended that a pragmatic approach be adopted where drivers and companies work in partnership with government to get answers to these pressing research questions. Neither the industry or government can accomplish these research objectives alone yet the answers are necessary. The future rests in cooperation with common objectives and a willingness to accept the results after involvement at all stages.

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