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HUMAN FACTORS/ERGONOMICS SPECIALISTS

Impact of Shiftwork and Overtime on Air Traffic Controllers

Phase II:
Analysis of Shift Schedule Effects on Sleep, Performance, Physiology and Social Activities

Prepared For:

Transportation Development Centre
Safety and Security
Transport Canada

October 1996

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by

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The contents of this report reflect the views of Rhodes & Associates Inc. and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

Since the accepted measurements in the aviation industry are imperial, miles, knots and feet are used in this document to represent distance, speed and altitude. Therefore, metric measurements could not be used.

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Un sommaire en français de ce rapport est inclus avant la table des matières.

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16. Abstract

This report covers Phase Two of the *Study of the Impact of Shiftwork and Overtime on Air Traffic Controllers*. Phase One identified research questions and research protocols. Phase Two examined the impact of certain shift-cycle types on performance, sleep, social activities, and diet. The study was conducted in three areas (Toronto, Gander and Moncton), using a comprehensive approach where controllers were assessed for cognitive performance, monitored for sleep physiology and on-the-job EEG brain-wave activity, and asked to keep a 24-hour activity log over a 13-day period.

Sleep was significantly reduced by the three most difficult shifts, resulting in reduced cognitive performance during the shift-cycle. Total average sleep loss for those working consecutive midnights was over 10 hours accumulated by the end of the shift-cycle. Single evening sleep periods indicated average sleep reductions of almost 3.5 hours, compared to baseline sleep. Sleep loss over the shift-cycle was high enough to be of concern with respect to both health and performance. Midnight shift results showed a drop in performance coinciding with the expected drop in bodily rhythms, suggesting a strong circadian effect. Midnights also disrupted meals, while all three of the most difficult shifts disrupted social activities.

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16. Résumé

Description des travaux de la phase II de l'étude sur les effets de l'organisation temporelle du travail ATC, à la lumière des travaux de la phase I portant sur les questions à élucider et sur les protocoles d'expérimentations à administrer. Les travaux de la phase II ont consisté à examiner l'effet de certains cycles de travail posté sur le rendement au travail, le sommeil, la vie sociale et le régime alimentaire des contrôleurs en poste dans trois villes (Toronto, Gander et Moncton). Une démarche globale a été utilisée, où des contrôleurs ont été soumis à des tests de performance cognitive et à des tests électrophysiologiques (enregistrement des ondes cérébrales par EEG) durant les périodes de sommeil et aussi à des moments précis durant le cycle de travail; il leur avait été demandé de tenir un journal quotidien de leur emploi du temps pendant 13 jours consécutifs.

Un déficit de sommeil considérable a été observé à l'issue des trois cycles de travail dits «durs», occasionnant une chute de la performance cognitive au travail. Les quarts de minuit consécutifs ont donné au total un déficit moyen de sommeil de plus de 10 heures en bout de cycle. Les périodes uniques de sommeil le soir occasionnent un déficit moyen de sommeil de presque 3,5 heures, par rapport à la quantité déclarée comme étant nécessaire. Le déficit de sommeil observé par cycle de travail est suffisamment élevé pour susciter des craintes quant à la santé et au rendement au travail des contrôleurs. Durant les quarts de minuit, une chute de la performance cognitive est observée, coïncidant avec le ralentissement prévu du rythme biologique et montrant un effet circadien prononcé. Il a été observé que les quarts de minuit font perdre un repas par jour et que trois cycles de travail dits «durs» perturbent la vie sociale des sujets.

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We thank the members of the steering committee. All contributed excellent guidance and direction for the research, ensuring the practical application of the results to the real world of Canadian air traffic control.

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EXECUTIVE SUMMARY

BACKGROUND

Phase Two of the *Study of the Impact of Shiftwork and Overtime on Air Traffic* was conducted on the basis of research findings from Phase One. Self-reports from operational controllers in Phase One suggested that certain shift-cycles (three in particular) could have negative effects on air traffic controllers in the areas of sleep, performance (especially during midnight shifts and overtime extensions of regular shifts), diet and social activity. Phase One research also indicated the need to research the effects of age on coping with shiftwork.

PHASE TWO PROTOCOL

Phase Two examined the impact of certain shift-cycles on performance, sleep, social activities, and diet. The study was conducted in three cities (Toronto, Gander and Moncton), using a comprehensive approach where 30 operational controllers (airports, en route and terminal) were assessed for cognitive performance during their shift-cycle, monitored for sleep and on-the-job EEG brain-wave activity during specific time periods during their shift-cycle, and asked to keep a 24-hour activity log over a 13-day period. Another 20 operational controllers were assessed for performance and were asked to keep activity logs. The purpose of this data collection was to provide data for the analysis of the relationship between sleep, social activities, and cognitive performance.

The shift-cycles investigated included:

<u>"Difficult" Shift-Cycles according to Phase I</u>
[M=midnight; E=evening; D=day; S=Swing; N=late evening/early midnight]
- Five consecutive midnight shifts (MMMMM);
- Double quick-change shift-cycle (EEDDM);
- Gander's Area Control Centre's standard ABCDE shift-cycle (ESDMN)

<u>Less Severe Shift-Cycles</u>
- Backward rotation single quick-change shift-cycle (EEDDD)
- Forward rotation days to evening shift-cycle (DDDEE).

The specific research questions examined during the study were:

- Does the shift structure negatively affect the controller's ability to obtain enough quality sleep (equivalent to their own baseline)?
- How large is the average sleep debt for each shift-cycle (if any)?
- Is performance affected by the resultant sleep debt, and the circadian rhythm? and
- Are diet and social activities affected by the shift-cycle structure?

RESULTS AND CONCLUSIONS

The main results and conclusions are:

- 5 consecutive daytime sleeps resulted in a total loss of more than **10** hours of sleep.
- Sleeping in the morning (daytime) and in the evening resulted in significantly greater losses of sleep than sleeping during the night, with evening sleeps being **1.5 times** shorter than day sleeps (**3.5** hours vs. **2.2** hours, respectively, of lost sleep for a single sleep period). In other words it appears controllers in the study got much less sleep during day-time and evening sleeps.
- Performance is reduced by an average of **5 to 20%** (group data) for the three difficult shift-cycles. This means that these cycles cause controllers to perform less well on a battery of cognitive tests.
- Cognitive performance is significantly reduced toward the end of backward rotating compressed shift-cycles (double quick-change and Gander) due to acute sleep loss. In other words, considerable sleep is lost during the night sleep before the day shift, and the evening sleep prior to the midnight shift.
- The circadian rhythm and a significant sleep debt (average of **2 hours lost per sleep period**) play a major role in reduced cognitive performance during midnight shifts. In other words, working during a time when the body wants to sleep makes it more difficult to remain alert and perform.
- Working midnights results in a reduced number of meals (average 2 meals per day) and a decreased quality in the content of the meals, i.e. it is more difficult for controllers to eat at regular intervals and to eat nutritious foods.
- The double quick-change and the Gander shift-cycles appear to reduce the amount of time spent with family and friends. More time is spent alone, sleeping or doing chores.
- Older controllers (>35 years old) get less sleep than younger controllers (most of the subjects in the study were under the age of 45, which is still a relatively young group).
- While caffeine use was not high, more was consumed during the difficult shifts.
- Melatonin patterns indicate that **no** beneficial shift in circadian rhythm occurs during five consecutive midnights. This means the body is not naturally awake and asleep at the appropriate times.
- EEG patterns show that on **midnight** shifts the probability of microsleeps and periods of inattention increases, i.e., controllers appear to have difficulty remaining alert during midnight shifts. Other shift-cycles could not be evaluated.

RECOMMENDATIONS

The study results led to the following recommendations:

- A program focusing on sleep strategies and sleep hygiene should be developed for controllers and their managers, as one of the chief means to help controllers cope with shiftwork.
- Shiftwork and sleep awareness training should be provided to managers, controllers and their families. Information about meal planning, diet, and scheduling strategies should be included in the training. The training content should be developed in conjunction with the stakeholders (operational controllers, unit and regional managers, Air Traffic Controller

Occupational Health Professionals, T.C. Counselling Services, Civil Aviation Medicine, Canadian Air Traffic Controller Association, and controllers' families), and promoted by all stakeholders.

- Overtime of any type should be avoided, immediately after consecutive midnights, double quick-changes, the Gander shift-cycles, or any other compressed shift-cycle including a midnight - in other words circadian effects and building sleep debts must be taken into account when formulating guidelines for overtime.
- Circadian rhythm effects should be considered when setting staffing levels.
- Sleep hardiness training approaches should be pilot tested to help identify viable techniques.
- A pilot project of formalized napping during midnights, or at least the opportunity for breaks, should be conducted to research their impact.
- The effectiveness of lighting and other stimuli improving alertness in the air traffic control environment should be investigated.
- A third phase should be conducted to develop, implement and evaluate the programs and studies recommended above.

SOMMAIRE ADMINISTRATIF

CONTEXTE

Les travaux de la phase II de l'étude sur les effets de l'organisation temporelle du travail ATC ont été menés à la lumière des résultats de la phase I. Les auto-évaluations obtenues des contrôleurs dans le cadre de la phase précédente montrent que certains cycles de travail posté (trois en particulier) peuvent avoir des effets nuisibles sur le sommeil, le rendement au travail (surtout durant les quarts de minuit et durant les heures supplémentaires prolongeant le travail posté normal), le régime alimentaire et la vie sociale des contrôleurs. La phase I a également montré la nécessité d'approfondir l'effet de l'âge sur le rendement au travail posté.

PROTOCOLE PHASE II

Les travaux de la phase II ont consisté à examiner l'effet de certains cycles de travail posté sur le rendement au travail, le sommeil, la vie sociale et le régime alimentaire des contrôleurs en poste dans trois villes (Toronto, Gander et Moncton). Une démarche globale a été utilisée, où 30 contrôleurs actifs divisés en trois spécialités (contrôle d'aéroport, contrôle en route et contrôle terminal) ont été soumis, durant leur cycle de travail, à des tests de performance cognitive et à des tests électrophysiologiques (enregistrement des ondes cérébrales par EEG) durant les périodes de sommeil et aussi à des moments précis durant leur cycle de travail; il leur avait également été demandé de tenir un journal quotidien de leur emploi du temps pendant 13 jours consécutifs. Vingt autres contrôleurs actifs ont été soumis à des tests de performance et à qui il avait été également demandé de tenir un journal quotidien. Une fois analysées, les données ainsi recueillies ont servi à établir des liens entre sommeil, vie sociale et performance cognitive.

Les cycles de travail analysés ont été les suivants :

<u>Cycles de travail «durs» selon la phase I</u>

[M = minuit; S = soir; J = de jour; R = Relève; T = fin de soirée ou début de nuit]
- Cinq quarts de minuit consécutifs (MMMMM);
- Double changement rapide (ou court) (SSJJM);
- Cycle de travail standard du Centre de contrôle régional de Gander (SRJMT).

<u>Cycles de travail plus souples</u>
- Rotation vers l'arrière changement rapide simple (SSJJJ);
- Rotation vers l'avant commençant par le service de jour avant de passer au service de soirée (JJJSS).

Cette phase visait plus particulièrement à trouver des réponses aux questions suivantes :

- L'organisation temporelle du travail a-t-elle des effets nuisibles sur l'aptitude des contrôleurs à obtenir une quantité suffisante de sommeil de qualité, par rapport à la quantité qu'ils déclarent leur être nécessaire?
- Quelle est l'ampleur moyenne du déficit de sommeil, s'il en est, par cycle de travail posté?
- Le rendement au travail est-il perturbé par ce déficit et par l'effet du rythme circadien?
- Le régime alimentaire et la vie sociale sont-ils perturbés par l'organisation temporelle du travail?

RÉSULTATS ET CONCLUSIONS

Voici les principaux résultats et les grandes conclusions de cette phase de la recherche :

- Cinq quarts de minuit consécutifs ont donné un déficit total de plus de **10** heures de sommeil.
- Le régime de sommeil le jour et le soir a débouché sur un déficit beaucoup plus important que le sommeil de nuit, les périodes de sommeil le soir étant **1,5** fois plus courtes que les périodes de sommeil de jour (déficit de **3,5** heures contre **2,2**, respectivement, par période de sommeil). En d'autres termes, les sujets auraient totalisé beaucoup moins d'heures de sommeil en dormant le jour et le soir.
- Pour les trois cycles de travail «durs» étudiés, le rendement a fléchi par une marge de **5 à 20 p. 100** en moyenne (données globales), ce qui signifie que, sous ces trois régimes, la performance des sujets dans la batterie de tests cognitifs est moins bonne.
- On observe une chute importante de la performance cognitive vers la fin d'un cycle intensif à rotation vers l'arrière avec changement rapide (cycles à double changement rapide et Gander), occasionnée par le déficit aigu de sommeil. En d'autres termes, une quantité considérable de sommeil est perdue durant la nuit de sommeil précédant le service de jour et durant le soir de sommeil précédant le quart de minuit.
- Le rythme circadien et l'important déficit de sommeil (moyenne de **2 heures de sommeil perdues par période de sommeil**) sont les principaux facteurs de la chute de la performance cognitive durant les quarts de minuit. En d'autres termes, travailler à un moment où l'horloge biologique de l'organisme est à l'heure de dormir fait baisser le niveau de vigilance et de performance.
- Les quarts de minuit font perdre un repas par jour (deux en moyenne) et les repas pris sont de moins bonne qualité: il est plus difficile d'observer des horaires réguliers pour les repas et de s'alimenter sainement.
- Les cycles de travail à double changement rapide et Gander raccourcissent peut-être aussi le temps passé en famille ou avec des amis. On passe plus de temps seul, à dormir ou à s'occuper autrement.
- Les sujets de plus de 35 ans obtiennent moins de temps de sommeil que les contrôleurs moins âgés (la plupart des sujets avaient moins de 45 ans, ce qui fait de ce groupe un groupe relativement jeune).
- Même si la quantité de caféine absorbée n'est pas très forte, elle est plus forte durant les cycles de travail «durs».

- L'observation du taux de mélatonine a permis de constater qu'il ne se **produit pas** d'adaptation du rythme circadien au cycle de cinq quarts de minuit consécutifs, montrant que l'horloge biologique de l'organisme ne va pas de pair avec l'horloge imposée par ce cycle.
- Les enregistrements électroencéphalographiques durant les quarts de **minuit** montrent une augmentation dans les probabilités de micro-sommeil et de baisse de vigilance. En d'autres termes, il est difficile de maintenir une vigilance soutenue au travail durant ces services. Les autres cycles de travail n'ont pas pu être évalués sous cet angle.

RECOMMANDATIONS

Les recommandations formulées à l'issue de cette recherche sont les suivantes :

- Élaborer à l'intention des contrôleurs et des gestionnaires une stratégie axée sur le sommeil et l'hygiène du sommeil, destinée à devenir l'outil principal permettant de maîtriser les effets négatifs du travail par roulement.
- Sensibiliser les gestionnaires, les contrôleurs et les familles de ces derniers à la réalité du travail par roulement et à la nécessité d'obtenir une quantité suffisante de sommeil, par une formation insistant en outre sur l'organisation des repas, le régime alimentaire et l'emploi du temps. Cette formation devrait être élaborée de commun accord entre toutes les parties intéressées et mise de l'avant par tous les intervenants : contrôleurs actifs, gestionnaires locaux et régionaux, responsables du programme de santé au travail pour les contrôleurs de la circulation aérienne, services de counselling de Transports Canada, direction de la médecine aéronautique civile, Association canadienne du contrôle du trafic aérien et familles des contrôleurs actifs.
- Éviter les heures supplémentaires sous quelque forme que ce soit : immédiatement après des quarts de minuit consécutifs, les doubles changements rapides, les cycles type Gander et après tout cycle de travail intensif impliquant des changements rapides et comprenant un quart de minuit. En d'autres termes, toute directive concernant les heures supplémentaires devra tenir compte des effets du rythme circadien et des déficits de sommeil.
- La dotation en ressources humaines doit tenir compte des effets du rythme circadien sur celles-ci.
- Mener des essais pilotes sur des techniques de résistance à la somnolence dans le but de déceler les plus prometteuses.
- Mener un projet pilote visant à montrer l'effet sur le rendement d'une période de sommeil, ou pour le moins, de pauses ponctuant les quarts de minuit.
- Approfondir l'effet sur le rendement d'un éclairage ou de tout autre stimulus visant à maintenir la vigilance au travail.
- Lancer la troisième phase des travaux dans le but de développer et d'exécuter les mesures recommandées, et d'en évaluer les résultats.

SYNOPSIS

S1.0 INTRODUCTION

Transport Canada identified the need to investigate the effects of working shiftwork and overtime on the health and well-being of air traffic controllers. The impetus for this concern was derived, partially, from the results of the report released in 1990 by the Canadian Aviation Safety Board (referred to as CASB, and now called the Transportation Safety Board) titled *Report on a Special Investigation into Air Traffic Control Services in Canada*. The report contained a number of recommendations concerning the shiftwork and overtime aspects of the controller's job. These CASB recommendations were:

1. That the Department of Transport make and enforce further restrictions on:
   - the maximum number of hours which can be worked at a particular control position without a relief break; and
   - the minimum number of rest hours between shifts;
2. That the Department of Transport, in co-operation with the Department of Health and Welfare and international authorities, initiate a program of research into the adverse effects of circadian dysrhythmia and sleep deficits on air traffic controllers and their job performance; and
3. That the Department of Transport initiate research into the effects of regularly working overtime shifts during normal days of rest on individual controller's job performance.

A research program was developed to examine all of the issues raised by these questions. The research program set out to provide the research data needed to answer these questions. Phase One (Rhodes et. al., 1995) of the research program identified the specific research questions and tools necessary to launch an investigation into the nature of problems posed in the CASB report.

S2.0 PURPOSE AND SCOPE

Phase Two was carried out to implement the tools identified in Phase One and to provide the research data necessary to help answer the specific research question relevant to the second recommendation raised in the CASB report.

The primary research question addressed by the Phase Two the study was:

What are the effects of working specific shift-cycle types on the sleep, physiology, performance, health and off-work activities of air traffic controllers?

The results of this study provide the basis for recommendations as to how the effects might be mitigated.

The Phase Two research addressed the impact of shiftwork on air traffic controllers by:

1. measuring the cognitive performance of controllers during their shift throughout a shift-cycle;
2. examining the quality and quantity of sleep achieved during sleep periods occurring at critical points in the shift-cycle;
3. obtaining a subjective assessment of mood and sleepiness at specific times during each shift in the cycle;
4. obtaining data on daily activities throughout the shift-cycle and during days off;
5. measuring brain-wave characteristics (i.e. EEG patterns) during specific shifts in the cycle;
6. measuring melatonin fluctuations during certain shifts to determine whether adaptation occurs in the circadian rhythm.

These data were then analysed with the goal of determining what steps would be necessary to alleviate the negative effects, if any, of the shift-cycle types on sleep, physiology, performance, health and off-work activities. The shift-cycle types investigated included:

<u>"Difficult" Shift-Cycle Types according to Phase One</u>

[M=midnight; E=evening; D=day; S=Swing; N=late evening/early midnight]

1. Five consecutive midnight shifts (MMMMM);
2. Double quick-change shift-cycle (EEDDM);
3. Gander's (Newfoundland Area Control Centre) ABCDE shift-cycle (ESDMN);

<u>Less Severe Shift-Cycle Types</u>

4. Backward Rotation Single Quick-change shift-cycle (EEDDD);
5. Forward Rotation Days to Evening shift-cycle (DDDEE).

Air traffic controllers were recruited from the Ontario Area Control Centre in Toronto, the Toronto Pearson International Airport Tower, the Newfoundland Area Control Centre in Gander, the Gander International Airport Tower, the Atlantic Area Control Centre in Moncton, and the Moncton Airport Tower. These centres and towers had the required shift-cycle types, as identified in Phase One, and their locations allowed for cost-effective travel and transportation of equipment.

S3.0 APPROACH

The study used an integrated approach and included two levels of participation from the subjects involved. The first group (the comprehensive protocol) included individuals who participated in the following research components:

1. Monitoring sleep during sleep periods deemed problematic according to Phase One results (e.g. sleeping in the daytime [between 07:00 and 15:00], evening [between 15:00 and 23:00] and during quick-changes [less than 12 hours between the end of one work shift and the following work shift]);

2. Physiology monitoring during the work shift immediately following the monitored sleep period;
3. Computerized performance tests performed three times during each work shift;
4. Urine collection during a 24-hour period surrounding their monitored sleep periods;
5. Activity log completion for 13 days.

This group represented the most difficult (MMMMM, ESDMN, EEDDM) of the five shift-cycle types. (More subjects in the shift-cycle types were included in some less demanding aspects of the study.)

The second group of subjects participated only in the performance testing and in maintaining an activity log. This group represented all of the five shift-cycle types.

The investigation during this phase represents a field-based study collecting data for real-world experiences and responses. This study was not carried out in a laboratory nor was it artificially constructed. The data were collected in as close to real conditions as possible. No attempt was made to control the environment or the controller's activities, though potential confounding variables were noted. All data collection were conducted in the workplace, or in the case of the activity logs, wherever the controller happened to be.

S4.0 RESEARCH DESIGN

Table S4-1 illustrates the number of subjects involved in the various components of the Phase Two study, showing the breakdown for each shift-cycle type. Note that each column shows the number of cases where data were either collected or attempted. In the case of performance assessment and physiology monitoring, data loss reduced the actual number of subjects whose data were analysed (see sections 5.1 and 5.3). Figure S4-1 shows the data collection schedules for the three shift-cycles that included all components. "S1", "S2", and "S3" are the three sleep periods which were monitored. "M1" and "M2" are the two work periods which were monitored using the Oxford Medilog system (portable physiology monitor) described below in the methods section. Table S4-2 shows the shift start and finish times.

Table S4-1: Experimental Design and Distribution of Subjects

Shift-cycle type	Number of Subjects	Sleep Monitoring	Physiology	Performance	Logs	Melatonin Collection
MMMMM	12	12	8	12	11	12
ESDMN	15	8	10	13	12	8
EEDDM	12	10	8	12	12	10
DDEEE	10	not collected	not collected	8	9	not collected
EEDDD	6	not collected	not collected	5	5	not collected
Total	55	30	26	50	49	30

Figure S4-1

DATA COLLECTION SCHEDULE

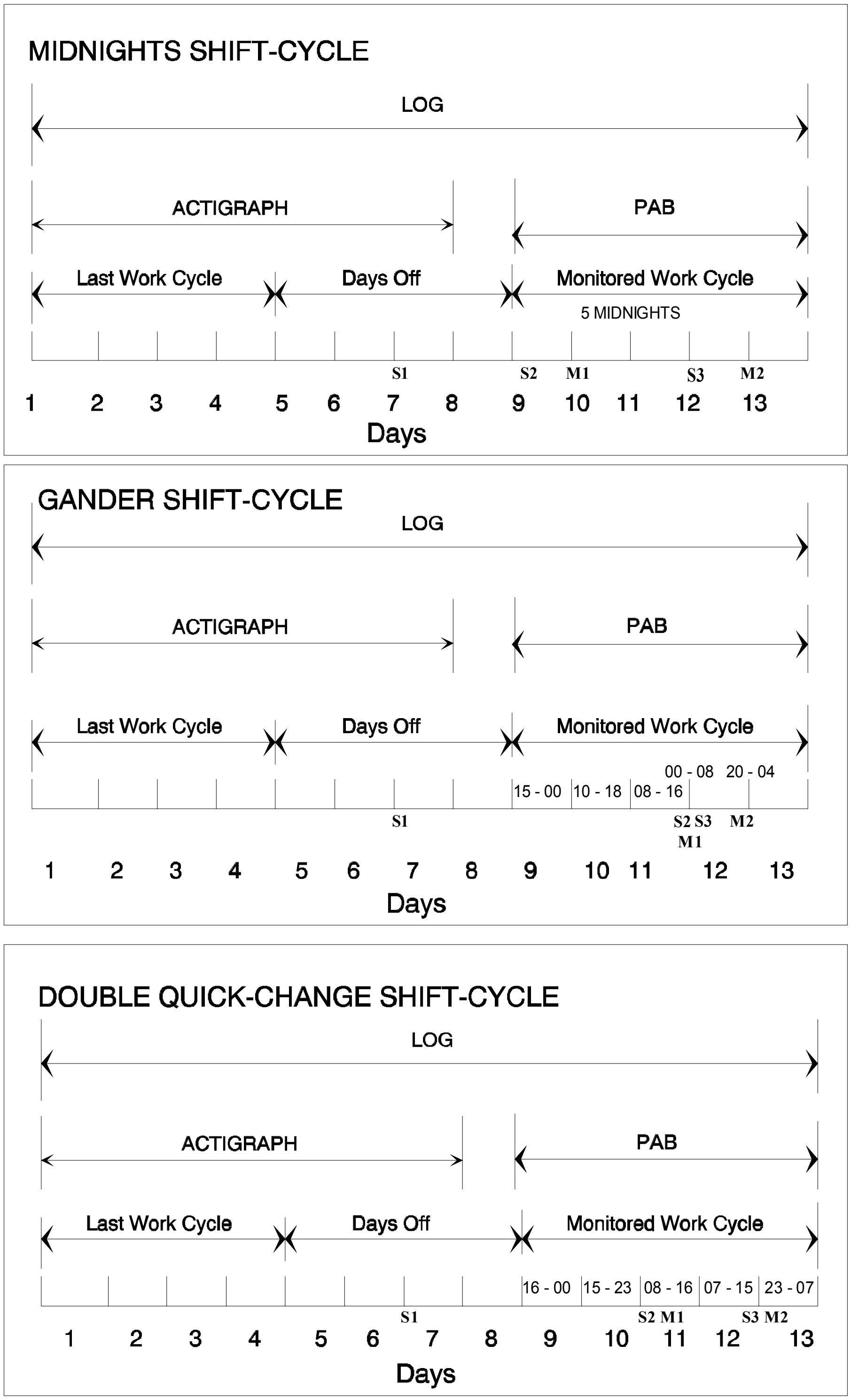

Table S4-2: Shift Start and Finish Times

Shift-Cycle	Shift	Start Time	Finish Time
MMMMM	M = Midnight	23:00	06:30
EEDDM	E = Evening D = Day M = Midnight	15:00 06:30 23:00	23:00 15:00 06:30
ESDMN	E = Evening S = Swing D = Day M = Midnight N = Night	15:00 10:00 06:30 23:00 20:00	23:00 18:00 15:00 06:30 04:00
EEEDD	E = Evening D = Day	15:00 06:30	23:00 15:00
DDDEE	D = Day E = Evening	06:30 15:00	15:00 23:00

The data collection schedules reflected the times in the shift-cycle when sleep is likely to be shortened or degraded in quality. Toronto controllers working the consecutive midnights shift-cycle (MMMMM) were monitored for their baseline nighttime sleep on a day in the middle of their four-day off period, a daytime sleep following their first midnight shift, and a daytime sleep following their fourth midnight sleep. The Gander (ESDMN) controllers were monitored for their sleep during a baseline (in the middle of their days off), during the evening sleep between the day shift and the midnight shift (quick-change - backward rotating), and during the daytime sleep following the midnight shift. The double quick-change (EEDDM) controllers were monitored for their sleep during a baseline nighttime sleep in the middle of their days off, during a nighttime sleep between the evening shift and the day shift (quick-change - backward rotating), and during an evening sleep between the day shift and the midnight shift.

Tables S4-3 and S4-4 show the age breakdown for the entire sample and for those involved in the sleep monitoring sample. The main objective was to get at least one subject in each age group (not always achieved) and obtain more in the 30-34, 35-39 and 40-44 age groups, since these age groups are the most represented in the Canadian air traffic controller population. Also, there was an interest in obtaining information on the over 45 age groups, since the controller population is aging and a proportionately greater number of controllers are expected to enter the over 45 age groups over the next decade. Furthermore, data from Phase One indicated that shiftwork difficulties can begin even at 35 years of age. The human circadian rhythm is more prone to disruption as a person gets older. The gradual decline in health of those over forty-five also begins to introduce other factors that interfere with sleep and cause resistance to changes in schedules and routines. The result is a physiology which has greater difficulty coping with the stress of shiftwork and overtime. Of course, the healthier a person is, the less this becomes a problem (Costa, 1996).

Table S4-3: Breakdown By Age Group for Complete Protocol
(including sleep monitoring, performance, logs, melatonin and physiology)

Shift-cycle type	Total Number of Subjects	Number Under 35 years old	Number Over 35 years old
MMMMM	12	6	6
ESDMN	8	5	3
EEDDM	10	4	6
Total	30	15	15

Table S4-4: Breakdown By Age Group for Performance/Log Protocol
(including performance and logs)

Shift-cycle type	Total Number of Subjects	Number Under 35 years old	Number Over 35 years old
MMMMM	12	6	6
ESDMN	15	8	7
EEDDM	12	4	8
DDEEE	10	6	4
EEDDD	6	3	3
Total	55	27	28

S5.0 METHODOLOGY

Phase Two set out to collect the following data:

a) performance results for the performance tests conducted at the beginning, middle and end of each shift during the work-cycle;
b) subjective assessment of fatigue, activity and sleepiness as reported during the performance sessions;
c) duration of sleep as recorded by polysomnography, and as reported in the logs;
d) quality and composition of the sleep as recorded by polysomnography;
e) amount of time spent on various activities during days off compared with workdays;
f) number of meals, snacks, caffeine drinks, and alcoholic drinks consumed during off days and workdays;
g) brain wave activity (as obtained using the Oxford monitoring system) during the shifts following Work Sleep 1 and Work Sleep 2;
h) levels of melatonin during the 24-hour period surrounding the three monitored sleep sessions, including the shifts monitored by the Oxford Medilog system.

The data collected and the methods used include:

1. Measurement of performance during the shift-cycle
   - administration of tests from the Performance Assessment Battery (PAB) developed by the Walter Reed Army Medical Institute

2. Measurement of subjective fatigue and sleepiness
   - PAB components for Stanford Sleepiness Scale and the Fatigue Scale
3. Measurement of sleep duration and assessment of quality of sleep
   - polysomnographic monitoring and data collection during sleep
   - sleep onset and offset times, and awakenings as recorded in activity logs
4. Record of sleep, meals, caffeine and off-work activities
   - recorded in a daily activity log
5. Record of alertness (EEG patterns) during work shift
   - physiological monitoring using the Oxford Medilog portable system
6. Record of circadian rhythm
   - measurement of melatonin levels in urine

S6.0 FINDINGS, CONCLUSIONS & RECOMMENDATIONS

Sections S6.1 to S6.5 summarise the major findings of the study along with the primary recommendations for future study and implementation, although the findings suggest many more strategies than are indicated. The main findings include:

- 5 consecutive daytime sleeps resulted in a total loss of more than **10** hours of sleep.
- Sleeping in the morning (daytime) and in the evening resulted in significantly greater losses of sleep than sleeping during the night, with evening sleeps being **1.5 times** shorter than day sleeps (**3.5** hours vs. **2.2** hours, respectively, of lost sleep for a single sleep period - group means). In other words it appears controllers in the study got much less sleep during daytime and evening sleeps.
- Performance is reduced by an average of **5 to 20%** (group data) for the three difficult shift-cycles. This means that these cycles cause controllers to perform less well on a battery of cognitive tests.
- Cognitive performance is significantly reduced toward the end of backward rotating compressed shift-cycles (double quick-change and Gander) due to acute sleep loss. In other words, considerable sleep is lost during the night sleep before the day shift, and the evening sleep prior to the midnight shift.
- The circadian rhythm and a significant sleep debt (average of **2 hours lost per sleep period**) play a major role in reduced cognitive performance during midnight shifts. In other words, working during a time when the body wants to sleep makes it more difficult to remain alert and perform.
- Working midnights results in a reduced number of meals (average 2 meals per day) and a decreased quality in the content of the meals, i.e. it is more difficult for controllers to eat at regular intervals and to eat nutritious foods.
- The double quick-change and the Gander shift-cycles appear to reduce the amount of time spent with family and friends. More time is spent alone, sleeping or doing chores.
- Older controllers (>35 years old) get less sleep than younger controllers. Overall, half of the subjects were over 35, which is still a relatively young population. Therefore, age effects begin early, and affect a large portion of the controller population.
- While caffeine use was not high, more was consumed during the difficult shifts.

- Melatonin patterns indicate that **no** beneficial shift in circadian rhythm occurs during five consecutive midnights. This means the body is not naturally awake and asleep at the appropriate times.
- EEG patterns show that on **midnight** shifts microsleeps and periods of inattention may be of concern, i.e., controllers appear to have difficulty remaining alert during midnight shifts. Other shift-cycles could not be evaluated due to unacceptably small sample sizes.

S6.1 Sleep Loss

S6.1.1 Findings

The findings of this research indicate that air traffic controllers are getting 25 - 30% less sleep during their shift-cycle than on days off. The results of the sleep and physiology monitoring show that this shortened sleep results in a sleep debt and affects the quality of sleep obtained. Early onset of slow wave sleep (SWS - deep sleep) and REM sleep (dream sleep), and increased levels of SWS, are evident for many of the controllers; these findings suggest the development of sleep debt and fatigue. The effects of such sleep loss on the body, performance and social activities have been well documented (for reviews see Costa, 1996; Folkard, 1996; Knauth & Costa, 1996). The effects on health include feelings of fatigue, longer recovery times once the shift-cycle is over (also seen in the present data), feeling ill (not being able to go into work), and increased instances of poor mood (irritable, short-tempered, etc.).

Phase One results showed that on midnights controllers self-reported that they were extremely tired and felt that their performance was reduced, in some cases, severely. Older controllers mentioned that the midnight shift and quick-changes were the hardest on them. Over half of the older controllers (over 40 years of age) said they never worked more than four consecutive midnight shifts, and usually worked only three in a row. Phase Two results confirm these Phase One results, showing that controllers do suffer significant sleep loss and reduced performance, and that older controllers do appear to be affected more.

Controllers also self-reported in Phase One that they get very little sleep during the quick-change between days and midnights. Phase Two showed that it is probably worse than they suggested, most getting only two or three hours of sleep during these sleep periods.

MMMMM (Toronto)

Controllers working five consecutive midnights self-reported the least amount of sleep (log data), averaged over the entire cycle. Their average sleep loss, over the shift-cycle (5 days) amounted to over 10 hours. However, when comparing the work sleeps recorded with the Alice3 Polysomnographic system, the daytime sleep periods of Toronto controllers were longer than the daytime sleep periods of Gander and Moncton (Double Quick Change) controllers. Controllers working straight midnights had shorter and poorer quality sleep during their first day sleep, compared with their baseline and second day sleeps. They also took shorter naps than most of the shift-cycle types (except when compared to DDEEE).

ESDMN (Gander)

The time of day at which the sleep period occurs profoundly affects how well and how long a person will sleep. Evening and daytime sleep, required during quick changes and following the midnight shift, is poorer and much shorter than sleep obtained during the night, particularly on a day off. Their napping levels outside of work were the highest of all shift-cycle types. Despite two very poor sleep periods (short daytime sleep and shorter evening sleep), controllers in Gander self-reported the second highest amount of sleep according to the logs.

EEDDM (Moncton)

Similar to Gander, the evening sleep after day shift, prior to the following midnight shift, was characterized by a high percentage of SWS with very little REM sleep. This sleep was also very short (sleep recordings averaged 2.7 hours). This group of controllers also relied on naps to recuperate, reporting the second longest naps (slightly less than Gander, both over 2 hours).

EEEDD (Moncton)

The controllers working the evening-to-day shift-cycle averaged more sleep during the work cycle than the controllers working the other shift-cycles, as well as the longest naps (from log data). The three evening shifts allow controllers to get longer sleep periods than during their two day shifts, since they can usually sleep in until rested. On the other shift-cycles only two evening shifts at most are worked, sometimes only one. Hence, the controllers working these cycles do not get the added benefit of an extra one or two evening shifts. The down side of this, unfortunately, is that social activities are negatively affected, reducing the opportunities to be with family and/or friends.

DDDEE (Toronto)

Controllers typically choose to go to bed between midnight and 01:00 prior to a day shift, particularly when they come off an evening shift. This results in a reduced sleep period, since work often starts between 05:30 and 06:00 on an early day shift. Five hours or less sleep is often two or three hours less than the daily requirement. Hence, controllers are building a sleep debt over their shift cycle whenever such sleep loss occurs.

Longer commutes between home and work also reduced the amount of time in which controllers can sleep. The sleep times for those working in centres which have average commute times of 25 minutes or less are longer by about an hour. This extra sleeping time helps to reduce the sleep debt. Controllers at the Toronto facilities typically travel for at least 60 minutes to and from work, which is one explanation for why the day shifts are associated with considerable sleep loss.

These controllers self reported the second lowest duration for average daily sleep during both workdays and days off. They also self-reported very little napping.

S6.1.2 Conclusion

Air traffic controllers must be given the opportunity to get enough sleep between shifts, and must be better equipped to apply natural techniques to help themselves to get to sleep. Longer periods of time for the opportunity to sleep, during the time in which the body is most susceptible to sleep, results in more sleep. This may seem obvious, but is not usually possible in our present society where daytime work starts during that time of the day when the human body is still in a state for sleep. If, like farmers, everyone was dedicated to the notion of "early to bed, early to rise", the likelihood of lost sleep would be almost nil, except when affected by outside conditions (the negative influences mentioned above like noise, caffeine, etc.). Since we live in a society where the television and busy schedules frustrate our attempts to get to bed, it is crucial to try various strategies such as taping shows with a VCR, or scheduling late night activities for a time which does not require an early wake-up, as ways to better ensure the proper amount of sleep.

S6.1.3 Recommendations

Sleep Hardiness and Sleeping Hygiene Strategies: A program should be developed which will teach shiftworkers, their supervisors and management how to develop countermeasures against fatigue and sleep loss. It is recommended that the committee members (ATCOH Program, CATCA, Air Traffic Services, TDC, and Civil Aviation Medicine) develop a training program which will help controllers, supervisors, managers, and operations personnel in the Air Navigation services understand what they can do to improve the shiftwork environment and to improve sleep hardiness and hygiene. This program might have four components:

1. Development of the shiftwork countermeasures program itself;
2. Training for those who will be responsible for conducting the training sessions;
3. Conducting a set of pilot training sessions;
4. Evaluation of the effectiveness of the training.

The development of the shiftwork countermeasures program should involve input from all of the stakeholders who will benefit from it. Using this input, shiftwork management experts would put the training program together and present the final product at a presentation meeting.

Those responsible for conducting the training once it is approved (e.g. ATCOHs) would receive train-the-trainer instruction from shiftwork management experts. This instruction would benefit from the shiftwork management experts' experiences as well as from other existing shiftwork and fatigue countermeasures programs.

The present study indicates that many of the controllers working all of the shifts, but particularly the double quick-change, consecutive midnights and the Gander shift-cycles, do not get enough sleep. In fact, severe sleep debts are likely to have been built up by many of these controllers, to the point that both health and performance may be compromised. The controllers must work hard to overcome growing fatigue and circadian effects.

Any intervention program for helping controllers to cope with shiftwork must include, as a main component, guidance on how to improve the sleeping environment and prepare for sleep, what to avoid prior to sleep, when to sleep, and how to stay asleep. The problem facing most of the controllers studied in this research was to be able to take advantage of the times they had to sleep. Often, controllers simply could not sleep during the short period of time they were given in which to sleep. Quick-changes and evening sleeps were particularly bad, leaving little time for bed and requiring sleep at a time when the body wanted to be awake. Daytime sleeping suffered from the latter problem as well.

There are many ways to alleviate both of these problems. The following interventions can be designed, developed and tested to be used individually or in combinations:

- Improving the sleep environment to help to induce sleep;
- Communicating with family and friends, letting them know when daytime sleep is planned;
- Preparing for sleep with a familiar routine to achieve a stimulus-response relationship between these preparation activities and the act of sleeping;
- Making adjustments which can increase energy and alertness on the job, while promoting sleepiness before bedtime;
- Investigating relaxation strategies such as autogenic training, relaxation exercises, meditation, reading, mild exercise, or any other means to relax the body and mind;
- Whenever possible, providing the opportunity for controllers to choose shifts which are compatible with their individual differences (e.g. age, morningness-eveningness, family commitments, etc.); and
- Providing counselling and psychosocial educational support for controllers seeking help to resolve issues regarding sleep problems, scheduling social and family activities and identifying patterns and conditions causing problems; referral to other health services should be made if necessary. Training for ATCOHs and other health professionals would provide the skills and knowledge necessary to provide such support.

S6.2 The Effects of Sleep Loss and Circadian Rhythm on Performance

S6.2.1 Findings

The results of the performance tests during consecutive midnights shows that controllers have more difficulty with cognitive tasks in the middle of the shift (about 03:00) than at the beginning or end. The tests most affected by this result include the logical reasoning, pattern recognition and mannikin tests, with the reaction time test being similarly affected, but to a lesser degree. The decrement in performance occurring mid-shift is the result of low activity and the body's circadian nadir (lowest point in the circadian rhythm according to temperature, heart rate and some hormonal levels) which occurs between 03:00 and 06:00. It is difficult to maintain alertness and mental clarity when the body is at the point where it most desires sleep. This seems evident in the overall patterns in performance shown by the controllers working the five consecutive midnight shifts.

Phase Two results show that the growing sleep debt and the final insult of little to almost no sleep between the day and midnight shifts coincide with large decrements in performance. The greatest decrement over the course of the midnight shift also occurs in the middle of that shift for Gander and the double quick-change cycles. Cognitive performance drops consistently through the late night shift in the Gander cycle, and a similar pattern is found in the double quick-change cycle on the second day shift (just before the midnight shift). This combination of large decrements in performance on the day shift, followed by little sleep, and working a midnight shift in less than eight hours after the previous day shift, must make it difficult to maintain alertness.

The poorer performance experienced during the second day shift suggests that the controller may be fatigued due to the early starting time. Typically, a controller expected to start the early day shift at 05:30 would have to awake at between 04:00 and 04:30 to have enough time to get ready, eat breakfast, and commute to work. Many of the Toronto controllers have long commutes ranging between 25 minutes to 1.5 hours. A very few face even longer commutes.

On day shifts controllers also can suffer sleep loss due to restricted sleep. Getting up at 04:00 is likely to result in sluggishness and a feeling of tiredness for two reasons. First, at 04:00 it is difficult for the body to overcome the effects of the circadian rhythm, since this time does coincide with the body's lowest temperature, heart rate and reduced arousal. Second, the sleep period is usually curtailed, resulting in less than the normal amount of sleep. Most controllers find it too difficult to get to bed early in order to obtain the proper amount of sleep. This is a common problem for most of us, and has been reported in the literature as such.

S6.3.2 Conclusion

Performance decrements on midnight shifts coincide with the body's circadian rhythm and may be due in part to this effect. This is further strengthened by the melatonin results which show that the controllers were not phase adjusting over the five days of midnights, and were still on the usual day/night cycle according to their bodies. This finding is very significant in that a past justification for combining midnight shifts was based on the premise that controllers would adapt to night work. Instead, the controllers' circadian rhythm may have contributed to their poorer mid-shift performance, and a chronic sleep loss. Also, acute fatigue caused by the significant sleep loss which occurs between the day and midnight shifts in both the Gander and double quick-change shift-cycles appears to cause degraded performance during the subsequent midnight shift (and for Gander, the last night shift as well). Often controllers with long commutes will sleep at the centre or a nearby hotel when they work a quick-change shift (less than 8 hours between shifts).

S6.3.3 Recommendations

It is recommended that research focussing on nap and break strategies be conducted in a simulated environment, or even in an operational environment if feasible, to provide the data to support specific strategies to be used.

Breaks: When controllers must work on a midnight shift it should be considered that they are less able to maintain alertness, handle sustained work, and perform demanding cognitive tasks. All of these are degraded even more if rest breaks are not provided. Though the workload is low, the pressure to sleep is strong and becomes stronger as the night progresses. Sustained work of any type or level, but particularly tasks involving vigilance and monitoring, will degrade very quickly after two or three hours. Therefore, the controller would benefit from a break away from the workstation to stretch, nap, do light exercise, or eat, anything to allow the body to revitalize. For example, it is recommended that controllers be provided with a 30 minute break every two hours when working midnights, or some other schedule determined from testing in an operational environment.

Napping: Midnight shifts are particularly difficult to work for many controllers because they occur during a period when the body wants to sleep. Since the sleepiness and fatigue felt during the midnight shift is probably one of the causes of declining performance over the course of the shift, taking a nap part way through the midnight shift may reduce the effects of fatigue and circadian rhythm, leading to more reliable cognitive functioning. There is evidence available showing that short naps (about 20 to 40 minutes in length) can enhance performance (see Costa, 1996b for a review). The benefit of napping has been investigated for pilots by Rosekind et. al. (1994), who found that naps of 40 minutes in duration, preceded by a 3 minute preparation time, and followed by a 10 minute recovery time, resulted in improved performance and considerably fewer micro-naps. However, the true benefit of short naps during rotating schedules involving midnights and quick-changes is largely unexplored and research dedicated to the short- and long-term effectiveness of napping would be extremely valuable.

It is recommended that napping strategies be investigated in a simulation or operational environment where the duration, time placement, and quality of the nap can be compared to on-the-job performance, subjective feedback and post-session interviews, using controllers trained in napping strategies, and a control group. Simulation would provide more control over the data collection (i.e. increase the chances of collecting complete data), but would be limited in the validity of the data. Both approaches might involve providing pre-trained controllers (trained in napping strategies, and the performance tests, and in providing useful information about their performance and mental and physical state) with scheduled nap opportunities during their shift. They could be asked to participate in performance, sleepiness, and mood assessments at specific points during the shift. A control group that did not nap could be compared to the groups using the napping strategies.

Scheduling of Overtime: Working an overtime shift immediately after the normal work-cycle is pushing the envelope for most controllers, particularly older controllers. Continuing to work past the normal shift-cycle adds to an already serious sleep debt which is beginning to affect both health and cognitive performance. Furthermore, disruption of social and other off-work activities will worsen due to deterioration in mood and cognitive functioning (short temperedness, irritability, forgetfulness, increased mental stress, and a focus on recovery). Long strings of overtime will result in controllers having to sleep more in order to recover from the sleep loss and accumulated fatigue during back-to-back shifts. This will result in less time spent with family and friends, eating meals and engaging in hobbies, relaxation time etc., and increased sick leave when the body just cannot continue to keep up.

Considering the acute and/or chronic sleep loss demonstrated in all shift types, two full days of rest following the normal shift-cycle are necessary to recover sleep and to adjust to a change in the time of day in which sleep must occur. Following this two-day reprieve, overtime will be much easier to do and work performance is likely to be better.

S6.3 Meal Planning

S6.3.1 Findings

Meal disruption was a serious problem for most shiftworkers. Maintaining a proper diet during the shift-cycle was difficult, and almost impossible during midnights. Planning meals so that they occur at optimum times during the day and night is one way to ensure a balanced nutritional intake. Controllers surveyed in Phase One self-reported that midnights made meal planning, and eating properly, almost impossible. Phase Two results bear this out very clearly.

S6.3.2 Conclusion

Guidance is needed for controllers to ensure that they avoid missing meals, avoid foods which disrupt sleep prior to bedtime (i.e. avoid caffeine, alcohol, and foods with high fat or simple carbohydrate content), and eat foods which promote alertness while at work (e.g. complex carbohydrates as in grains, foods high in protein and low in fats, and foods high in natural sugars such as fruit). Controllers need to plan meals that provide the daily nutritional requirements.

S6.3.3 Recommendation

The development of a controller's shiftwork food guide could be one way to help increase awareness of the problem and its solutions. Provision of a food planning booklet such as those used in diet-control programs, but geared toward controllers, may help with meal planning. Other strategies might involve making fruit, vegetables and bread etc. available during the midnight shift.

S6.4 Inattention and Sleepiness is Significant During Consecutive Midnights

S6.4.1 Findings

Brain wave activity, as indicated by the EEG data collected for some individuals working the midnight shift, was analysed. The data show a shift in the power toward more slow, synchronous activity, primarily in the theta range of wavelength. This indicates that there is an increased probability of micronaps and periods of inattention across the midnight shifts. Unfortunately, too little useful data could be obtained from the Gander and Moncton recordings. Technical limitations of the equipment and time constraints during the hook-up resulted in poor conductivity between the Medilog electrodes and the scalp, leading to poor signal strength. Because the Toronto conditions were closer to ideal, with no back-to-back hook-ups such as occurred in Gander and Moncton (due to having controllers go directly from sleep monitoring to on-the-job monitoring), more time was available for electrode hookup. Hence, the quality of the signal strength was better.

S6.4.2 Conclusion

Controllers working consecutive midnight shifts are at risk of nodding off, and are experiencing periods of inattention which may be long enough to compromise performance. Research analysing incidents and accidents in the aviation industry have indicated that problems arise most often during low to moderate workload levels (Stager & Hameluck, 1988; Redding, 1992; Schroeder, 1987).

S6.4.3 Recommendations

Further research on the severity of this problem is warranted by the findings of this research. The approach might involve having controllers work in a simulated or operational ATC environment, while being monitored closely and tested for performance four or five times over the night. Such a protocol should involve one researcher dedicated to checking monitoring and testing equipment, and recording traffic levels and control centre activities. Equipment which can easily check the signal strength of leads and which can ensure adequate calibration must be available at all times to the assigned researcher.

S6.5 Impact of Circadian Effects and Fatigue on Staffing Levels and Scheduling

S6.5.1 Findings

Planning staff levels is difficult. Each day has different traffic. Even if there are similar trends, illness and unforeseen circumstances can cause staff shortages, often at the last minute. Running an operation at its most efficient staffing levels usually means that very little surplus staff is tolerated. Of course the down side to this is that the system will have difficulty meeting contingencies, and short staffing may result. Unfortunately, in a safety-critical working environment, redundancy in system components is a requirement, including the human side of the system. Safety critical operations must have redundancy to remain at an acceptable safe level.

S6.5.2 Conclusions

It is difficult to maintain staffing levels which will comply with this requirement, particularly when operating 24 hours a day. For example, when traffic levels are too low to justify the required redundancy, it is removed, as a means of maintaining efficiency. Safety, therefore, is entirely a function of the ability of the individuals responsible for each specific job. If that individual cannot meet the demands of the job, there is no one to step in and take over, unless others can do that individual's job, as well as their own. The danger, then, is that during conditions where individual staff are stressed by fatigue, circadian effects, and sustained workload, such as working a midnight shift alone, their abilities are degraded, there is no margin of safety, and the chances of error are increased considerably. Furthermore, the likelihood of a failure to respond effectively to emergencies is seriously heightened.

This research identified the strengths and weaknesses of five shift schedules currently used by Air Traffic Services. None were ideal, though some aspects of each schedule can be effectively applied to a given staffing requirement. We have presented recommendations for shiftwork countermeasures which can help the air traffic controllers better adapt to the work schedules. However, it has long been recognised within the field of ergonomics that it is generally more effective if the work system can be made to match the abilities and limitations of the human, rather than trying just to adapt the human.

S6.5.3 Recommendations

It is recommended that the factors discussed above be included in planning staff levels. If surplus staff can be made available for contingencies, either through multiple job capabilities, such as supervisors familiar with all of the job types, or through training for multiple jobs, individual staff can step in to relieve individuals requiring a break due to fatigue or to suppressed alertness caused by circadian rhythm or long working hours. If this multiple training is not possible, then technological support should be considered to make job sharing possible. Finally, if no job sharing can be achieved, the only option available is to provide redundancy in all job specialties. Although this may be prohibitively expensive, the fact remains that the **system must have the necessary redundancy** required of safety critical systems.

Furthermore, research to confirm the results of this study and to help support scheduling decisions should be considered. Such research should examine various shift schedules to determine those which offer optimum sleep, rest and break opportunities, allow for meals, least disrupt the circadian rhythm, and promote improved performance. This research should focus on two goals:

1. Comparing new alternative schedules with existing schedules in a lab and/or field setting;
2. Assessing the impact of the Shiftwork Countermeasures Program on the most promising schedules.

Combining systems-based modifications with controller-based countermeasures will be more effective than each intervention can be individually. For example, the scientific literature indicates that forward shift rotation is better than backwards rotation in terms of sleep and circadian effects. However, our research indicated that controllers working from days to evenings had less sleep overall compared to controllers working from evening to days. The main problem with the days to evenings shift is the early start combined with the controllers' preference to go to bed late. This was attributed to controllers going to sleep late prior to starting the day shift, thereby self-restricting their sleep. Sleep hygiene techniques can improve the quality and quantity of sleep prior to starting a day shift (DDDEE cycle), thereby reducing fatigue and optimizing the schedule's interaction with controller's circadian rhythms, and thus improving performance, health and systems safety.

Finally, it is recommended that planning for research and intervention strategies be considered within the context of future organizational and technological advances in the Air Traffic Services of Canada.

SYNTHÈSE

S1.0 INTRODUCTION

Transports Canada a commandé une étude sur les effets de l'organisation du travail par roulement et des heures supplémentaires sur la santé et le bien-être des contrôleurs de la circulation aérienne, notamment au vu des résultats du rapport publié en 1990 par le Bureau canadien de la sécurité aérienne (maintenant appelé Bureau de la sécurité des transports du Canada) intitulé *Rapport sur l'enquête spéciale portant sur les services de la circulation aérienne au Canada*. Le BCSA avait formulé une série de recommandations concernant l'organisation du travail par roulement et les heures supplémentaires en contrôle de la circulation aérienne, à savoir :

1. Que le ministère des Transports prépare et mette en vigueur des restrictions supplémentaires portant sur :
   - le nombre maximal d'heures qu'un contrôleur peut travailler à un poste de contrôle donné sans bénéficier d'une pause;
   - le nombre minimal d'heures de repos entre les quarts de travail.
2. Que le ministère des Transports, de concert avec le ministère de la Santé et du Bien-être social et les experts internationaux, mette sur pied un programme de recherches sur les effets néfastes de la disrythmie circadienne et du manque de sommeil sur le rendement au travail des contrôleurs de la circulation aérienne.
3. Que le ministère des Transports entreprenne immédiatement une étude sur le rendement au travail des contrôleurs qui effectuent régulièrement des quarts de travail supplémentaires pendant leurs jours de repos normaux.

Afin d'approfondir ces questions, un programme de recherche a été lancé visant à recueillir les données permettant d'y répondre. La phase I de ce programme, menée par Rhodes et coll. (1995), a permis de cerner les questions auxquelles il fallait trouver des réponses et de définir les outils de recherche pour la mise en oeuvre de cette démarche.

S2.0 MANDAT ET PORTÉE DE LA RECHERCHE

La phase II avait pour objet de mettre en oeuvre les outils de recherche définis par la phase précédente, et de recueillir les données qui permettraient de donner suite à la deuxième des trois recommandations du rapport du Bureau canadien de la sécurité aérienne.

Cette recommandation posait la question suivante :

Quels sont les effets de certains cycles de travail posté sur le sommeil, la performance, la santé et les activités hors service des contrôleurs de la circulation aérienne?

À la lumière des réponses obtenues, il sera possible de formuler des recommandations visant à atténuer ces effets.

Les chercheurs ont réussi à mettre en évidence les effets des cycles de travail posté en :

1. mesurant la performance cognitive au travail des contrôleurs durant chacun des quarts formant un cycle de travail posté;
2. analysant la qualité et la quantité de sommeil durant les périodes de sommeil prises à certains moments précis du cycle de travail;
3. demandant aux contrôleurs d'établir des auto-évaluations quant à leur humeur et à l'état de somnolence à des moments précis durant chacun des quarts formant le cycle de travail;
4. recueillant des données relatives à l'emploi du temps des contrôleurs tant durant les heures de service que durant les heures de repos;
5. prenant des électroencéphalogrammes (mesure des ondes cérébrales) durant certains quarts du cycle de travail;
6. observant les variations du taux de mélatonine durant certains quarts dans le but de déterminer s'il y a eu adaptation du rythme circadien.

Les données recueillies ont été analysées dans le but de déterminer les mesures susceptibles d'atténuer les effets nuisibles éventuels du cycle de travail sur le sommeil, la physiologie, la performance, la santé et les activités durant les heures de repos des contrôleurs. Les cycles de travail analysés ont été les suivants :

<u>Cycles de travail «durs» selon la phase I</u>
[M = minuit; S = soir; J = de jour; R = Relève; T = fin de soirée ou début de nuit]
1. Cinq quarts de minuit consécutifs (MMMMM)
2. Double changement rapide (ou court) (SSJJM)
3. Cycle de travail standard du Centre de contrôle régional de Terre-Neuve à Gander (SRJMT)

<u>Cycles de travail plus souples</u>
4. Rotation vers l'arrière changement rapide simple (SSJJJ)
5. Rotation vers l'avant commençant par le service de jour avant de passer au service de soirée (JJJSS)

Les sujets de la présente recherche ont été recrutés dans le Centre de contrôle régional de l'Ontario à Toronto; dans la tour de contrôle de l'aéroport international de Toronto; dans le Centre de contrôle régional de Terre-Neuve à Gander, dans la tour de contrôle de l'aéroport international de Gander; dans le Centre de contrôle régional atlantique à Moncton et dans la tour de contrôle de l'aéroport de Moncton. Ces Centres et tours de contrôles ont été sélectionnés parce qu'ils mettent en oeuvre des cycles de travail du type préconisé par la phase I et que leur emplacement permet des déplacements et le transport d'équipement sans trop de frais.

S3.0 DÉMARCHE DE RECHERCHE

Une démarche globale a été utilisée, faisant appel à deux groupes de sujets distincts. Le premier groupe était régi par le protocole au complet, c'est-à-dire qu'il a participé à toutes les expérimentations comprises dans ce protocole, à savoir :

1. Surveillance du sommeil durant les périodes jugées critiques selon la phase I (dormir le jour [de 7 h à 15 h], le soir [entre 15 h et 23 h] et durant les cycles de changement rapide [moins de 12 heures entre la fin d'un quart et le début du quart suivant]);
2. Tests physiologiques durant le quart venant aussitôt après la période de sommeil surveillé;
3. Tests de performance pilotés par ordinateur, trois fois durant chacun des quarts;
4. Prélèvements d'urine lors d'une période de 24 heures avant et après les périodes de sommeil surveillé;
5. Tenue d'un journal quotidien de l'emploi du temps pendant 13 jours consécutifs.

Ce groupe était affecté aux trois cycles de travail considérés comme les plus durs des cinq analysés (MMMMM, SRJMT, SSJJM). (Pour les cycles de travail, plus de sujets ont été analysés dans les aspects moins exigeants de l'étude.)

Le second groupe de sujets n'a participé qu'aux tests de performance, en plus de tenir un journal quotidien de l'emploi du temps. Ce groupe était réparti sur les cinq cycles de travail analysés.

La recherche menée au cours de la phase II correspondait à une étude sur le terrain, recueillant des données dans un contexte de service réel, et analysant des comportements réels. Il ne s'agissait pas d'une étude en laboratoire, ni d'une étude dans des conditions artificielles. De plus, rien n'a été fait pour modifier l'environnement de travail ou l'emploi du temps des sujets, même si des variables potentiellement dérangeantes ont pu être observées. Les données recueillies correspondaient à des réalités vécues en milieu de travail, ou notées dans le journal quotidien.

S4.0 PLAN DE RECHERCHE

Le tableau S4-1 ventile les sujets selon les expérimentations prévues par la phase II et selon les cinq cycles de travail visés. Sous chaque rubrique, une note apparaît chaque fois que la saisie de données n'a pas pu se faire. Pour ce qui est des tests de performance et des tests physiologiques, des pertes de données ont réduit le nombre de sujets pour lesquels les données saisies ont pu être analysées (voir parties 5.1 et 5.3). La figure S4-1 montre le calendrier des saisies de données à l'égard des trois cycles de travail du groupe 1. S1, S2 et S3 correspondent aux trois périodes de sommeil surveillé, et M1 et M2 aux deux cycles durant lesquels les tests physiologiques ont été effectués à l'aide de l'appareil d'observations médicales portable Medilog d'Oxford (décrit dans la section décrivant la méthodologie de la recherche). Quant au tableau S4-2, il fait la ventilation des heures de début et de fin des divers cycles de travail analysés.

Tableau S4-1 : Ventilation des sujets participant au protocole, selon le cycle de travail

Cycle de travail	Nombre de sujets	Sommeil surveillé	Tests physiologiques	Tests de performance	Journal quotidien	Taux de mélatonine
MMMMM	12	12	8	12	11	12
SRJMT	15	8	10	13	12	8
SSJJM	12	10	8	12	12	10
JJSSS	10	aucune saisie	aucune saisie	8	9	aucune saisie
SSJJJ	6	aucune saisie	aucune saisie	5	5	aucune saisie
Total	55	30	26	50	49	30

Le calendrier de saisie des données correspond aux périodes d'un cycle de travail susceptibles d'aboutir à un déficit de sommeil ou à une qualité de sommeil amoindrie. Les contrôleurs de Toronto faisant cinq quarts de minuit consécutifs ont eu 1) une période de sommeil surveillé au milieu de leur période de repos de 4 jours pour obtenir une base de comparaison sur la qualité de leur sommeil la nuit, 2) une période de sommeil surveillé le jour après leur premier quart de minuit et 3) une période de sommeil surveillé le jour après leur quatrième quart de minuit. Les contrôleurs de Gander (SRJMT) ont eu une période de sommeil surveillé au milieu de leur période de repos pour obtenir une base de comparaison sur la qualité de leur sommeil, 2) une période de sommeil surveillé le soir entre le quart de jour et le quart de minuit (changement rapide - rotation vers l'arrière) et 3) une période de sommeil surveillé durant le jour après le quart de minuit. Les contrôleurs effectuant le double changement rapide (SSJJM) ont eu 1) une période de sommeil surveillé au milieu de leur période de repos pour obtenir une base de comparaison sur la qualité de leur sommeil la nuit, 2) une période de sommeil surveillé la nuit entre le quart de soirée et le quart de jour (changement rapide - rotation à l'arrière) et 3) une période de sommeil surveillé le soir entre le quart de jour et le quart de minuit.

Les tableaux S4-3 et S4-4 font la ventilation selon l'âge des sujets du groupe 1 et 2, respectivement. Il s'agissait surtout de repérer au moins un sujet par groupe d'âge (objectif pas toujours réalisé) et d'en réunir le maximum pour les groupes d'âge 30-34 ans, 35-39 ans et 40-44 ans, qui sont les plus représentatifs de la population des contrôleurs de la circulation aérienne au Canada. On a cherché en outre à se renseigner sur le groupe âgé de 45 ans et plus, étant donné que la population des contrôleurs aériens est en train de vieillir et qu'un nombre proportionnellement plus élevé atteindra l'âge de 45 ans au cours de la prochaine décennie. D'autant que la phase I avait montré que les effets du travail posté peuvent se manifester dès l'âge de 35 ans, bien que l'incidence d'une disrythmie circadienne augmente surtout avec l'âge. De plus, la santé qui commence à décliner à partir de 45 ans fait intervenir des facteurs dont l'effet est d'altérer le sommeil et de rendre ces personnes récalcitrantes à tout changement dans les horaires et dans les habitudes. Il en résulte un organisme dont la physiologie résiste de plus en plus mal au stress produit par les cycles de travail posté et par les heures supplémentaires. Ce problème sera cependant d'autant moins aigu que la personne est en bonne santé (Costa, 1996).

Figure S4-1

DATA COLLECTION SCHEDULE

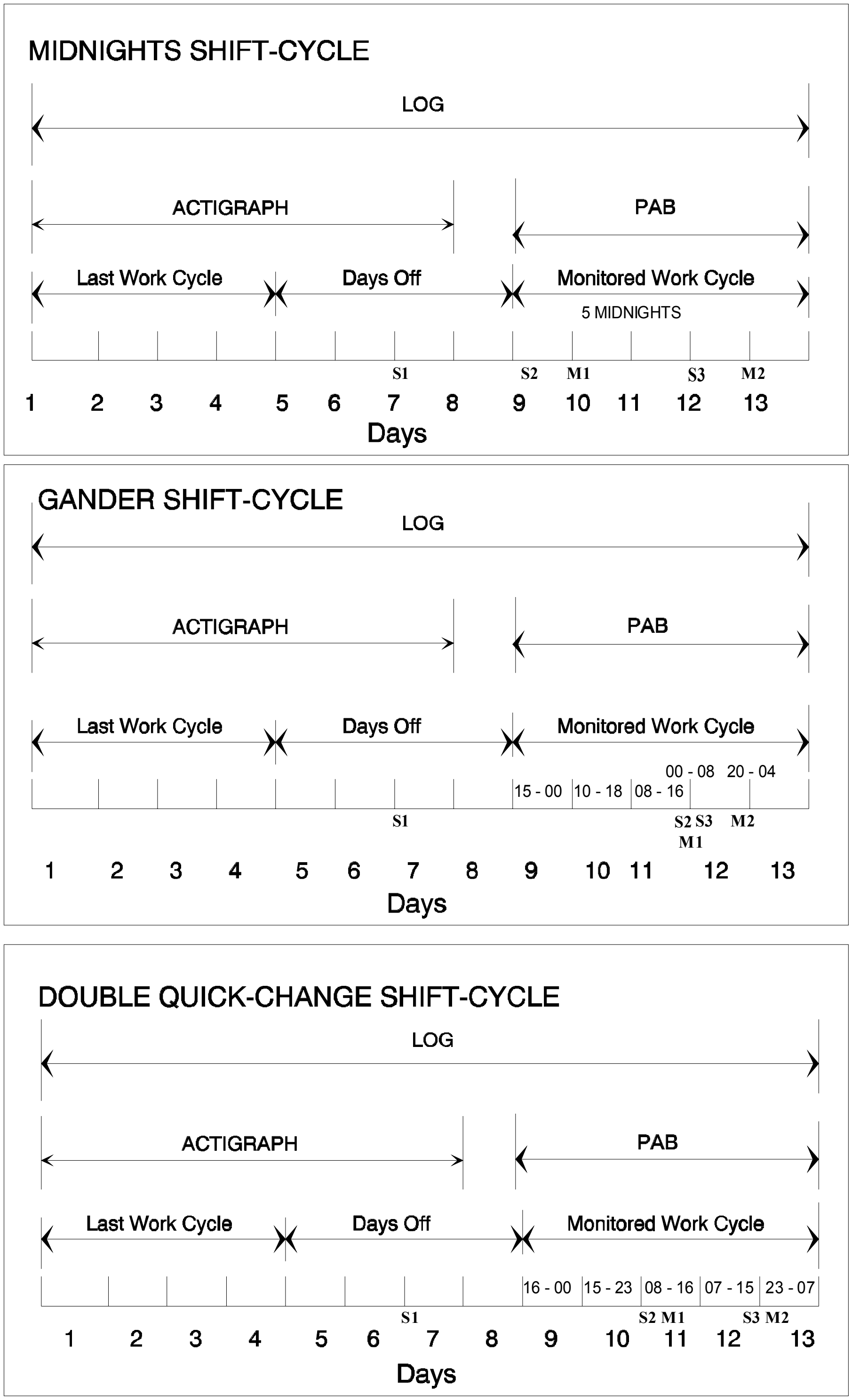

Tableau S4-2 : Heures de début et de fin des quarts

Cycle	Quart	Début	Fin
MMMMM	M = Minuit	23:00	06:30
SSJJM	S = Soir J = Jour M = Minuit	15:00 06:30 23:00	23:00 15:00 06:30
SRJMT	S = Soir R = Relève J = Jour M = Minuit T = Nuit	15:00 10:00 06:30 23:00 20:00	23:00 18:00 15:00 06:30 04:00
SSSJJ	S = Soir J = Jour	15:00 06:30	23:00 15:00
JJJSS	J = Jour S = Soir	06:30 15:00	15:00 23:00

Tableau S4-3 : Ventilation selon le groupe d'âge, sujets groupe 1
(Protocole complet : sommeil surveillé, tests de performance et physiologiques, taux de mélatonine, journal quotidien)

Cycle de travail posté	Nombre total de sujets	35 ans et moins	Plus de 35 ans
MMMMM	12	6	6
SRJMT	8	5	3
SSJJM	10	4	6
Total	30	15	15

Tableau S4-4 : Ventilation selon le groupe d'âge, sujets groupe 2
(tests de performance et journal quotidien, seulement)

Cycle de travail posté	Nombre total de sujets	35 ans et moins	Plus de 35 ans
MMMMM	12	6	6
SRJMT	15	8	7
SSJJM	12	4	8
JJSSS	10	6	4
SSJJJ	6	3	3
Total	55	27	28

S5.0 MÉTHODOLOGIE

La phase II a permis la saisie des données suivantes :

a) quarts formant un cycle de travail posté;
b) auto-évaluations sur l'état de fatigue, la somnolence et l'emploi du temps;
c) quantité de sommeil par enregistrements polysomnographiques et au vu des journaux quotidiens;

d) qualité et nature du sommeil par enregistrements polysomnographiques;
e) emploi du temps durant les jours de repos, comparativement aux jours de travail;
f) nombre de repas et de collations, quantité de caféine et boissons alcooliques consommés durant les jours de repos et durant les jours de travail;
g) enregistrements électroencéphalographiques (à l'aide du système Oxford) durant les quarts venant après leur période de travail-sommeil 1 et de travail-sommeil 2.
h) taux de mélatonine pendant une période de 24 heures avant et après les trois périodes de sommeil surveillé, y compris les quarts placés sous observation médicale (Oxford Medilog).

Les méthodes d'observation et les tests effectués ont été les suivantes :

1. Performance durant le cycle de travail
   - Administration de la batterie de tests de performance, mise au point par le Walter Reed Army Medical Institute
2. Évaluation de l'état de fatigue et de la somnolence
   - Somnolence et état de fatigue selon l'échelle Stanford
3. Mesure de la quantité de sommeil et évaluation de la qualité du sommeil
   - enregistrements polysomnographiques et saisie de données hypnologiques
   - heure d'endormissement et de réveil, nombre de fois que le sujet s'est réveillé (journal quotidien)
4. Compte rendu des périodes de sommeil, du nombre de repas, de la quantité de caféine et de l'emploi du temps
   - notés dans le journal quotidien
5. État de vigilance (électroencéphalogrammes) durant les quarts
   - enregistrements physiologiques au moyen de l'appareil Oxford Medilog
6. Rythme circadien
   - observation du taux de mélatonine dans l'urine

S6.0 CONSTATATIONS, CONCLUSIONS ET RECOMMANDATIONS

Dans les parties S6.1 à S6.5 sont récapitulées les principales constatations de l'étude et sont formulées les grandes recommandations concernant les recherches à venir et la mise en oeuvre, bien que les constatations laissent entrevoir des stratégies plus nombreuses que ce qui est répertorié. Voici les principaux résultats de cette phase de la recherche :

- Cinq services de nuit consécutifs ont donné un déficit total de plus de **10** heures de sommeil.
- Le régime de sommeil le jour et le soir a débouché sur un déficit beaucoup plus important que le sommeil de nuit, les périodes de sommeil le soir étant **1,5** fois plus courtes que les périodes de sommeil de jour (déficit de **3,5** heures contre **2,2**, respectivement, par période de sommeil - moyenne collective). En d'autres termes, les sujets ont totalisé beaucoup moins d'heures de sommeil en dormant le jour et le soir.
- Pour les trois cycles de travail «durs» étudiés, le rendement a fléchi par une marge de **5 à 20 p. 100** en moyenne (données globales), ce qui signifie que, sous ces trois régimes, la performance des sujets dans la batterie de tests cognitifs est moins bonne.

- On observe une chute importante de la performance cognitive vers la fin d'un cycle intensif à rotation vers l'arrière avec changement rapide (soit cycles à double changement rapide et Gander), occasionnée par le déficit aigu de sommeil. En d'autres termes, une quantité considérable de sommeil est perdue durant la nuit de sommeil précédant le service de jour et durant l'après-midi de sommeil précédant le quart de minuit.
- Le rythme circadien et l'important déficit de sommeil (moyenne de **2 heures de sommeil perdues par période de sommeil**) sont les principaux facteurs de la chute de performance cognitive durant les quarts de minuit. En d'autres termes, travailler à un moment où l'horloge biologique de l'organisme est à l'heure de dormir fait baisser le niveau de vigilance et de performance.
- Les quarts de minuit font perdre un repas par jour et les repas pris sont de moins bonne qualité : il est plus difficile d'observer des horaires réguliers pour les repas et de s'alimenter sainement.
- Les cycles de travail à double changement rapide et Gander semblent raccourcir le temps passé en famille ou avec des amis. On passe plus de temps seul, à dormir ou à s'occuper autrement.
- Les sujets de plus de 35 ans obtiennent moins de temps de sommeil que les contrôleurs moins âgés (plus de la moitié des sujets avaient plus de 35 ans, mais il reste que ce groupe est relativement jeune). Les effets de l'âge se manifestent tôt et se font sentir chez une partie importante de la population visée.
- Même si la quantité de caféine absorbée n'est pas très forte, elle est plus forte durant les cycles de travail «durs».
- L'observation du taux de mélatonine a permis de constater qu'il ne se produit **pas** d'adaptation du rythme circadien au cycle de cinq quarts de minuit consécutifs. Cele signifie que l'horloge biologique de l'organisme ne va pas de pair avec l'horaire imposé par ce cycle.
- Les enregistrements électroencéphalographiques durant les quarts de **minuit** montrent une augmentation dans les probabilités de micro-sommeil et de baisse de vigilance. En d'autres termes, il est difficile de maintenir une vigilance soutenue au travail durant ces quarts. Les autres cycles de travail n'ont pas pu être évalués sous cet angle, vu la taille trop faible des échantillonnages.

S6.1 Déficits de sommeil

S6.1.1 <u>Constatations</u>

La recherche montre que les contrôleurs de la circulation aérienne obtiennent entre 25 et 30 p. 100 moins de sommeil durant leur cycle de travail, par rapport aux périodes de repos. Les tests hypnologiques et physiologiques montrent que cela débouche sur un déficit de sommeil en plus d'amoindrir la qualité du sommeil obtenu. Une apparition précoce du stade de sommeil lent (sommeil profond) et du stade de sommeil paradoxal (sommeil onirique), et une augmentation du sommeil lent ont été observées chez un grand nombre de sujets, signes indicateurs de fatigue et d'un déficit de sommeil. L'effet d'un déficit de sommeil sur l'organisme, sur le rendement au travail et sur le comportement social a été bien étudié par Costa, 1996; Folkard, 1996 et Knauth et Costa, 1996. Les symptômes en sont un sentiment de fatigue, une récupération plus lente après le cycle de travail (observée également dans la présente recherche), un malaise prononcé (incapacité de se rendre au travail) et des épisodes fréquents de mauvaise humeur (irritabilité, irascibilité, etc.).

Les résultats de la phase I indiquaient que les contrôleurs effectuant des quarts de minuit se sentaient très fatigués et qu'ils estimaient que leur rendement avait diminué, parfois considérablement. Pour les contrôleurs plus âgés, les quarts de minuit et les changements rapides étaient les plus éprouvants. Plus de la moitié des contrôleurs âgés (plus de 40 ans) avaient déclaré ne pas travailler plus de quatre quarts de minuit consécutifs, le plus souvent trois seulement. Confirmant les conclusions de la phase I, la phase II a montré que les contrôleurs en général, et les contrôleurs âgés en particulier, souffrent d'un manque profond de sommeil, menant à un rendement diminué.

Les auto-évaluations faites durant la phase I avaient montré que les contrôleurs dormaient très peu lorsqu'ils effectuaient des changements rapides entre les quarts de jour et les quarts de minuit. La phase II a fait constater que cette situation était pire que ce que l'on avait cru, la plupart des contrôleurs n'obtenant que deux ou trois heures de sommeil par période de sommeil durant ces cycles.

MMMMM (Toronto)

Le journal tenu par les contrôleurs faisant cinq quarts de minuit consécutifs montre que la quantité moyenne de sommeil sur un cycle complet a été la plus faible de tous les groupes, le déficit moyen s'élevant à plus de 10 heures. Cependant, en comparant les quantités de sommeil enregistrées par le système polysomnograpique Alice3, il a été observé que les périodes de sommeil diurne chez les contrôleurs de Toronto ont été plus longues que chez ceux de Gander et de Moncton (double changement rapide). Le sommeil des contrôleurs faisant des quarts de minuit consécutifs a été plus court et de moins bonne qualité durant leur première période de sommeil diurne, par rapport à la base de comparaison et à la deuxième période de sommeil diurne. Les sommes pris par eux ont été, eux aussi, plus courts que chez les contrôleurs faisant la plupart des autres cycles de travail (à l'exception du cycle JJSSS).

SRJMT (Gander)

La qualité et la durée du sommeil sont généralement conditionnées par la période du jour ou de la nuit à laquelle on dort. La période de sommeil durant le jour ou en soirée, imposée par les cycles à changement rapide et après un quart de minuit, est beaucoup plus courte et donne une qualité de sommeil moindre qu'une période de sommeil nocturne, surtout en période de repos. La durée des sommes pris durant les périodes de repos a été la plus forte de tous les cycles de travail. Malgré deux périodes de sommeil très médiocres (périodes de sommeil le jour et en soirée écourtées), la quantité de sommeil que les contrôleurs de Gander ont eue et qu'ils ont déclarée dans leur journal vient en deuxième position.

SSJJM (Moncton)

Comme à Gander, le sommeil pris le soir après un quart de jour, et précédant un quart de minuit, a été marqué par un pourcentage élevé de sommeil lent et d'un pourcentage beaucoup plus faible de sommeil paradoxal, en plus d'avoir été très court (moyenne enregistrée de 2,7 heures de sommeil). Pour récupérer, ces contrôleurs prenaient des sommes, dont la durée a suivi de près celle des contrôleurs de Gander, mais dans les deux cas dépassant les 2 heures.

SSSJJ (Moncton)

Les contrôleurs faisant le passage des quarts de soirée aux quarts de jour ont eu plus de sommeil en moyenne durant leur cycle que les contrôleurs faisant les autres types de cycles, en plus d'avoir pris des sommes dont la durée a été la plus longue (d'après le journal quotidien). Les trois quarts successifs faits en soirée leur permettent de dormir plus que durant les quarts de jour, et donc de récupérer. Pour ce qui est des autres cycles, on ne fait tout au plus que deux quarts de soirée, et parfois rien qu'un. Les contrôleurs faisant ces cycles n'ont pas l'avantage de faire un ou deux quarts de soirée de plus. Par contre, leur vie sociale est perturbée, vu qu'ils n'ont que peu d'occasion de rester avec leur famille ou des amis.

JJJSS (Toronto)

Règle générale, les contrôleurs préfèrent, avant un quart de jour, aller se coucher entre minuit et 1 heure du matin, surtout après un quart de soirée. La période de sommeil est donc écourtée, étant donné que le quart commence entre 5 h 30 et 6 h 30 du matin. Ils obtiennent de la sorte entre deux et trois heures de sommeil de moins que le strict nécessaire par jour. Il s'ensuit un déficit de sommeil qui, au lieu de se résorber, se creusera de plus en plus tout au long du cycle.

La période de temps disponible pour le sommeil est encore écourtée par le temps de déplacement domicile-travail. Ceux dont le temps de déplacement n'est en moyenne que de 25 minutes ou moins bénéficient d'une heure de sommeil de plus, grâce à laquelle ils peuvent résorber le déficit de sommeil. Règle générale, les contrôleurs de Toronto consacrent au moins 1 heure à leurs déplacements, ce qui explique en partie pourquoi, pour eux, faire des quarts de jour c'est perdre beaucoup d'heures de sommeil par cycle.

L'analyse de leur journal quotidien montre que la quantité de sommeil pris par jour se situe à l'avant-dernier rang, autant les jours de travail que les jours de repos. Ils ont également déclaré prendre très peu de sommes.

S6.1.2 Conclusions

Il faudra donner aux contrôleurs de la circulation aérienne l'occasion de dormir suffisamment entre leurs quarts de travail et les mieux préparer à utiliser les moyens naturels pour dormir vite et bien. Ce qu'il faut c'est plus de temps pour dormir lorsque l'organisme est le plus porté à dormir. Cela peut paraître évident, mais ce n'est pas ce qui se passe normalement dans notre société d'aujourd'hui, où l'on commence à travailler de jour alors que l'organisme est encore en état de sommeil. Si, à l'instar des fermiers, nous dormions tous tôt pour nous réveiller tôt, il n'y aurait plus de sommeil perdu, sauf lorsqu'interviennent des facteurs externes (bruit, caféine, etc.). Or, vu que nous sommes souvent régis par la télévision ou des horaires serrés qui interfèrent avec le besoin de dormir, il faudra user d'astuces, comme programmer d'avance notre magnétoscope à cassettes ou réorganiser les activités nocturnes de façon qu'elles précèdent un jour de repos, afin d'obtenir la quantité de sommeil nécessaire.

S6.1.3 Recommandations

Bien dormir par une hygiène appropriée : Il faudrait élaborer un programme visant à enseigner aux contrôleurs, aux gestionnaires et à la direction les contre-mesures à la fatigue et au manque de sommeil. On recommande que les membres du comité concerné (programme ATCOH, ACCTA, services de la circulation aérienne, CDT et direction de la médecine aéronautique civile) proposent un programme de formation renseignant les contrôleurs, les gestionnaires, la direction et le personnel d'exploitation des Services de la navigation aérienne sur les moyens d'améliorer l'environnement du travail posté, notamment en leur montrant comment il est possible de dormir vite et bien. Ce programme aurait les quatre volets suivants :

1. Élaboration du programme de contre-mesures;
2. Formation des instructeurs;
3. Série de séances de formation pilotes;
4. Évaluation de l'efficacité de la formation.

Le programme de contre-mesures doit être élaboré avec la participation de toutes les parties susceptibles d'en profiter. Leur apport permettra aux spécialistes de la gestion du travail posté de mettre au point un programme de formation qu'ils soumettront à l'appréciation du comité.

Une fois ce programme approuvé, les instructeurs (agents ATCOH par exemple) devront recevoir une formation appropriée par les spécialistes de la gestion du travail posté qui puiseront dans leur propre expérience, et dans d'autres programmes similaires ailleurs.

La présente recherche montre qu'un grand nombre des contrôleurs tous cycles confondus, mais plus particulièrement ceux qui effectuent un double changement rapide, ceux qui font des quarts de minuit consécutifs et ceux du cycle Gander, n'obtiennent leur juste part de sommeil. À force d'accumuler un déficit de sommeil, ces contrôleurs finissent par compromettre et leur santé et leur rendement au travail, en plus de se forcer toujours plus pour surmonter les effets d'une fatigue croissante et de la disrythmie circadienne.

Tout programme d'aide aux contrôleurs faisant du travail posté doit les renseigner d'abord et avant tout sur les mesures à prendre pour dormir vite et bien : comment s'y préparer, qu'est-ce qu'on doit éviter, quand dormir et comment rester endormi. Pour la plupart des sujets de cette recherche, la principale difficulté était de réussir à tirer parti du temps de repos alloué pour dormir. Les changements doubles et le sommeil le soir étaient les pires de toutes les épreuves, laissant peu de temps au sommeil et obligeant l'organisme à dormir alors que l'horloge biologique n'était pas au sommeil. Ce dernier problème touchait également ceux qui devaient dormir le jour.

Il existe plusieurs palliatifs à ces deux problèmes. Les mesures suivantes peuvent être essayées une à la fois ou plusieurs à la fois :

- Créer un environnement propice au sommeil;
- Faire savoir à son entourage quand on prévoit devoir dormir le jour;
- Faire des ajustements susceptibles de rehausser la vitalité et la vigilance au travail et de favoriser un état de somnolence préparatoire au sommeil;
- Se conditionner mentalement par une méthode qui, en plus de mener à une vigilance accrue au travail, favorisera un état de somnolence préparatoire au sommeil;
- Favoriser la relaxation du corps et de l'esprit par diverses méthodes telles que la formation autogène, les exercices de relaxation, la méditation, la lecture, de l'exercice léger, ou autres;
- Dans la mesure du possible, donner aux contrôleurs l'occasion de suivre un horaire compatible avec leur âge, leur tempérament (diurne ou nocturne), leur situation familiale, etc.;
- Proposer des services de counselling et de soutien psychosocial de nature à aider les contrôleurs à trouver des solutions concernant le sommeil, à organiser leur vie familiale et sociale et à cerner les comportements et les circonstances posant problème; le cas échéant, les orienter vers les services de santé appropriés. La formation des instructeurs ATCOH et d'autres professionnels de la santé permettra de rehausser l'efficacité de ce type de soutien.

S6.2 Effets du manque de sommeil et du rythme circadien sur le rendement

S6.2.1 Constatations

Les tests de performance effectués durant les quarts de minuit consécutifs montrent que la performance cognitive est plus basse au milieu d'un quart (vers les 3 heures du matin) qu'au début ou qu'à la fin. Les tests dont les résultats sont les plus faibles sont ceux de raisonnement logique, de reconnaissance des formes, et le test de Mannikin. Les temps de réaction sont également touchés, mais à un degré moindre. Le déclin dans la performance cognitive se manifestant à mi-quart résulte d'une activité cérébrale et d'un rythme circadien au ralenti (température du corps, rythme cardiaque et sécrétions hormonales à leur point le plus bas) qui se produisent entre 3 et 6 heures du matin. Il est difficile de faire preuve de vigilance et de clarté d'esprit lorsque l'horloge biologique de l'organisme est à l'heure de dormir. Cela ressort clairement dans le rendement des contrôleurs qui font cinq quarts de minuit consécutifs.

La phase II montre qu'un déficit de sommeil grandissant et qu'un nombre ridicule d'heures de sommeil entre la fin d'un quart de jour et le début d'un quart de minuit se traduisent par un déclin sensible du rendement. Le déclin prononcé qui se manifeste au cours des quarts de minuit consécutifs se constate également au milieu du quart de minuit dans les cycles Gander et à double changement rapide. Le déclin de la performance cognitive est une caractéristique permanente du quart de fin de journée dans le cycle de Gander, alors qu'un déclin similaire a été observé au cours du deuxième quart de jour du cycle à double changement rapide (venant juste avant le quart de minuit). Un déclin sensible du rendement dans le quart de jour, un nombre insuffisant d'heures de sommeil et un quart de minuit à peine huit heures après le quart de jour rendent difficile le maintien d'un état de vigilance.

La moins bonne performance se manifestant durant le deuxième quart de jour permet de croire que la fatigue ressentie pourrait être attribuée à l'heure trop matinale à laquelle débute le quart. Le quart du matin commençant typiquement à 5 h 30, le contrôleur doit donc se lever à 4 h ou à 4 h 30 pour avoir le temps de se préparer, de prendre son petit déjeuner et de se rendre au travail. Les contrôleurs de Toronto mettent entre 25 minutes et 90 minutes pour se rendre au travail, et parfois plus, dans quelques cas rares.

Les contrôleurs qui font le quart du matin souffrent, en plus, d'un manque de sommeil dû à une difficulté de dormir. La torpeur et le sentiment de fatigue qu'on éprouve lorsqu'on doit se lever à 4 heures du matin s'expliquent par les deux raisons suivantes. D'abord, à cette heure-là l'organisme doit surmonter l'effet du rythme circadien au ralenti : température corporelle, rythme cardiaque et état de vigilance à leur point le plus bas. Ensuite, la période de sommeil est forcément écourtée, le contrôleur obtenant moins d'heures de sommeil que le strict nécessaire. La plupart des contrôleurs ont de la difficulté à se coucher tôt, ce qui leur aurait permis de rattraper le sommeil perdu. Ce phénomène est très répandu et il a fait l'objet d'études spécifiques.

S6.3.2 Conclusions

Le déclin dans le rendement constaté durant les quarts de minuit va de pair avec le rythme circadien de l'organisme et il y trouve partiellement son explication. À preuve, les taux de mélatonine enregistrés qui indiquent que l'organisme ne parvient pas à s'adapter au cycle de cinq quarts de minuit et que l'horloge biologique est toujours à l'heure circadienne habituelle. C'est là une constatation fort intéressante étant donné que, dans le passé, on avait justifié les quarts de minuit consécutifs par l'hypothèse que l'organisme finira pas s'adapter. Au lieu de cela, on constate aujourd'hui que c'est au rythme circadien qu'il faut attribuer non seulement les chutes de rendement à mi-quart, mais aussi les déficits de sommeil. De même, la fatigue aiguë occasionnée par les profonds déficits de sommeil qui résultent du passage d'un quart de jour à un quart de minuit dans les cycles Gander et à double changement rapide apparaît comme la cause du déclin de rendement constaté dans le quart de minuit (et pour

Gander, dans le dernier quart de minuit, également). Il arrive souvent que les contrôleurs ayant un long chemin à faire pour se rendre au travail préfèrent dormir sur place ou dans un hôtel proche, lorsque vient leur tour de faire un changement rapide (moins de huit heures avant le quart suivant).

S6.3.3 Recommandations

Il est recommandé d'approfondir par des recherches en contexte de simulation ou mieux encore de service réel, la possibilité d'autoriser des sommes et des pauses durant les quarts, dans le but de recueillir des données peuvent sous-tendre l'élaboration de stratégies d'hygiène du sommeil.

Pauses : Les quarts de minuit sont caractérisés par des états de vigilance, d'énergie et de performance cognitive amoindris, et ce d'autant plus lorsqu'aucune pause n'est autorisée. La tâche de travail est faible, certes, mais l'envie de dormir, forte au début, augmente au fil des heures. Un travail de quelque forme que ce soit, et encore plus s'il s'agit d'une tâche de surveillance nécessitant un état de vigilance soutenue, se dégrade en qualité au bout de deux ou de trois heures. Il faudrait donc que les contrôleurs puissent bénéficier d'une pause leur permettant de s'éloigner de leur poste et de récupérer : exercice, somme, collation, etc. Une pause d'une demi-heure toutes les deux heures d'un quart de minuit est recommandée, à moins que les tests effectués en contexte de service ne montrent une meilleure façon de procéder.

Sommes : Les quarts de minuit sont les plus éprouvants parce qu'ils interviennent à un moment où l'horloge biologique de l'organisme est à l'heure de dormir. Et puisque la somnolence et la fatigue ressenties durant ces quarts sont en toute probabilité parmi les variables explicatives de la baisse de rendement, il est logique de penser qu'un somme pris à mi-quart permettra d'atténuer l'effet conjugué de la fatigue et du rythme circadien, et de redresser la courbe faiblissante du rendement. Des preuves existent (Costa, 1996b) montrant qu'un somme de 20 à 40 minutes environ permet de redresser la performance. Rosekind et coll. (1994) ont étudié les avantages que procure chez les pilotes d'avion un somme d'une quarantaine de minutes, précédé de 3 minutes préparatoires et suivi d'une dizaine de minutes pour se remettre à l'heure. Ils ont constaté un redressement dans la performance et beaucoup moins de micro-sommeils. Cependant, on ignore presque tout de l'effet bénéfique des sommes pris durant les quarts de minuit et les cycles à changement rapide, et des recherches sur l'effet produit à court et à long termes seraient particulièrement utiles.

On recommande que soient expérimentées, en simulation ou dans un contexte de service, des stratégies de sommes durant certains quarts, en variant les paramètres de durée, de choix du moment et de qualité d'ambiance afin d'évaluer les effets de ces stratégies sur le rendement au travail, sur les auto-évaluations et sur les interviews de suivi. On pourra faire appel à des contrôleurs ayant une expérience dans ce domaine que l'on confrontera à un groupe témoin. L'avantage de la simulation est de pouvoir exercer un contrôle plus serré du processus de saisie de données (obtention de données complètes, par exemple), mais au détriment de la validité de celles-ci. Dans les deux cas, des contrôleurs dûment formés (aux stratégies de sommeil, aux tests de performance et aux auto-évaluations de leur performance et de leur état mental et physique) seraient autorisés à prendre un somme durant leur quart, moyennant quoi, ils devraient se soumettre à des tests d'évaluation du rendement, de l'état de somnolence et de l'humeur à certains moments précis du quart. Le rendement au travail du groupe autorisé à prendre un somme serait comparé à celui du groupe témoin qui, lui, n'aura pas eu une telle autorisation.

Heures supplémentaires : Faire des heures supplémentaires immédiatement après un cycle de travail normal c'est, pour la plupart des contrôleurs et surtout pour les plus âgés, pousser les choses beaucoup trop loin. En agissant ainsi, on ne fait que creuser davantage le déficit de sommeil, déjà grave, au point d'affaiblir sa santé et ses facultés cognitives. Sans compter la dégradation de la vie sociale et des diverses activités qui suivra la détérioration de l'humeur et du fonctionnement cognitif, et dont les symptômes sont l'irritabilité, l'irascibilité, les pertes de mémoire, un stress mental accru et une fixation sur le rétablissement. Plus on fait des heures supplémentaires, plus il faudra dormir davantage afin de rattraper le sommeil perdu et de chasser la fatigue accumulée. Il restera donc moins de temps pour la famille, les amis, les repas, les loisirs, la relaxation, etc., le tout débouchant sur des congés de maladie de plus en plus fréquents lorsque l'organisme n'arrive plus à suivre.

Considérant le déficit de sommeil aigu ou chronique qui semble être lié au travail posté, quel qu'en soit la forme, il faudra après chaque cycle de travail normal deux jours pleins de repos pour rattraper le sommeil perdu et pour que l'organisme se réadapte au changement imposé dans les horaires. Au bout de deux jours de repos, on se sentira plus disposé à faire des heures supplémentaires et le rendement sera probablement meilleur.

S6.3 Organisation des repas

S6.3.1 Constatations

La plupart des contrôleurs s'accordent à dire que l'organisation des repas constitue un problème : de difficile qu'elle est déjà durant un cycle de travail normal, elle devient quasiment illusoire durant les quarts de minuit. Or, en vue d'un régime alimentaire sain et équilibré, les repas doivent être pris au bon moment, de jour comme de nuit. La phase I avait montré que les contrôleurs étudiés trouvaient que les quarts de minuit rendaient impossible toute tentative d'organiser des repas réguliers et nourrissants. La phase II vient confirmer ces dires d'une façon éclatante.

S6.3.2 Conclusions

Il faut aider les contrôleurs à agir dans l'intérêt de leur santé : ne pas sauter des repas, éviter de prendre, avant d'aller se coucher, des aliments qui excitent (caféine, alcool et aliments à teneur élevée en gras ou en glucides simples) et choisir des aliments qui favorisent la vigilance au travail (glucides complexes tels que céréales, aliments riches en protéines et faibles en gras et des fruits riches en glucose. Il faut les aider aussi à se préparer des repas qui répondent aux besoins de leur organisme.

S6.3.3 Recommandation

Une solution qui aurait l'avantage de sensibiliser davantage à ce problème serait de produire un guide alimentaire semblable à ceux qu'utilisent les personnes qui suivent un régime alimentaire, mais axé sur les besoins spécifiques des contrôleurs. Une autre solution serait de mettre des fruits, des légumes, du pain, etc. à la disposition des personnes faisant des quarts de minuit.

S6.4 Baisses de vigilance et somnolence durant les quarts de minuit successifs

S6.4.1 Constatations

L'analyse des électroencéphalogrammes de contrôleurs sélectionnés faisant des quarts de minuit montre un décalage des longueurs d'onde vers la gamme des ondes thêta, synchrones et plus lentes, indiquant une incidence plus prononcée des micro-sommeils et des baisses de vigilance qui sont la marque des quarts de minuit. Les EEG pris à Gander et à Moncton n'ont malheureusement apporté que peu d'information utile. Des contraintes de temps et un équipement mal adapté ont gêné l'implantation des électrodes sur le scalp, entraînant l'affaiblissement des signaux captés par celles-ci (les contrôleurs devaient se rendre du laboratoire de sommeil directement à leur travail). En revanche, à Toronto, où on bénéficiait de conditions quasi idéales, ces contraintes de temps n'existaient pas, d'où une meilleure qualité des signaux.

S6.4.2 Conclusions

Les contrôleurs faisant des quarts de minuit consécutifs risquent de connaître des épisodes d'endormissement au travail. Les baisses de vigilance observées chez eux peuvent se prolonger au point de compromettre la sécurité. Les recherches sur les incidents et les accidents dans le secteur de l'aviation ont montré que les risques de tels occurrences sont plus élevés lorsque la charge de travail est faible ou moyenne (Stager et Hameluck, 1988; Redding, 1992; Schroeder, 1987).

S6.4.3 Recommandations

La présente recherche montre la nécessité de recherches plus poussées afin de cerner l'ampleur de ce problème. La démarche consistera à mener des expérimentations dans un contexte de simulation ou de service réel et à demander aux contrôleurs d'effectuer des tests de performance quatre ou cinq fois durant les quarts de minuit. Le protocole en question sera dirigé par un chercheur chargé spécifiquement de vérifier l'équipement de surveillance et de contrôle, et de noter l'intensité de la circulation aérienne et les activités correspondantes dans le centre de contrôle. Il devra disposer d'appareils permettant de vérifier le bon fonctionnement des électrodes, l'intensité des signaux qu'elles transmettent et l'étalonnage des circuits.

S6.5 Effets du rythme circadien et de la fatigue sur l'organisation du travail et du personnel

S6.5.1 Constatations

L'organisation du travail est difficile, vu les fluctuations quotidiennes dans la circulation aérienne. Et même en l'absence de fluctuations, une pénurie de main-d'oeuvre, souvent de dernière minute, peut survenir, causée par des congés de maladie ou par des imprévus. Vouloir fonctionner avec un effectif optimisé en nombre signifie la plupart du temps n'admettre aucun personnel excédentaire. Dans ce cas, il faudra parer aux imprévus avec un effectif réduit. Or, dans tout contexte fortement relié à la sécurité, la redondance est de rigueur, y compris de l'effectif, faute de quoi la sécurité risque d'être compromise.

S6.5.2 Conclusions

Une organisation temporelle du travail qui tiendrait compte de cette contrainte est difficile, surtout lorsqu'il faut opérer 24 heures par jour. Lorsque, par exemple, le trafic est trop faible pour justifier une redondance d'effectif, on la sacrifie au profit de l'efficacité. Il s'ensuit que la sécurité dépendra avant tout de l'aptitude de chaque personne à s'acquitter du travail qui lui est confié. Si une personne fait défaut, il faudra que son remplaçant éventuel soit en mesure de la suppléer. Or, dans un contexte de fatigue, de disrythmie circadienne et de charge de travail ininterrompue, qui sont les caractéristiques des quarts de minuit en solitaire, les facultés se dégradent, ne laissant aucune marge de sécurité. Les risques d'erreur augmentent considérablement, augmentant du coup les risques de défaillance au travail si une situation d'urgence devait se présenter.

La présente recherche a analysé les avantages et les faiblesses de cinq cycles de travail couramment mis en oeuvre par les Services de la circulation aérienne. Aucun d'eux n'a été trouvé parfait, bien que chaque cycle possède des particularités qui conviendraient à un contexte de service particulier. Nous avons proposé des contre-mesures au stress du travail posté, par lesquelles les contrôleurs pourront mieux s'adapter aux horaires de travail imposés. Or, les ergonomistes savent depuis longtemps qu'il vaut mieux adapter un système aux aptitudes et aux limitations de l'être humain, plutôt que le contraire.

S6.5.3 Recommandations

On recommande que les facteurs abordés dans ce document soient pris en compte dans toute décision concernant l'organisation du travail. Pour suppléer la personne trop fatiguée pour fonctionner efficacement ou dont la vigilance est en baisse pour cause de disrythmie circadienne ou trop longues heures de travail, une solution serait d'avoir dans l'effectif en poste des personnes qualifiées pour occuper plusieurs types de postes, un surveillant, par exemple, ou une personne spécialement formée à cette fin. À défaut de formation multiple, la possibilité d'un partage de poste devrait être considérée, avec le soutien technologique nécessaire. Enfin, si le travail partagé n'est pas possible, la seule option sera celle de la redondance pour tous les postes spécialisés. Solution coûteuse, certes, mais justifiée par **la nécessité de doter tout système étroitement lié à la sécurité de la redondance nécessaire**.

On recommande aussi de poursuivre cette recherche par d’autres visant à confirmer les résultats obtenus et à proposer des moyens pour aider la prise de décision en matière d’organisation du travail. Il s’agirait de déterminer, de tous les cycles de travail en présence, ceux qui offrent des conditions optimales de sommeil, de repos, de pause, qui permettent d’organiser les repas, qui perturbent le moins le rythme circadien et qui débouchent sur un rendement accru au travail. Leur objet sera double :

1. Comparer de nouveaux cycles à ceux couramment mis en oeuvre, dans un contexte de simulation et (ou) de service réel;
2. Évaluer les effets des contre-mesures à la fatigue sur les cycles les plus prometteurs.

En combinant des modifications des cycles de travail et contre-mesures à la fatigue, on agit plus efficacement qu’en intervenant au niveau de l’individu. Les ouvrages scientifiques montrent que les rotations vers l’avant sont plus avantageuses que les rotations vers l’arrière, pour ce qui est de leur effet sur le sommeil et sur le rythme circadien. Or, nos recherches montrent que le passage des quarts de jour aux quarts de soirée fait perdre plus d’heures de sommeil que le passage contraire, vu l’heure trop matinale à laquelle débute le quart du matin et eu égard au fait que les contrôleurs aiment se coucher tard. En fait, ils se couchent tard avant de commencer un quart de jour, amputant de la sorte la période de sommeil intermédiaire. Par des techniques d’hygiène du sommeil, il est possible d’améliorer la qualité et la quantité de sommeil avant un quart de jour (cycle JJJSS), ce qui atténuera la fatigue ressentie et fera concorder les activités du quart avec le rythme circadien, d’où un rendement au travail accru, sécurité améliorée et une meilleure santé.

Enfin, on recommande d’envisager des stratégies de recherche et d’intervention dans le contexte de la réorganisation et de la modernisation technologique des Services de la circulation aérienne au Canada.

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1.0 INTRODUCTION

Transport Canada identified the need to investigate the effects of working shiftwork and overtime on health and well-being of air traffic controllers. The impetus for this concern was derived, partially, from the results of the report released in 1990 by the Canadian Aviation Safety Board (referred to as CASB, and now called the Transportation Safety Board) *Report on a Special Investigation into Air Traffic Control Services in Canada*. The report contained a number of recommendations concerning the shiftwork and overtime aspects of the controller's job. These CASB recommendations were:

1. That the Department of Transport make and enforce further restrictions on:
    - the maximum number of hours which can be worked at a particular control position without a relief break; and
    - the minimum number of rest hours between shifts;
2. That the Department of Transport, in co-operation with the Department of Health and Welfare and international authorities, initiate a program of research into the adverse effects of circadian dysrhythmia and sleep deficits on air traffic controllers and their job performance; and
3. That the Department of Transport initiate research into the effects of regularly working overtime shifts during normal days of rest on individual controller's job performance.

A research program was developed to examine all of the issues raised by these questions. The research program set out to provide the research data needed to answer these questions. Phase One (Rhodes et. al., 1995) of the research program identified the specific research questions and tools necessary to launch an investigation into the nature of problems posed in the CASB report.

The first phase of this project ("A Study of the Impact of Shiftwork & Overtime on Air Traffic Controllers - *Phase I: Determining Appropriate Research Tools and Issues*") identified research questions and methodologies which could be used to investigate specific issues related to the impact of shiftwork on air traffic controllers in Canada. Phase One also surveyed a sample of the entire air traffic controller population (921 responded out of 1750) in Canada to better understand the impact of shiftwork on the job performance, health and family circumstances of shiftworkers.

The results of Phase One helped the researchers target certain groups of the controller population for more extensive study in Phase Two, *Objective Analysis of Shift Schedules on Sleep, Performance, Physiology and Social Activities*. Phase Two examines the impact of specific shift schedules (shift-cycles) which were seen to be potentially detrimental to controller health, performance and social-psychological well-being of controllers. The study goals of all phases of the study were to:

- develop practical, valid and reliable research tools for the Study of the Impact of Shiftwork & Overtime on Air Traffic Controllers, based on past research methods and expert opinion;
- identify research questions, to evaluate the merit of the selected protocols, and to direct future larger scale and specific research in the field of shiftwork and overtime;
- objectively assess the impact of shiftwork and overtime on controllers' mental and physical health, and social-psychological well-being, as well as the subsequent effects on job performance;

1.1 Purpose And Scope

The Phase One results showed that controllers felt that certain shift-cycle types were more difficult than others. Controllers identified consecutive midnights (five midnight shifts in a row), double quick-changes (two shortened rest periods between shifts of less than 8 hours), and the Gander shift-cycle, which consists of a quick-change and two shifts having all or much of their time during the time when most of us sleep, as being very difficult shifts to work. There is considerable evidence suggesting that working midnights can cause significant sleep loss, reduced performance, and health problems. Sleep restriction, as occurs during quick-changes (also referred to as compressed work weeks), itself can lead to reduced performance and poorer quality of life.

The purpose of Phase Two is to examine the effects of different shift-cycle types on cognitive and psychomotor performance, quality and quantity of sleep, on-shift physiology, and social activities. **Phase Two** set out to:

- examine the quality and quantity of sleep achieved during sleep periods occurring at critical points in the shift-cycle;
- measure the cognitive performance of controllers during their shift throughout a shift-cycle;
- obtain a subjective assessment of mood and sleepiness during certain points of each shift in the cycle;
- obtain data on daily activities throughout the shift-cycle and during days off;
- measure brain correlates of drowsiness (EEG) during specific shifts in the cycle;
- measure melatonin fluctuations during certain shifts to determine phase changes in circadian rhythms.

The study was confined to examining five shift-cycle types. Three were hypothesised as having a greater negative impact on controllers (termed "difficult"), as indicated by the preliminary work in Phase One, and two were considered less severe by controllers generally, although not completely without complaint.

“Difficult” Shift-Cycle Types (according to Phase One)
[M=midnight; E=evening; D=day; S=Swing; N=late evening/early midnight - start and finish times are given in Table 3.1-3 in section 3.1 below]

- Five consecutive midnight shifts (MMMMM);
- Double Quick-change shift-cycle (EEDDM);
- Gander’s (Newfoundland Area Control Centre) ABCDE shift-cycle (ESDMN)

Less Severe Shift-Cycle Types

- Backward Rotation Single Quick-change shift-cycle (EEEDD)
- Forward Rotation Days to Evening shift-cycle (DDDEE)

The study included subjects from the Toronto Area Control Centre for the Ontario Region, the Toronto Pearson International Airport Tower, the Gander Area Control Centre for the Newfoundland Region, the Gander International Airport Tower, the Moncton Area Control Centre for the Atlantic Region, and the Moncton Airport Tower. These centres and towers had the required shift-cycle types, and their locations allowed for cost-effective travel and transportation of equipment.

The shift-cycle types listed above were located as follows:

- MMMMM - Toronto ACC and Toronto Tower
- DDDEE - Toronto ACC and Toronto Tower
- ESDMN - Gander ACC
- EEDDM - Gander Tower and Moncton ACC
- EEEDD - Moncton ACC and Moncton Tower

The study used an integrated approach which set out to examine sleep, physiology, performance, and social activities. Such an approach has been recommended by various researchers (Costa, 1996; H←rm←, 1993; Kogi & Thurman, 1993; Kogi, 1996; Monk & Folkard, 1992). Although this approach makes large sample sizes impractical and reduces the experimental control possible using a more focused experimental approach, it does allow the researchers to examine the relationships between the many factors affecting controller health and well-being. Such an approach also focuses on more naturalistic observations leading to enhanced generality and relevance.

The approach is field-based and benefits from the increased reality of the work environment, along with the pitfalls of field research. However, many of the normal pitfalls were improved through the use of technology and careful data collection methods. Polysomnographic equipment was moved into the field, allowing for high-quality sleep monitoring. Constant monitoring of the controller environment and considerable controller feedback helped to identify any extraneous effects (traffic levels, equipment failure, controller illness, etc.). Assistance was just a phone call away, or often just a matter of getting on the centre’s intercom.

2.0 BACKGROUND

2.1 Study Locations

The study locations are described here to give an understanding of their different natures. The Toronto area locations (Toronto ACC and Pearson Tower) are in a high density area where traffic jams and long commutes are common. Also, near-by cities and towns where rents and housing prices are lower attract controllers away from Toronto. The levels of stress, due to these geographical and demographic factors, are markedly higher in this location than that found in the others. In Gander for instance, the average commute (which includes almost everyone) is about 10 minutes, on roads where there is little or no traffic. The standard of living is high, but the pace of life is more relaxed than in Toronto. Moncton lies somewhere in between with respect to the length of commute and driving stress. The city of Moncton is growing and traffic jams do occur.

Levels of air traffic handled do differ between the centres and the towers, with Toronto being the busiest. Gander has what amounts to a 24 hour operation with a short lull between 04:00 and 06:00. Moncton also is busy late into the night, feeding oceanic-bound traffic to Gander until past midnight. Toronto on the other hand has a steady decline in traffic toward the late evening, with little traffic throughout the midnight hours, although some sectors experience a burst of activity from couriers out of nearby airports.

2.1.1 Toronto Area Control Centre and Toronto Pearson Airport Tower

The Toronto (Ontario Region) Area Control Centre in Toronto is a 24 hour operation which handles aircraft within approximately the Ontario borders. The centre has 6 specialties - North Bay, North, South, East, West, and the Toronto Terminal area. Within each of these specialties there are up to four sectors operating during daytime and evening periods (approximately from 05:30 to 00.00) depending on the traffic. When traffic eases off some sectors will be consolidated with others (e.g. the low level sector for a specific geographical area will be consolidated with that area's high level sector). Each specialty's sectors are collapsed into a single position during the midnight period (00:00 to 05:30), North Bay also being consolidated with the North. Hence, on midnights, each specialty (except North Bay) has only one person handling all of that specialty's sectors; therefore, flight information and radio communications for that specialty's areas of responsibility, must be consolidated into a single console position. This means that there are only five controllers working the midnight shift.

The traffic flow levels fluctuate up and down throughout the day, and week, and change seasonally, with peak periods occurring from June through to October, and to a lesser degree during the Christmas and March Break holidays. Weekdays are typically busier than weekends, and rush periods for all specialties occur in mornings and evenings, though specific times vary for each. Terminal, for instance, experiences very dense traffic early in the morning at about 05:30 through to 10:00, other peaks occurring between 11:30 and 14:30, and 16:00 to 20:00. South and East low level specialties experience their morning rush, between 07:00 and 10:00. High level sectors for South, East, and West have their morning peak later between 08:00 and 11:00, as increasing traffic flies over their sector's area, and as aircraft climb or descend through the sector to depart or land at local airports. Another busy time occurs in the evenings, but again a little later than Terminal or Low Level, from approximately 18:00 to 22:00. The North and North Bay sectors are steadier throughout the day and experience only small increases in the morning and evening, compared to the other specialties.

Of course, if thunder storm activity occurs in nearby regions, traffic flows can be changed dramatically, causing a great deal of last minute planning to be done and some quick, creative thinking to anticipate how the flows will be affected and how they should be handled. Often delays and re-routing of aircraft through the area or to the local airports will cause significant increases in traffic flow (delaying several aircraft, which then arrive in the area all at once). Since the schedules for these flights have changed from their usual times, controllers must maintain more communications with the aircraft and the other area control centres to get a better picture as it develops. Flow Control can help this situation considerably, but a great deal of co-ordination between controllers and Flow Control is necessary to make this work smoothly. Hence, work loads for everyone increase, and can rapidly come close to reaching the saturation point, and the flow of air traffic into the area must be reduced. This is a time when it is crucial to have adequate, experienced staff.

The Toronto Pearson International Airport Tower is a Class 5 tower, handling the highest traffic levels (29,074 movements in 1995 - Vancouver next with 27,711 movements) of all Canadian airports. The tower uses a split North/South parallel runway system which requires, during busy times, two tower crews: one crew handling aircraft taking off and/or landing on the north parallel runway (6L/24R) and the other controlling aircraft on the south parallel runway (6R/24L), and an equal north/south split between taxi-ways. During normal operating conditions, the scheduled procedural nature of this operation requires only minimal amounts of co-ordination between the two sides in the tower cab. However, when weather conditions are poor a considerable increase in co-ordination is required between the two sides of the cab and with the Terminal crew in the ACC, as well as with pilots on the ground and in the air.

Increased traffic levels occur from about 06:30 through to 10:00, and again they peak from 11:30 to 14:30, and from 16:00 to 20:00. A smaller peak occurs at about 23:00 to 00:00 as aircraft try to meet the curfew (at 00:00). Thursday evenings also seem to be heavier than the other weekdays. Weekends, as in the ACC, are quiet, though steady, except through the night, where traffic levels are extremely low.

Most of the controllers at the ACC and tower must travel long distances to get to work. Many live north of the airport, and a few live as far away as St. Catharines and Buffalo, New York State. Travelling times range from 15 minutes to 3 hours, with the mean duration of approximately 1 hour, all one way. Some of these trips must be done during heavy traffic and poor weather conditions, causing a fair amount of stress at times.

2.1.2 Gander (Newfoundland Region) Area Control Centre and Gander International Airport Tower

The Gander Area Control Centre specialises in oceanic flights although it is also responsible for controlling air space over Newfoundland. This operation has peak traffic levels occurring through the night as well as during the morning hours. The centre has 4 specialties: oceanic planning, oceanic control, high level, and low level. Within these specialties there are up to 8 sectors.

Oceanic planning has about a dozen "tracks" which can be used to send aircraft eastbound over the ocean. Also, they have 6 altitudes per track at which aircraft may fly (from 29,000 to 39,000 ft.) with 2,000 feet vertical, 10 minute longitudinal, and 60 nautical miles lateral separation between aircraft. In order to provide the best service, planners must try to slot the aircraft in the jet stream at an optimum altitude, so that aircraft can reduce operational costs.

The jet stream moves north and south such that sometimes the traffic is more north and sometimes it is more south. This means that certain altitudes and certain tracks are popular, and are requested by the airlines. Since all aircraft tend to want to cross the ocean at similar times, to avoid the curfews at some airports, the planners must find the best compromise to provide good service and still maintain the separation required between aircraft. The levels of traffic range from 300 to 800 flights that must be handled each night, depending on season and weather. Hence, since all of the overseas flights want to depart at roughly the same time, this large volume of traffic will arrive or be sent in a constant stream.

The high level controllers handling the eastbound flights are then given the flight information for these planned flights. As the aircraft approach the high level sectors the controllers monitor their progress, calculating the airspeed and altitudes which will send them on their way along the selected track, 10 miles apart, hopefully, at the altitude, route and speed they requested. Sometimes, aircraft arrive at the high-level controllers' area early or late and end up losing their requested route, speed and altitude.

Eastbound Oceanic controllers must then take the hand-off from high level controllers, sending the aircraft across the ocean, adjusting speeds and altitudes further, as aircraft are given their instructions requiring them to maintain the mandatory separation. The only information Oceanic has once the aircraft are out of VHF radio contact is the position reports collected from the pilots by the centre's radio operators on high frequency band-width radios. These reports are provided via a computer link with the radio operators to the centre. Radar is not available to controllers once the aircraft are beyond the range of the radar.

The Westbound flow which occurs in the morning (around 08:00) arrives as a steady stream of aircraft which must be routed either westbound or southbound through a bottle-neck caused by the location of the jet-stream. Westbound aircraft tend to favour westbound tracks which are north or south of the jet-stream (to avoid its easterly effects) and squeeze through a corridor located over Newfoundland on their way to their western and southern destinations. The Westbound oceanic controllers must slot these aircraft into appropriate routes, altitudes and speeds which will meet the scheduling demands of the airlines, and of the high level controllers who will have to control them through a denser, more complex air space. This means separations will be tighter than those over the ocean, and adjustments will be more frequent.

Eastbound Oceanic flights start at about 19:00. The pace quickly increases and stays steady until 06:00. The morning rush for the Westbound Oceanic occurs from 08:00 through to 12:00 as aircraft return from Europe to their North American destinations. The planes are then handed off to the high level controllers to be given their instructions for the route overland, and sent on their way. The high level controllers are busy from 08:00 to 15:00 as well.

Low level controllers on the other hand have very little activity through the night, experiencing rapidly increasing levels of traffic from 05:30 to 06:00 which remain high until about 10:00. Then the traffic tapers off somewhat and remains steady throughout the day, again peaking slightly in the early evening. Low level is responsible for a number of airports, including Gander, St. Johns, Deer Lake, Stephenville and St. Anthony, with varying levels of activity.

The Gander Tower is unique in that it must handle international traffic for stop-overs for maintenance, fuel, medical emergencies and some military activities. This means that the controllers must service anything from local single-engine private aircraft, helicopters, high performance military aircraft, and all sizes of jetliners up to Boeing 777s and 747s, and specialised aircraft like the Concorde. The scheduling of these flights is variable and as a result, the tower can change from being extremely busy for two or three hours, to being only mildly active for the next three. There is no patterned routine at this tower, and the controllers must be ready to deal with almost anything.

The controllers working at the centre and Gander tower all live close by, most living only a few minutes from work. The average travelling time is about 10 minutes, in absolutely no traffic.

2.1.3 Moncton Area Control Centre and Moncton Airport Tower

The Moncton (Atlantic Region) Area Control Centre provides service to aircraft flying within an area bounded by the Gander Centre's area, Montreal's area, and the New York and Boston Centres' areas. The responsibility of the centre is to control aircraft flying over the Atlantic Region on their way to or from the other regions, including the high volume of oceanic traffic, as well as controlling traffic at various local airports (e.g. Fredericton, Moncton, Charlottetown, Sydney). The ACC also includes the terminal control for Halifax Airport.

The ACC is organised into high level, low level and Halifax terminal specialties, with 10 sectors in high level, 5 sectors for low level, and 4 sectors for Halifax terminal. The traffic load for many of the high level crews mimics that of the Newfoundland high level controllers, except that the peaks occur ahead of Newfoundland for eastbound, and lagging after for the westbound flow. Moncton high level controllers must funnel the eastbound aircraft into the bottleneck over Newfoundland as the planes move into position to cross the ocean. Next morning they must route the rush of westbound oceanic traffic being fed to them by Gander Centre as these aircraft head west and south. In addition to this traffic, the high level controllers must handle planes ascending and descending through their air space, as well as many commuter flights in the area. The oceanic east-bound flights pass through the Moncton area between 20:00 and 00:00 with some stragglers until about 01:30. The morning oceanic flow through the Moncton region occurs from 11:00 to about 14:00.

The low level crews are responsible for a number of airports in the area, and usually start weekday mornings with a rush of traffic from about 06:30 through to 10:00, and experience another rush from about 16:00 to 20:00. Some courier activities will cause a mild rush later from 23:00 to 00:00. After this the low level controllers see traffic drop off considerably. Midnights are usually very quiet for both the low level and high level crews.

Halifax terminal does not operate through the night, closing down at 23:00. Next morning the crews start at 06:00 and are very busy until 10:00, traffic tapering off to a steady flow until 16:00 when another rush occurs lasting until 20:00. Occasional courier traffic keeps the workload steady up to the terminal's closing time.

The Moncton tower controllers experience a steady flow of traffic throughout the day, with mild peaks occurring in the morning (07:00 to 10:00) and the evening (17:00 to 20:00). Midnight activity is very low.

Aircraft handled at the airport include small commuter jets (DC-9, BAe 146), small jet courier aircraft, private jets, many sizes of multi-engined propeller driven planes, helicopters, and various sizes of single-engined aircraft.

Most of the Moncton ACC and Moncton tower controllers travel about 10 to 15 minutes to and from work. Automobile traffic levels are usually low, although Moncton does have a short rush hour in the morning and late afternoon. Recently, there has been a trend to live out of town in the surrounding rural communities, which may increase travelling times in the future.

2.2 The Nature of Sleep and Its Relationship to Shiftwork

In order to fully understand the results of the sleep section, a brief review of the nature of sleep is provided. The various sleep parameters and the characteristics of these parameters in normal sleep are discussed.

Normal sleep cycles in approximately 90 minute periods. When a person falls asleep, he/she progresses through stages 1,2,3,4 of sleep then usually returns to stage 2 for a few minutes before entering Rapid Eye Movement (REM) sleep. Typically people obtain about 15 - 20% of their total sleep period as Slow Wave Sleep (SWS - Stage 3 and Stage 4 sleep). Another 15 to 20% is usually REM sleep.

The first REM period of sleep is usually the shortest of the night, while the first period of Slow Wave Sleep (SWS) is usually the longest. Later in the night, SWS periods become shorter, while REM periods increase in length. The presence of significant amounts of SWS (about 30% of the total SWS) in the last third of the sleep period is often a sign of sleep restriction (reduced length of actual sleep period) and/or an accumulated sleep debt which a person is trying to “pay off”. High amounts of REM in the first third of the sleep period (over 30%) indicates that sleep has been seriously limited (below the minimum required hours of sleep, appropriate for each individual). Such a reduction in sleep duration and in REM sleep may cause problems with cognitive functioning and mood.

It is important to note the effect of age on the sleep cycle. For reasons which we do not yet understand, our brain-waves decrease in amplitude throughout our lifetime. Since SWS (delta waves) have a specific amplitude criteria, older adults typically have significantly less SWS than younger adults. Older adults often never reach Stage 4 sleep.

Other reasons for marked decreases in amount of SWS include the presence of a sleep disorder (e.g. sleep apnea) which prevents a person from reaching deeper stages of sleep. Persons with sleep disorders often arise feeling unrefreshed and experience continued daytime fatigue.

Sleep efficiency is an indicator of the proportion of the time in bed which was actual sleep. The higher the efficiency the less time a person has spent awake (periodic arousals) or had their sleep disrupted (become fully awake). However, since a short sleep latency period (e.g. as may be caused by fatigue) will contribute to an apparent higher sleep efficiency, caution must be used in interpreting sleep efficiency results. In other words, knowledge of the sleep history prior to the measured period, and an examination of the sleep profile, will indicate whether the efficiency is due to good natural sleeping qualities, or due to fatigue. Results where sleep efficiency is less than 80% are indicative of poor sleep.

An arousal is a brief moment of awakening that lasts for only a few seconds or fraction of a second. Some movement arousals are a natural part of the sleep cycle. However, frequent and consecutive movement arousals, as happens when suffering from sleep apnea or periodic leg movement disorders, or due to the effects of alcohol or caffeine, result in a fitful and unrefreshing sleep. Typically less than 20 arousals per hour of sleep is considered normal.

Hypopneas and apneas are respiratory events which usually occur when the muscles at the opening of the windpipe relax. This relaxation sometimes causes constriction of the opening resulting in decreased air flow (hypopnea). If the airway becomes completely closed and all air flow is cut off this respiratory event is called an apnea.

Hypopneas are generally less severe than apneas (i.e. the complete cessation of breathing) and normally occur during certain sleep stages. Up to 10 respiratory events per hour of sleep is considered normal. However, hypopneas may develop into apnea after having alcohol or other substances that relax the muscles of the throat. Frequent hypopneas and/or apneas disrupt sleep and often cause daytime fatigue.

3.0 GENERAL APPROACH

Information was collected to answer the following questions:

1. How do shift-cycles considered "difficult" according to the Phase One results affect controller cognitive and psycho-motor performance while at work, sleep patterns, brain physiology, and activities outside of work?
2. How do these shift-cycles compare to easier shifts with respect to performance, sleep patterns, and activities outside of work?
3. What is the effect of these shift cycles on younger vs. older controllers?
4. What type of interventions may be successful in enhancing the health and efficiency of air traffic controllers.

The investigation during this phase (Phase Two) represents a field-based study collecting data on real-world experiences and responses. This study was not carried out in a laboratory nor was it artificially constructed. The data were collected in as close to real conditions as possible. Although our equipment and procedural constraints, (e.g. size and weight and sensitivity of equipment, not wanting to intrude on the controllers' homes, and the need for responding to contingencies such as loose electrodes etc.), required that we operate out of a set of hotel rooms, no attempt was made to control the environment or the controller's activities. Hence, the level of noise and lighting were left alone, much as the controller would find in his/her home environment (dark curtains were used if the controller had them at home). We did, however, choose hotels which were reasonably quiet and conducive to sleep, and asked that large parties of people be directed elsewhere if possible. For the most part the hotel staff were able to do this.

All other data collection was conducted in the work-place, or in the case of the activity logs, wherever the controller happened to be.

3.1 Research Design

Tables 3.1-1 illustrates the total number of subjects involved in the comprehensive protocol, showing the breakdown for each shift-cycle type. Performance, log, sleep and EEG physiology data were collected for 20 individuals. Table 3.1-2 shows the breakdown according to shift-cycle for individuals involved in the performance and logs only (includes those who participated in the complete protocol plus those who only did the performance tests and the log). Figure 3.1-1 shows the data collection schedules for the three shift-cycles that included all components. "S1", "S2", and "S3" are the three sleep periods which were monitored. "M1" and "M2" are the two work periods which were monitored using the Medilog system (portable physiology monitor) described below in the methods section. Table 3.1-3 shows the shift start and finish times. Table 3.1-4 shows the breakdown for gender.

Table 3.1-1: Breakdown By Age Group for Complete Protocol (including sleep monitoring, melatonin and physiology - subset of total sample)

Shift-cycle type	Total Number of Subjects	Number Under 35 years old	Number Over 35 years old
MMMMM	12	6	6
ESDMN	8	5	3
EEDDM	10	4	6
Total	30	15	15

Table 3.1-2: Breakdown By Age Group for Performance/Log Protocol (including performance and logs - all subjects included in total sample)

Shift-cycle type	Total Number of Subjects	Number Under 35 years old	Number Over 35 years old
MMMMM	12	6	6
ESDMN	15	8	7
EEDDM	12	4	8
DDDEE	10	6	4
EEEDD	6	3	3
Total	55	27	28

Table 3.1-3: Shift Start and Finish Times

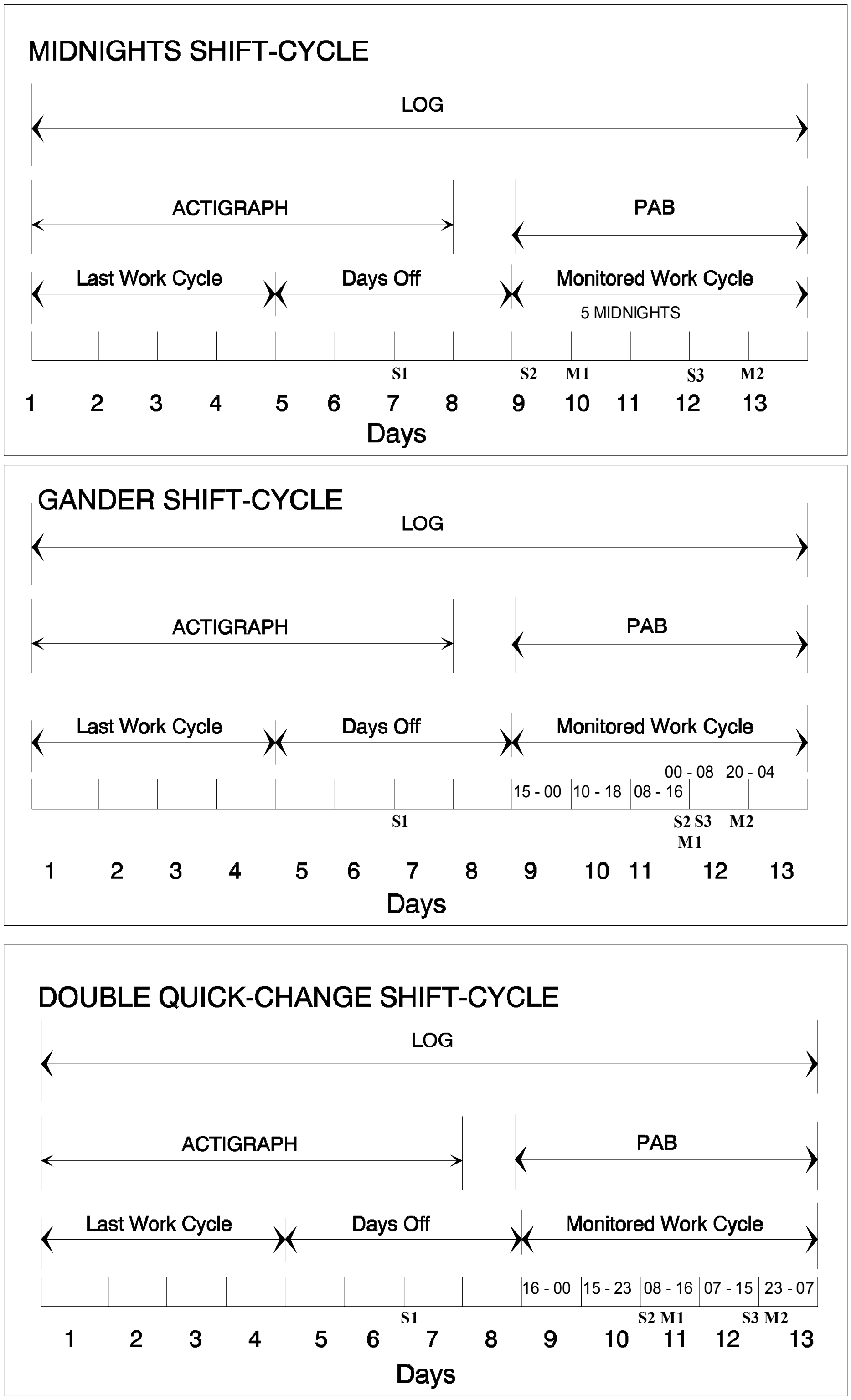
Shift-Cycle	Shift	Start Time	Finish Time
MMMMM	M = Midnight	23:00	06:30
EEDDM	E = Evening D = Day M = Midnight	15:00 06:30 23:00	23:00 15:00 06:30
ESDMN	E = Evening S = Swing D = Day M = Midnight N = Night	15:00 10:00 06:30 23:00 20:00	23:00 18:00 15:00 06:30 04:00
EEEDD	E = Evening D = Day	15:00 06:30	23:00 15:00
DDDEE	D = Day E = Evening	06:30 15:00	15:00 23:00

Table 3.1-4: Breakdown By Shift and Gender

Shift-cycle type	Total Number of Male Subjects	Total Number of Female Subjects	Total Subjects
MMMMM	10	2	12
ESDMN	14	1	15
EEDDM	11	1	12
DDDEE	9	1	10
EEEDD	4	2	6
Total	48	7	55

Figure 3.1-1

DATA COLLECTION SCHEDULE



S = Sleep Monitored by Polysomnograph; M = EEG Monitored by Medilog

The data collection schedules reflected the times in the shift-cycle when sleep is likely to be shortened or degraded in quality. Controllers working the consecutive midnight shift-cycle (MMMMM) were monitored for night-time sleep on a day in the middle of their four-day off period, considered their baseline sleep, a day-time sleep following their first midnight shift, and a day-time sleep following their fourth midnight sleep. The Gander (EDSMN) controllers were monitored for their sleep during a baseline (in the middle of their days off), during the evening sleep between the day shift and the midnight shift (quick-change - backward rotating), and during the day-time sleep following the midnight shift. The Double Quick-Change (EEDDM) controllers were monitored for their sleep during a baseline night-time sleep in the middle of their days off, during a night-time sleep between the evening shift and the day shift (quick-change - backward rotating), and an evening sleep between the day shift and the midnight shift.

3.2 Demographic Make-up of the Study Sample

Figures 3.2-1 and 3.2.-2 show the age breakdown for the entire sample and for those involved in the sleep monitoring sample. The main objective was to get at least one subject in each age group (not always achieved) and obtain more in the 30-34, 35-39 and 40-44 age groups since these age groups are the most represented in the Canadian air traffic controller population. Also, there was an interest in obtaining information on the over 45 age groups since the controller population is ageing and a proportionately greater number of controllers are expected to enter the over 45 years age groups over the next decade. In addition, the results from Phase One suggested that older controllers were more affected by shiftwork. This effect in other workers has been documented by Tepas et. al. (1993) showing that as shiftworkers age, they are able to sleep less (shorter sleep durations) and may suffer greater health problems.

Figure 3.2-1

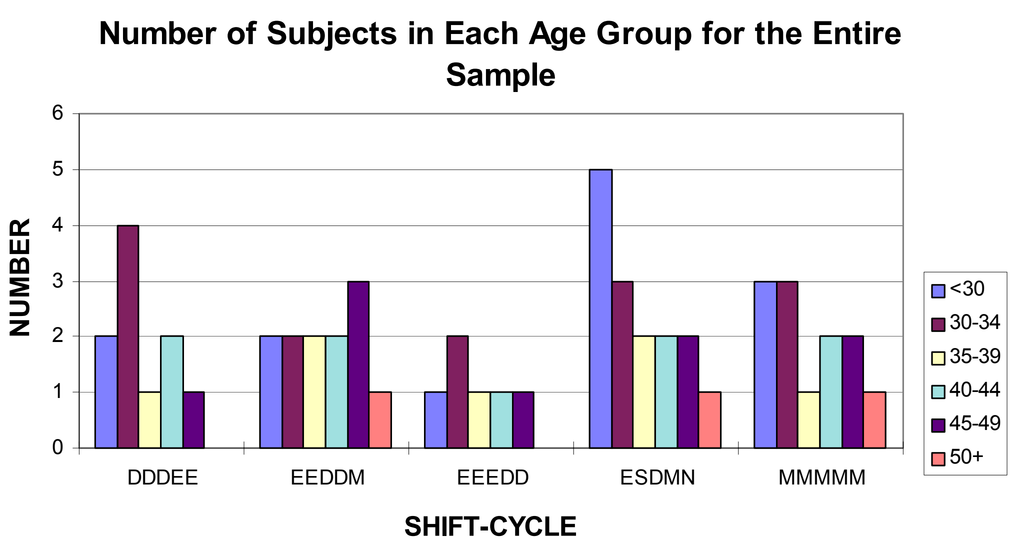
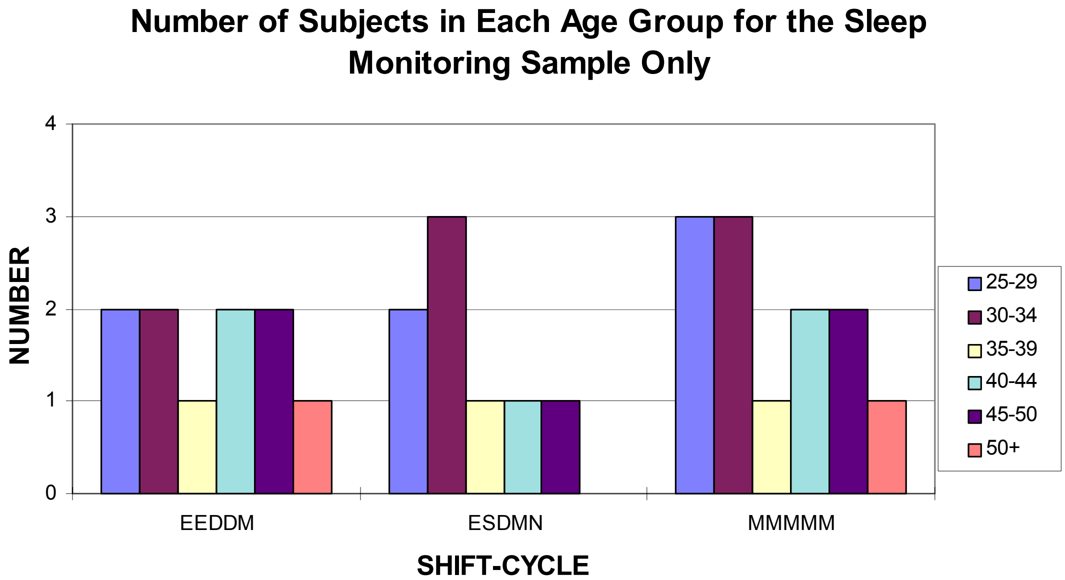


Figure 3.2-2



Number of Subjects in Each Age Group for the Sleep Monitoring Sample Only
NUMBER
4
3
2
1
0
EEDDM
ESDMN
MMMMM
SHIFT-CYCLE
25-29
30-34
35-39
40-44
45-50
50+

4.0 METHODOLOGY

Comparisons between the different shift-cycle types were performed examining the following variables:

a) duration of sleep as recorded by polysomnography, and as reported in the logs;

b) quality and composition of the sleep as recorded by polysomnography;

c) performance results for the PAB tests conducted at the beginning, middle and end of each shift during the work-cycle

d) subjective assessment of fatigue, activity and sleepiness as reported during the PAB sessions;

e) amount of time spent on various activities during days off compared with work days

f) number of meals, snacks, caffeine drinks, and alcoholic drinks consumed during off days and work days;

g) brain-wave activity (as obtained using the Oxford Medilog monitoring system) during the shifts following Work Sleep 1 and Work Sleep 2;

h) levels of melatonin during the 24-hour period surrounding each of the three monitored sleep sessions, including the shifts monitored by the Oxford Medilog system.

Actigraphs (movement measuring devices) were used for some of the subjects, to confirm the validity of activity logs, which showed excellent correspondence. Core temperature was estimated from tympanic (ear canal) measurements for those being monitored while they worked. The tympanic record proved to be completely unreliable, and the data were dropped from the analysis.

4.1 Performance Data Collection

It is important to assess how different shift schedules impact on the controllers' performance. The Walter-Reed Performance Assessment Battery was tested in the initial phase of this research as a means of collecting generic performance data. Initial results indicated some trends in the data which partially led to this focus in the Phase Two research.

In Phase Two all subjects were asked to perform three computer-based test batteries during each shift of their cycle, at the start, midpoint and end of the shift. The computer test battery consisted of cognitive and psychomotor performance tests, a mood-scale and a sleepiness index. On average, it required just over 10 minutes to complete.

The Walter-Reed Performance Assessment Battery (Thorne, et al., 1985) was used to assess certain psychomotor, perceptual, and cognitive skills over the course of a shift cycle. These tests are useful and **valid** for assessing generic skills underlying air traffic control performance over time. The change in performance can be used to indicate fatigue. The type of tasks, their number, and duration were customized according to the needs of the study. The tasks described below were selected, since they were believed to be representative of some of the fundamental elements of the air traffic controllers job, and are well **validated** tests and procedures that have been applied in shiftwork and sleep loss studies.

Stanford Sleepiness Scale - This is a subjective assessment of sleepiness. This seven point scale ranges from highly alert to extremely sleepy. The seven levels of sleepiness are listed below.

1. Feel active and vital; alert; wide awake
2. Functioning at a high level, but not at peak; able to concentrate
3. Relaxed; awake; not at full alertness; responsive
4. A little foggy; not at peak; let down
5. Fogginess; beginning to lose interest in staying awake; slowed down
6. Sleepiness; prefer to be lying down; fighting sleep; woozy
7. Almost reverie; sleep onset soon; lost struggle to remain awake

Pattern Recognition - This is a spatial memory task. A random pattern of 15 asterisks is displayed for 1.5 seconds then followed after a one second blank retention interval by a second pattern that may be the same or different (Figure 4.1-1). The subject decides whether the two patterns were the Same or Different and presses the "S" or "D" key accordingly. The pattern of dots may be analogous to aircraft locations which are components of the controller's mental model of the sector under her/his control. The duration of this test was 2 minutes.

Wilkinson Serial Reaction Time Task - This choice reaction time task, though not as representative of actual controller tasks as some other tests, can indicate changes in psychomotor ability. The subject is presented with a two by two matrix on the computer screen which contains 4 small boxes (Figure 4.1-2). These boxes are arranged to correspond with the "1", "2", "4", and "5" keys on the numbers key pad of a standard keyboard. A small red square appears randomly in one of the four boxes, and the subject is to press the corresponding key as quickly and accurately as possible. Immediately following the reaction time response the red square randomly appears in one the four boxes. This 4-choice serial reaction time task continues for 2 minutes. This is an effective indicator of fatigue since psychomotor skills often exhibit fatigue effects after cognitive or perceptual skills have been affected.

Grammatical Reasoning - This test has been shown to be very sensitive to fatigue effects, and is representative of reasoning tasks that the controller may be expected to perform on the job. The letter pair "AB" or "BA" is presented along with a statement that correctly or incorrectly describes the order of the letters within the pair (e.g., "B follows A", or "A is not preceded by B"). The subject decides whether the letter pair and the statement are the Same or Different and presses the "S" or "D" key accordingly (Figure 4.1-3). The S and D keys are chosen over the"T" and "F" keys because they are adjacent to one another on a conventional keyboard. The duration of this task was 2 minutes.

Figure 4.1-1 : Pattern Recognition Test Display

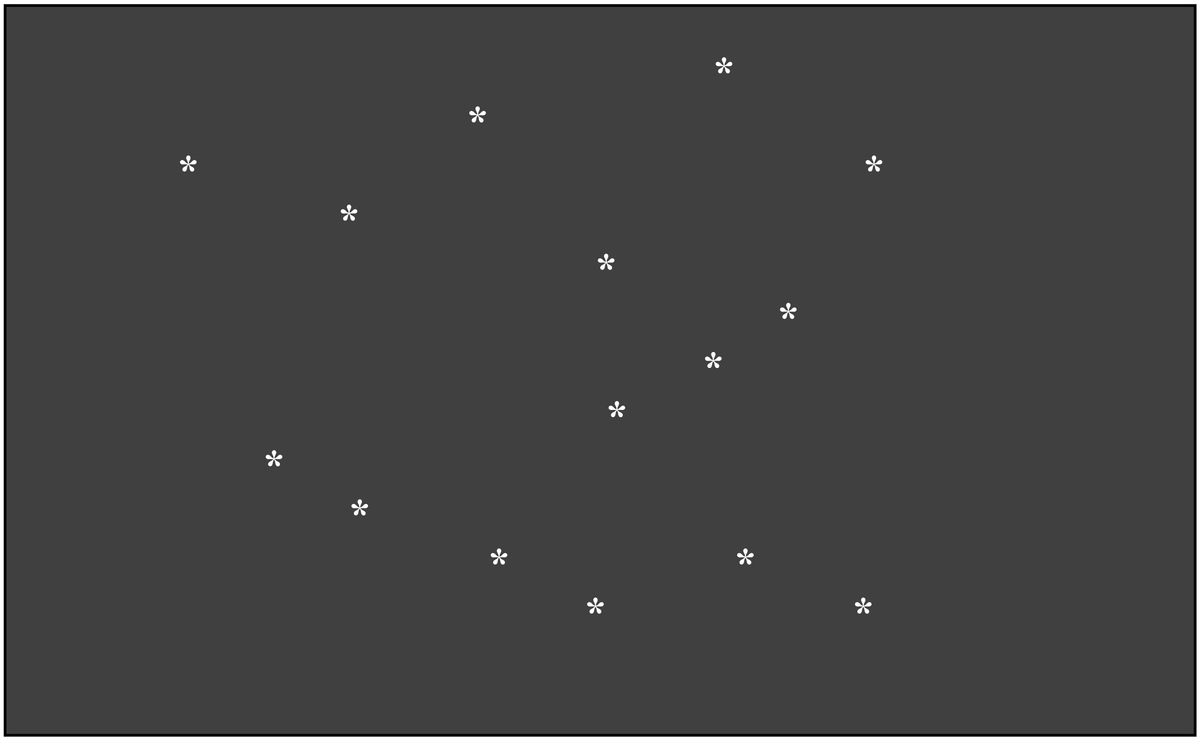


Figure 4.1-2 : Wilkinson Serial Reaction Time Test Display

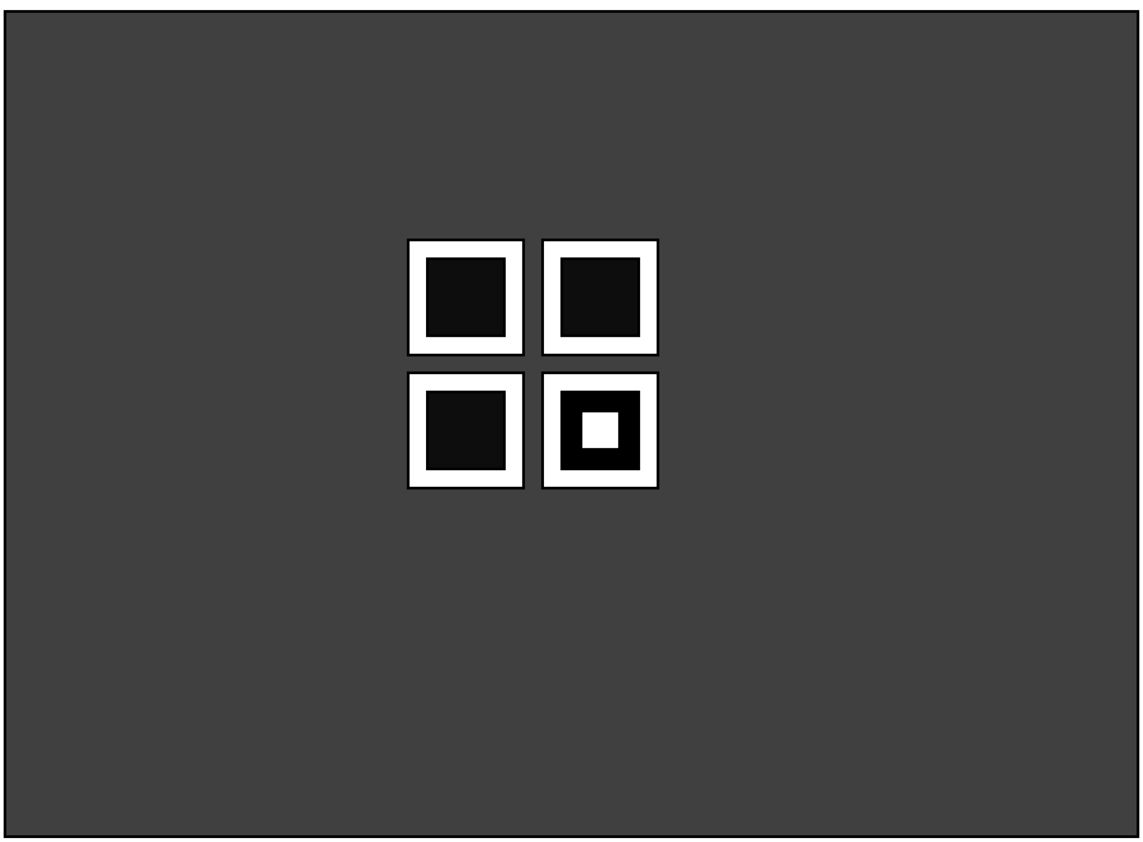


Figure 4.1-3 : Logical Reasoning Test Display

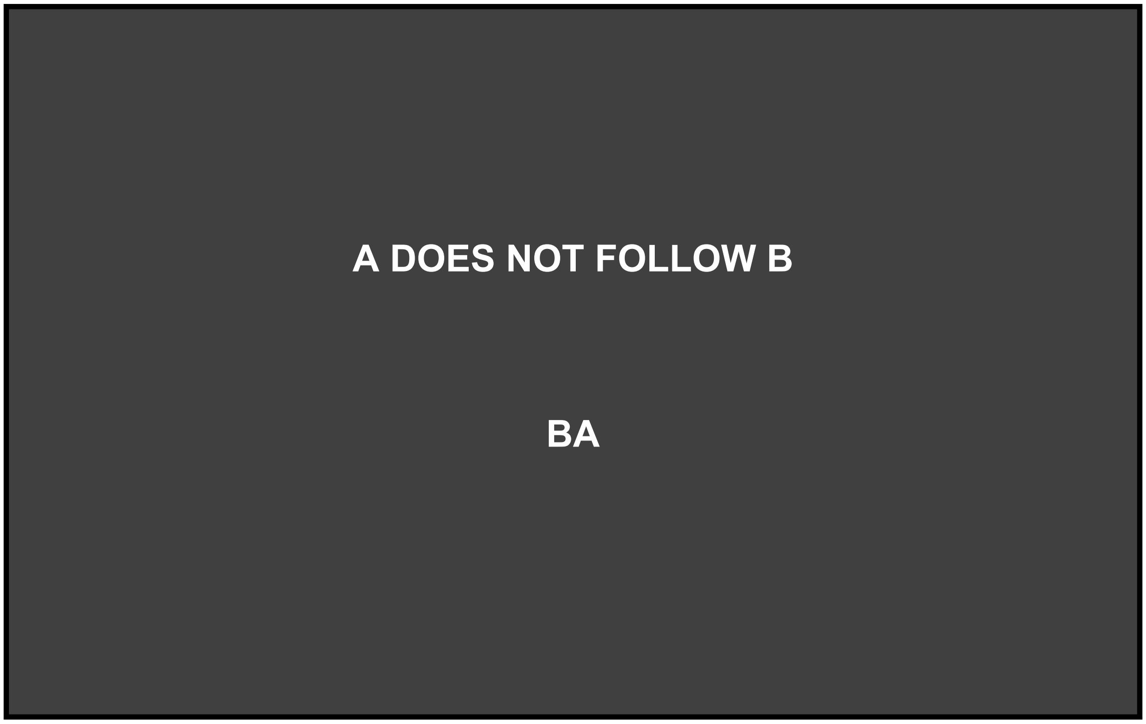
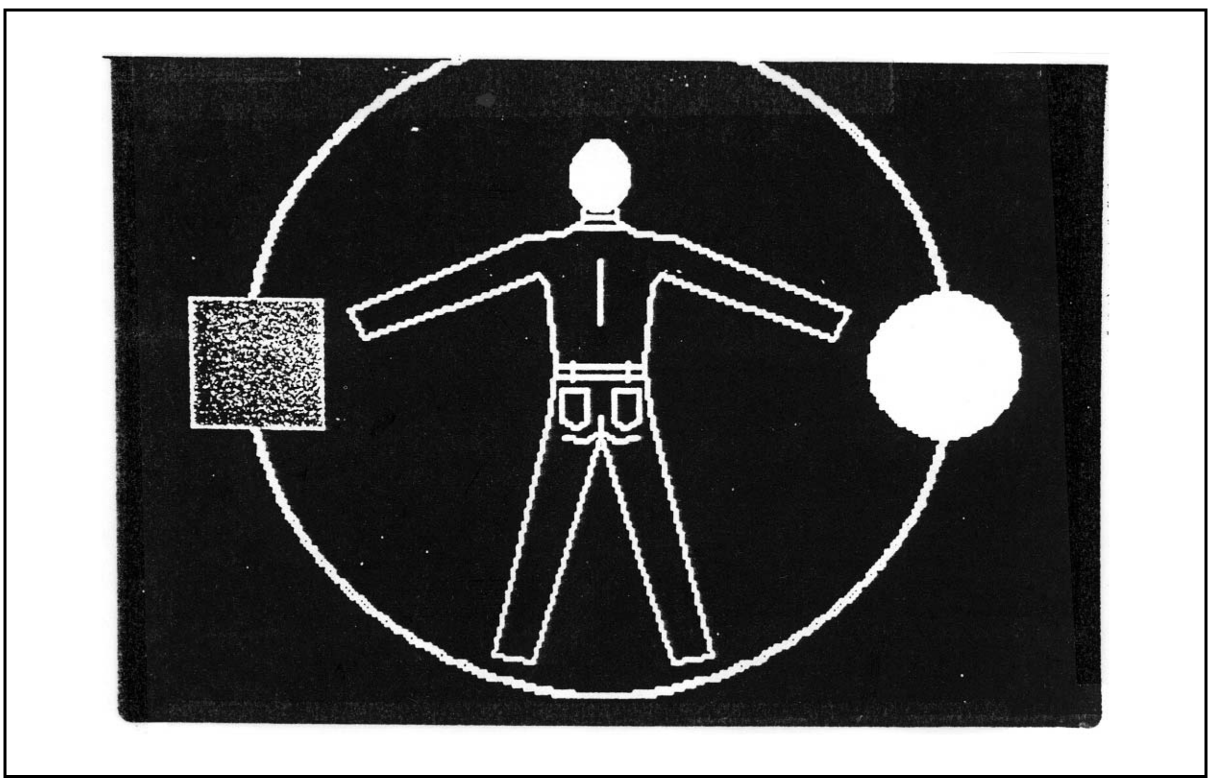


Figure 4.1-4: Mannikin Test



Mannikin Test - This task has been shown to be a sensitive spatial ability test. A mannikin is displayed on the screen facing forward or backward, and is either upright or inverted. In the mannikin hands are a circle or square (Figure 4.1-4). This figure is presented inside a square or a circle. The outside circle, or square, is the stimulus which dictates the way the subject is to respond. The subject's task is to determine which hand contains the outside symbol. When the mannikin is pictured inside a circle, the subject must enter an "R" or "L" depending upon which hand holds the circle. The fact that the mannikin is pictured facing forward or backward, upward or inverted increases the spatial complexity of the task. The duration of this task was 2 minutes.

Three computers were equipped each with a special timing board for the presentation of stimuli and recording of accurately timed responses, and the Performance Assessment Battery (PAB) software identified above. These computers were set up in each of the Area Control Centres (ACC) and towers as follows:

- two at the Toronto ACC and one at the Toronto Pearson tower;
- two at the Gander ACC and one at the Gander tower;
- two at the Moncton ACC and one at the Moncton tower.

The performance data collected during this study are valid and representative of the population sampled. These are field-based data and must be considered in light of this fact. Measures were taken to collect the necessary volume and quality of data for valid research results. This was achieved. However, the data are not comparitive to lab-based results, nor are they free of the typical confounding effects found in studies conducted in the operational field environment. Therefore, interpretation of the data must be cautious, and reflective of the field-based nature of the study.

For example, learning of the performance test battery tasks was not as complete as one would like, as would be expected for a lab study. Unfortunately for the field researcher, operational controllers are busy, work shifts, and have somewhat unpredictable workload schedules (i.e. they can not be pinned down to a specific time to practice the tests). Secondly, not all tests could be performed by some controllers, who due to work load had to skip one or more tests. This left our research team with some incomplete records, and threatened to reduce the sample size down to an unacceptable number.

4.2 Polysomnographic Sleep Data Collection

Sleep physiologic data were collected using the Healthdyne® Alice 3™ (DOS Version 1.15) computerised polysomnographic system with the Healthdyne® Calvin™ system amplifier unit -- a portable polysomnographic system found to have significant agreement with standard polysomnography (see Abstract in Appendix D). Data included standard measures used to allow detailed analysis of sleep physiology. All electrodes were surface style and were applied using hypoallergenic tape or gauze and electroconductive paste. Two EEG sites (C3, C4) were used to allow detailed analysis of sleep stages. Left and right electrooculogram (EOG) sites allowed the detection of rapid eye movement (REM) sleep. EEG and EOG electrodes were referenced contralaterally to the left and right mastoid bone (Al, A2) located behind the ear. Muscle tone was monitored by the application of two electrodes under the chin producing a submental electromyogram (EMG) signal. Electrocardiogram (ECG) electrodes enabled the monitoring of heart rate. Respiratory effort sensors for chest and abdominal movement and an airflow sensor allowed respiratory assessment and a body position sensor was also applied. The placement of electrodes and sensors is shown in Figure 4.2-1.

Polysomnography was used to allow objective assessment of both the quantity and quality of sleep obtained by controllers. EEG, EOG, and EMG are all necessary parameters to allow for accurate sleep staging. Although respiratory variables were not expected to be influenced by varying shift work-cycles in of themselves, respiratory recordings were collected to avoid erroneous conclusions of high spontaneous arousal rates since some arousals could be caused by changes in respiration.

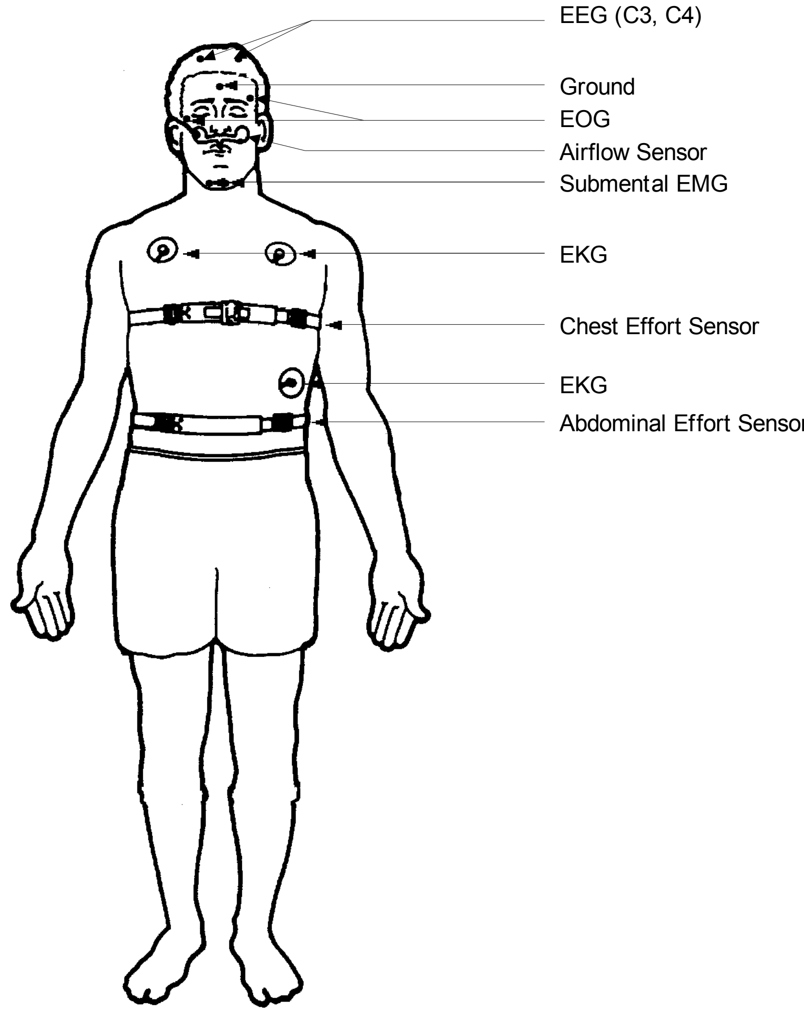
Data were analysed by a registered polysomnographic technologist using automated assisted scoring and the Alice 3™ software (DOS Version 1.18).

4.3 Physiological (EEG) Data Collection - Exploratory Data

To examine the question of how well both subjective and objective performance data reflect the underlying physiological state of the controller, EEG data were collected during the two primary work shifts where melatonin and sleep data were collected. For the controllers at the Toronto ACC and tower, the EEG were collected during the second and fifth midnight shift. The data collected from controllers at Gander and Moncton sites were incomplete and not usable. The recordings for the controllers working the Toronto consecutive midnight shift-cycle (MMMMM) were the only reliable data, where there were enough sessions containing acceptable signal strengths throughout the entire collection period. Fortunately, this shift-cycle was the most interesting from a circadian rhythm point of view.

EEG data were collected using the Oxford Medilog 8-channel 9000-series ambulatory system (frequency range of 0 to 35 Hz.). The Oxford system allows for the collection of 8 channels of physiological data for 24 hours on a cassette tape in a blocked analogue format on a sec-by-sec basis. For exploratory purposes, EEG data were collected using two recording devices with no other equipment. Because of this limitation, it was decided to collect only two channels of EEG data from controllers on two Medilog 9200 recorders using the same EEG configuration as the sleep data. The two EEG channels were acquired from electrodes pasted at C3 and C4 sites (see earlier description of sleep recordings) which were referenced contralaterally to the A1 and A2 sites on the mastoid bone behind the left and right ear. A reference (ground) electrode attached to the forehead. This restricted configuration offered minimal discomfort and was well tolerated by the controllers.

Figure: 4.2-1 Subject Hook up for Polysomnographic Monitoring



In consultation with the project's steering committee, the decision was made to collect the signals without the benefit of a playback system (to verify results) based on the past reliability of the system and the understanding that these data were exploratory in nature due to the small sample size and high probability of data loss. As this study was a unique opportunity to collect objective physiological data on air traffic controllers across a variety of shift regimens, the limited effort associated with the collection of the EEG data was considered justified.

Subsequent to the data collection period, access to a playback system was facilitated at the University of Ottawa and access to a scoring system (Stellate Systems software) was also made available. Unfortunately, the blind collection (no playback system available during collection) of the data resulted in significant data loss due to either undetected equipment failure or poor signal quality. The poor quality of the signals probably resulted from the attachment of electrodes to the scalp (no glue was used), and the calibration of the signal (calibration equipment could not be acquired on time). Glue was not used for the electrode attachment because electrode swapping had to be done between the ambulatory work periods (Medilog electrodes) and the sleeping periods (Alice 3 electrodes). The use of glue would have expanded the hookup times to unacceptable levels, resulting in less sleep time for controllers working quick-change shift-cycles. Also, some controllers had to be hooked up with the Medilog system on-site at the control centre or in the tower prior to their shift. Sometimes high traffic levels demanded that the controller help out, disrupting the hookup procedure momentarily.

The remainder of this section describes the data reduction system and the statistical analysis applied to the raw EEG signals. Since the results section will focus only on the data from the Toronto ACC and tower because only these data were sufficient for group analysis of trends, the data reduction description will use the midnight shift-cycle as the context for this description.

4.3.1 Data Reduction and Analysis

To score the collected EEG data, the blocked analogue EEG data on tape were decoded using an Oxford 9000 playback unit. The playback unit allows for playback of the tapes at real time and 20x or 60x real time. Playback at 20x real time facilitates rapid assessment of the signal quality of the data and artefact detection. The data reduction technique employed in this study was a multi-stage process in which each data segment was assessed for artefact prior to accepting the data. In this study, the basic units of analysis were 30 minute segments starting from approximately midnight and scored for as long as the data were acceptable. In most instances acceptable data lasted for about 6 hours or 12 segments or trials so that reasonable changes over the midnight shift could be assessed.

The first stage in the data reduction process was to transfer the data from the Medilog tapes to a computer for analysis. This was accomplished by playing back each 30-min segment at 20x real time with the output from the two EEG channels being acquired by custom hardware and software supplied by Stellate Systems of Montreal. Since the output from the Medilog playback unit is in analogue form, the Stellate Rhythm software utilised an A/D digital acquisition device which digitises the incoming analogue signal, after passing through a low-pass FIR 100 Hz filter and 60 Hz notch filter, with an effective sampling frequency of 256 Hz. These data were then submitted to Stellate's Rhythm software (version 10c) and Compressed Band Array analyses were conducted and plotted for a visual representation of power by frequency values in the various frequency bandwidths over time. Based on this analysis, peaks of high power in the traditional bandwidths of delta, theta, alpha, sigma and beta were identified and recorded. Using these peaks as a guide to identify areas in time that should primarily reflect power in specific bandwidths as well as identifying areas in time that revealed abnormal peaks, the 30 minute EEG segment was then visually inspected for artefact and for reasonable adherence to the identified power peaks for traditional bandwidths. In terms of artefact, the EEG data were assessed for general movement artefact (and electrode movement from head scratching), EMG tonic artefact (constant high frequency activity in the 20-60 Hz range), EMG phasic activity (periodic high frequency bursts), electrocardiogram artefact (ECG signal cross-talk on the EEG signal), 60 Hz noise, poor electrode attachment (flat line or low amplitude signals), sweat artefact (low frequency rolling), and elevated impedance (high frequency and/or 60 Hz activity).

Based on a reasonable coherence between the compressed band array analysis and the visual EEG data and the lack of artefact, the largest artefact-free period of EEG for each 30 minute period was submitted for power spectral analysis using the fast Fourier transform method. Across all scoreable 30-min periods, artefact-free samples ranged from approximately 2 to 20 minutes. The actual power spectral analysis is based on an epoch length of 2 seconds and the power in 0.5 Hz frequency bins was calculated for the frequencies between 1.5 Hz and 60 Hz. Thus, each 2 second window is analysed for the power in all frequency bins within that window and all available, continuous, artefact-free epochs are then averaged to produce the mean power in each artefact-free period. The 0.5 Hz frequency bins were then summed across the following traditional frequency bandwidths to produce the total power with the delta, theta, alpha, sigma and beta bands: delta - 1.5-4.0 Hz, theta - 4.0-8.0 Hz, alpha - 8.0-12.0 Hz, sigma -12.0-16.0 Hz, and beta - 16.0-30.0 Hz. To summarise, for each 30-minute segment the power within the delta, theta, alpha, sigma, and beta bandwidths were estimated using the mean of all available artefact-free, continuous periods with that 30-minute period based on the power in 0.5 Hz frequency bins over a 2-second epoch.

Based on these data a number of variables were calculated and analysed. These included the raw spectral power within each band, the relative power within each band based on the total spectral power for all frequencies, the mean frequency within each band based on the distribution of power values across each of the 0.5 Hz bands within the band (e.g., for delta this would be the mean frequency of the six 0.5 Hz bands between 1.5 and 4.0 Hz weighted by the power within each 0.5 Hz band), and the following 5 ratios: delta/alpha, theta/alpha, delta/beta, theta/beta, and (delta+theta)/(alpha+beta). The mean frequencies were calculated to asses whether the power within frequency bands systematically shifted across the midnight shift. The ratios were calculated because there is a significant amount of evidence to suggest that as drowsiness becomes stronger, the power in low frequency bands becomes more predominant relative to high frequency bands.

4.4 Activity Log

Appendix C contains an example of the pocket-sized paper log used to collect activity data. The subjects were instructed to start the log on a certain date (see schedule Figure 3.1-1 above) and continue entering information until it was completed. The log had codes which the controller used to indicate the times when he/she was engaged in certain activities. The codes were grouped as follows:

- Work Activities
  - ⇒ Brackets to be placed around the time when the work shift occurred;
  - ⇒ "O" to indicate an overtime shift, or work time beyond the normal shift time;
  - ⇒ "J" to show time spent on other job-type activities such as volunteer work or other part-time work;
  - ⇒ "R" for rest periods at work (breaks);

⇒ "Z" for travel to and from work;

- Sleep Activities
  - ⇒ ↓ to show when the subject goes to bed;
  - ⇒ ↑ to show when the subject gets out of bed;
  - ⇒ | at the beginning (the start of sleep) and end (when the subject awakes) of the sleep period;
  - ⇒ B indicates when the subject has to use the bathroom during the sleep period;
  - ⇒ N indicates when a noise occurs;
  - ⇒ W is used to indicate the method used to awake (alarm clock, wake-up call, naturally awake etc.);

- Leisure Activities
  - ⇒ L to show the time spent alone;
  - ⇒ F to indicate the time spent with friends or family;
  - ⇒ D was used for domestic work;
  - ⇒ R indicated errands;
  - ⇒ X to show when exercise occurred.

- Food and Drink
  - ⇒ M indicates when a meal occurred;
  - ⇒ S was used to show when the subject had a snack;
  - ⇒ an "A" was entered for each alcoholic drink;
  - ⇒ a "C" was entered for each caffeinated drink;
  - ⇒ a "T" was entered for each cigarette, cigar or pipeful of tobacco consumed.

The codes for leisure activities are entered in the blocks where they occurred, and vertical lines are used to show the start and finish of the period. The subjects were shown how to enter information on the timeline, and were encouraged to add comments about what kind of food they had for each meal, any unusual circumstances, or other information which could explain why certain codes were entered. For example, if they were having difficulty sleeping they could comment that it was too hot to sleep. Also, if a noise woke them up they could indicate the cause (baby, lawn-mower, spouse getting up, etc.).

4.5 Profiles for Individual Controllers

Profiles for each controller who took part in the study were prepared (see Appendix A for an example). The profiles were prepared to provide feedback to those controllers who participated in the project. The information given was a brief illustration of their sleep sessions and their performance during the Performance Assessment Battery (PAB) tests. Such information gave individuals a snapshot of their own results, which they may compare to the overall group results described in a summary report, which they also received at a later date.

Two levels of profiles were prepared, containing information on sleep sessions, performance results, and actigraphy plots (where available) for those who participated in the complete integrated protocol, or just the performance results and actigraphy plots (where applicable) for those who only completed logs and participated in the PAB tests.

4.6 Melatonin Data Collection

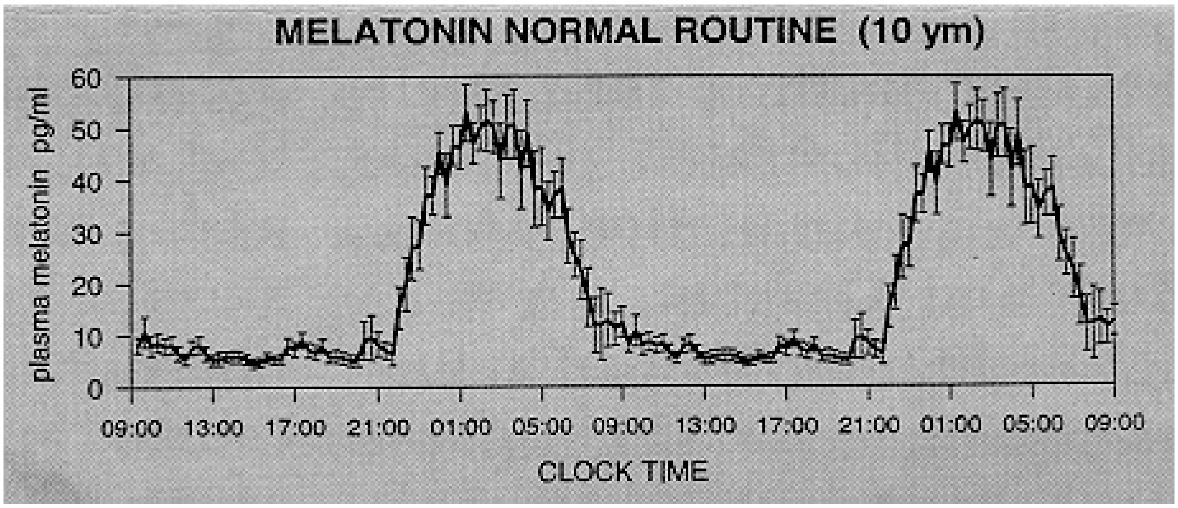
4.6.1 Procedure

In an attempt to better understand whether any shift in circadian rhythm is associated with working a prolonged night period, an attempt was made to examine changes in basic circadian rhythms by examining changes in melatonin production overnight for the air traffic controllers at Toronto who worked 5 consecutive midnights. Additionally, urine was also collected from controllers at Gander and Moncton for comparison purposes.

The usual circadian rhythm for melatonin is that it is low during the day (as light suppresses the production of melatonin by the pineal gland) and begins to rise during the evening peaking overnight when one is asleep (see Figure 4.6-1 below). This pattern is maintained in night shiftworkers (Folkard, 1996), however, even though they do not sleep at night. Folkard (1996) also reports that endogenous indicators (such as melatonin and body temperature) do not easily shift, whereas exogenous indicators show significant shift (e.g. heart rate, blood pressure etc.). What this means is that the body does not readily adapt to night-time work. The objective in the current study was to examine whether the circadian rhythm of night shiftworkers working consecutive midnight shifts would become phase-shifted (change from a diurnal wake/sleep cycle to a nocturnal cycle) and show adaptation to their night work, as occurs in many other jobs. Since the theory, that we adapt to night work, seems prevalent in the general population of night workers, it was worth pursuing whether this adaptation actually occurs in air traffic controllers working midnights.

To accomplish this goal, 24-hour urine collections were gathered during the same 24-hour period in which their sleep data were collected and included their sleep period. Specifically, urine collections were done to incorporate their baseline sleep period and the two subsequent sleep periods on Day 2 and Day 5. For the 24-hour baseline period, urine was collected in 3 samples from 1500h-2300h, 2300h-0700h, and 0700-1500h. Since controllers were normally asleep in the overnight period during this phase of the study, only a single overnight sample was collected. During the 2 remaining periods of the study, controllers were working overnight and the overnight period was divided in half for the collections yielding 4 samples. Specifically, samples were gathered from 1500-2300h prior to their shift, from 2300h-0300h and 0300h-0700h during their shift, and from 0700h-1500h during their subsequent sleep period. If working consecutive midnights resulted in phase-shift in their circadian rhythm, it would be expected that melatonin would become more abundant in their urine during the between 0300h-0700h of their shift on the second work night (Night 4) compared to the first work night (Night 1). Similar periods of urine collection were used for the controllers in Gander and Moncton. While systematic shifts in circadian rhythms were not expected in these groups, their circadian rhythms may have been disrupted because of their unusual shift routine and this study afforded on opportunity to examine any disruption in circadian rhythms in these groups of controllers.

Figure 4.6-1
Usual Circadian Rhythm for Melatonin



from: Monk, T.H. (1994) Circadian Factors and Travel. *Sleep Medicine Review*, **2**, 5., p. 1-2.

The collection for the Gander Moncton subjects followed the same schedule over the 24 hour period, but the work day collections were carried out on different days during the shift-cycle. For the Gander subjects (except the two that worked a double quick-change shift-cycle - they followed the same collection days as Moncton), the collection occurred as follows: the first work-day collection occurred between 15:00 of the afternoon prior to the midnight shift through to 23:00, the second from 23:00 to 03:00, the third between 03:00 and 07:00, and the fourth between 07:00 and 15:00; the first collection for the next work day occurred immediately after the first day's collections, at 15:00 that day to 23:00 (during the night shift which runs from 20:00 to 04:00), the second from 23:00 to 03:00, the third from 03:00 to 07:00, and the fourth from 07:00 to 15:00. This collection, therefore, was conducted over a consecutive 48 hour period.

The Moncton collections were conducted as follows: the first work-day collection from 15:00 to 23:00 prior to the sleep during the first quick-change (between the evening and day shifts), the second from 23:00 to 03:00, the third from 03:00 to 07:00, and the fourth from 07:00 to 15:00.

4.6.2 Data Collection

Melatonin secretion from the pineal gland was estimated by measuring 6-Hydroxymelatonin sulphate, aMT6s, from urine. 6-sulphatoxymelatonin is the primary metabolite of the pineal hormone melatonin and provides an accurate reflection of melatonin production which has been validated in both humans and rats. The measurement of aMT6s is a valid alternative to blood melatonin to study pineal gland activity and is preferable to blood samples in field settings.

In this study and as detailed above 11 urine samples were collected from each controller over the 3 24-hour periods. (Missing data were due to either failure to void during the period of collection or failure to comply with instructions.) All urine samples were measured for volume and the volume was recorded in order to correct the amount of aMT6s that would later be determined for the volume of urine. Following the volume measurement, 10 ml were put into test tubes for later analysis, labelled, and refrigerated. All samples were shipped to the laboratory of Dr. Greg Brown at the Clarke Institute of Psychiatry for analysis.

The laboratory analysis of aMT6s was done by radioimmunoassay using kits supplied by CIDtech Research Inc. of Mississauga. (Details of assay procedures are available from the authors of this report, Dr. Brown or CIDtech Research Inc.) In summary, aMT6s determination by radioimmunoassay depends on the competition of aMT6s in urine and ^{125}I-labelled aMT6s for a limited number of high affinity binding sites on CIDtech ultra-specific aMT6s antiserum. The amount of radioactivity bound to the antiserum is inversely related to the amount of aMT6s present in the urine. When the system is in equilibrium, the antibody free aMT6s is absorbed with charcoal. The precipitate is counted by a gamma counter. Quantification of unknowns is achieved by comparing their activity with a response curve prepared using known standards. Sufficient sheep anti-aMT6s antiserum is supplied in each kit to assay 150 tubes of urine or approximately 60 samples in duplicate. In this study all samples were analysed in duplicate. The amount of aMT6s is measured and corrected for urine volume (based on supplied and known standards) resulting in aMT6s measured in ug/ml.

5.0 RESULTS

The results section is organised in the following manner:

1. Performance Results
   - ⇒ percent of change in individual tests and combined performance from the start to end of **each shift** (across each shift)
   - ⇒ amount and nature of the change in performance for each **shift-cycle type**
   - ⇒ amount and nature of the changes in **subjective indicators of fatigue**
   - ⇒ relationship of performance with other factors such as age

2. Results of Analysis of Polysomnographic data
   - ⇒ mean duration of sleep for baseline sleep, first work sleep, and second work sleep for **each shift-cycle type**;
   - ⇒ descriptions of quality of sleep (number of disruptions, distribution of sleep stages, sleep efficiency, sleep latency) for **each shift-cycle type**;
   - ⇒ average sleep duration for baseline sleep, first work sleep, and second work sleep for **each age group and younger vs. older controllers**;
   - ⇒ comparison of log sleep data and actual scored sleep data;
   - ⇒ comparison of sleep on days off to those on shifts.

3. Physiological (EEG) Data Results - Exploratory Data
   - ⇒ EEG waveform analysis examining low frequency and high frequency activity for the Toronto midnight shift-cycle group - gathered using portable Oxford Medilog

4. Results Log Data Analysis
   - ⇒ comparison of activities on work days vs. days off

5. Melatonin Data Analysis Results
6. Overview of Shift Cycle Effects - Summary
   - ⇒ description of "typical" problems and effects experienced by controllers working the shift-cycle type

5.1 Performance Results

These performance data should be considered to be conservative estimates of the actual degree of performance impairment due to procedural limitations. The tests typically obtain data which are underestimates of differences in performance. Where small differences occur in the data, larger actual differences are probably existent in actual operational tasks involving the same type of cognitive activity (Thorne et. al., 1985).

The interpretation of the performance results should consider the fact that the study was carried out in field conditions. Since maintaining ATC systems safety was the priority, subjects could only participate in the study when they could be relieved from duty. Most did, however, participate at the appropriate times. The PAB had to be practised at work during work hours, resulting in limited opportunity for training. Finally, the tests were self-administered. Therefore, subjects were free to choose when they would complete the testing within a given 1 hour window of opportunity. They could, then, choose an optimal time, when they felt more refreshed, to do the tests. For example, a controller might choose to do the test at 03:30 rather than 03:00, because they may have felt less motivated at 03:00. It was decided that the controller must have this control to ensure that operational safety was maintained. These situations led, in some cases, to the loss of data and incomplete learning.

The collection of data for some subjects was incomplete due to the reasons described above. Therefore, some subjects had missing data from a single trial, while others may have missed an entire shift because they were ill that day or for some other reason. Any comparative statistical analysis requires that data exist for all trials for all subjects. If even a single data point is missing, that subject's entire data-set is removed from the analysis since this is a within subject experimental design. This reduces the number of subjects considerably, and effectively eliminates any value in performing the analysis.

Five subjects missed one shift entirely, one missed two shifts, and six subjects had missing data from the Mannikin test during a single trial. Thirty-one subjects missed one or more trials, fourteen of these individuals missing more than two trials. Missing data is a common problem in field research where critical operations are involved. If a controller could not work the shift, or if operations were busy enough to warrant skipping the trial, the controller was given the freedom to do just that. It was absolutely necessary to have a mandate that stated that the study must be as unobtrusive as possible, and that it never compromise the safety of the operation or public safety.

It was determined that the inclusion of data taken from the subject's completed adjacent trials, as replacement for the missing data fields would represent the subject's performance well enough to include that individual in the analysis. After adding the data, comparisons were made between the data-set containing missing data, and that of the new data set including the additional data. Most of the data (about 98%) were within a 5 % difference. The differences were often consistent with the existing trends in the data and only a very few departures from the original data were found.

There were three instances where the difference was over 5%: two instances for the forward rotating cycle where there was a 10% difference between the old and new data occurred (the last trial of the shift for Pattern Recognition Tests, and the last trial of the second last shift for the Mannikin Test); another instance, in the double quick-change shift-cycle involved a difference of only 6%, and occurred during the second trial of the fourth shift for the Mannikin Test. Since most of the data remained similar, it was decided that the new data set be used for the analysis.

Actual performance results for the throughput data, which are the number of hits (correct responses) per minute, can be found in Appendix B of this report. This representation shows how controllers performed, but does not control for their learning during the tests. Training was included and practice was encouraged, but was not always completed as required. The resulting learning curve seen in the graphs in Appendix B illustrates this. It was decided that control over these learning effects was required to make better sense out of the data, and reduce the confounding effect of the learning which was obviously going on during the testing. The method which seemed most appropriate was to make the first trial of each shift as a baseline and calculate the percent difference for trial 2 and three of each shift. If learning persists within each shift then performance would still increase over the shift. If, on the other hand, shift effects predominated, then effects would be more clear.

Sub-section 5.1.1 contains the graphs using this percent difference as a measure of the performance change occurring in each shift. The graphs are presented with the three trials per shift grouped so that five separate sets of trials are shown (i.e. - [1,2,3]; [4,5,6]; [7,8,9]; [10,11,12]; [13,14,15]). Refer to these graphs for the effects of specific shifts on performance. It is important to consider the change over the shift when determining how the shift is affecting test performance. For example, if there is a increase in performance through to the end of the shift, it is possible that learning is still occurring.

Sleepiness, fatigue and activity scales are reported in sub-section 5.1.2.

The data is presented for each shift first, followed by comparative graphs which appear near the end of this section (5.1).

5.1.1 Percent-Change Results for All Performance Tests

An analysis of variance performed on the new data set shows significant shift (first, second, third, fourth, fifth) and trial effects (1 to 15) for the mannikin test, sleepiness and fatigue ($p<0.05$), and a significant interaction between shift and trials for all tests (although the interaction is weak for pattern recognition). These results apply to all of the shift-cycle types and should be considered with respect to the results given below.

Figures 5.1.1-1 to 5.1.1-5 give the performance results for each of the five shift-cycle types.

The performance data for the Midnight Shift-Cycle, shown in Figure 5.1.1-1, show the adverse effects of the building chronic sleep debt which is evident in the sleep data (see section 5.2.9 below). The impairment in performance is most striking for the reasoning and visual/spatial tasks, and seems to develop progressively over the shifts with the exception of the last performance data collection period at the end of the experiment. However, performance seems to be worse in the middle of the shift with some recovery in the morning test (at the end of each shift).

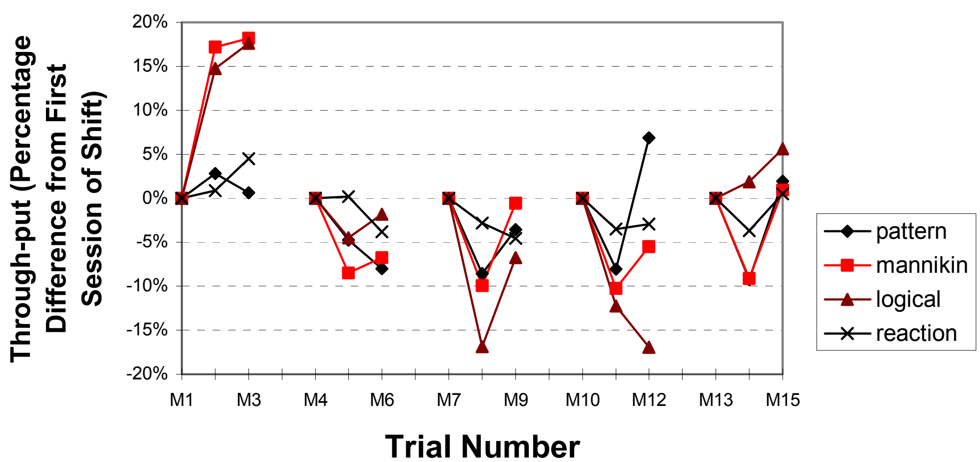
If all sleep periods for the five day shift-cycle are considered, as the analysis of the logged sleep data below shows, controllers working the midnight shift-cycle got much less sleep than the other shift-cycles. This reduction in sleep results in a sleep debt which often explain the fatigue effects. The data in section 5.2.3 below also shows that the last day sleep monitored showed a pattern consistent with the repayment of a serious sleep debt (higher levels of Slow Wave Sleep and REM sleep).
There were marked drops in performance during the last three shifts at the mid-point in the shift. In other words they did more poorly in the middle of their night shift, about the time

when the circadian rhythm was at its lowest (03:00). The circadian effect appears to be a more important factor in the case of night work. There seems to be a consistent pattern of lowered performance during the middle of midnight shifts (also seen in the Gander and Double-Quick-Change midnight shifts). This mid-shift drop may be reflecting the lowered alertness which controllers often complain about during this time of the night shift (~0:300 - 04:00). Logical reasoning is degraded the most, particularly on nights three and four, and this task represents the most difficult cognitive task. The improvement in performance following this dip may be due to some increased arousal occurring at the end of the shift, which may be motivational, related to a circadian upswing, or a combination of both.

The last midnight shift departs slightly from the general pattern in that logical reasoning improves throughout the shift, showing definite improvement by the third trial of the night. Either performance is being impacted by the psychological effect of knowing that this is the very last time these tests will be performed, or that their improvement is a result of the fact that the midnight shifts have ended for another few months. However, both the visual/spatial and psychomotor tasks continue to show performance impairment in the middle of the last shift.

Figure 5.1.1-1

Changes in Performance Over Individual Shifts of a 5 Midnights Cycle



The Gander shift (ESDMN) shows performance levels dropping during the last two shifts (see Figure 5.1.1-2). This is consistent with the nature of an acute sleep debt which occurs on the last two shifts due to both circadian effects and shift schedule effects. The sleep between the third and fourth shift is an evening sleep which is typically very short and of poor quality (see section 5.3 below). The shift following this sleep is a midnight shift, in fact the only one in the cycle. Performance decrements occur during this midnight shift, showing the same "V"-shaped pattern we see in the midnight shifts of the Midnight Shift-Cycle (MMMMM).

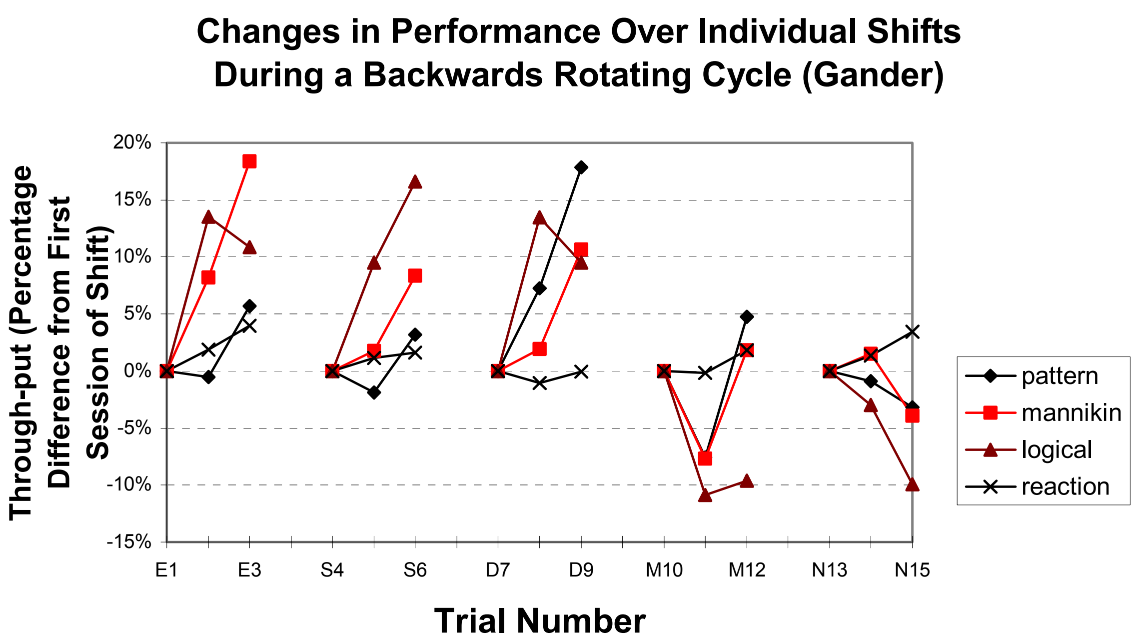
The first two shifts (evening and swing) allowed two sleeps at the beginning which were of similar length to the sleep obtained on days off. The third night sleep (between the swing and the day shifts) was the beginning of the sleep restriction due to the early morning start. Hence, performance shows a drop after this day shift, and continues to degrade through to the end of the cycle.

The day sleep following the midnight shift further contributes to the sleep debt, resulting from its short duration and poor quality. Performance reflects this as seen in the fifth shift's performance results shown in Figure 5.1.1-2 below. In addition to experiencing some degree of sleep deprivation, controllers are also working during normal sleeping hours during the final two shifts, which may contribute to the observed performance decrement.

Note that all three cognitive tests are affected and show similar decrements on the last two shifts.

Reaction Time changes very little over each shift and from shift to shift.

Figure 5.1.1-2



A progressive decrease in performance occurred toward the end of each shift for controllers working the double quick-change shift-cycle, particularly during the last two shifts (day shift and midnight shift). Again, the characteristic "V"-shape seen in the midnight data <u>did</u> show up in the last shift (midnight shift) of the double quick-change data for reaction-time and visual/spatial tests, although the visual memory and the logical reasoning tasks continued to decline.

Figure 5.1.1-3

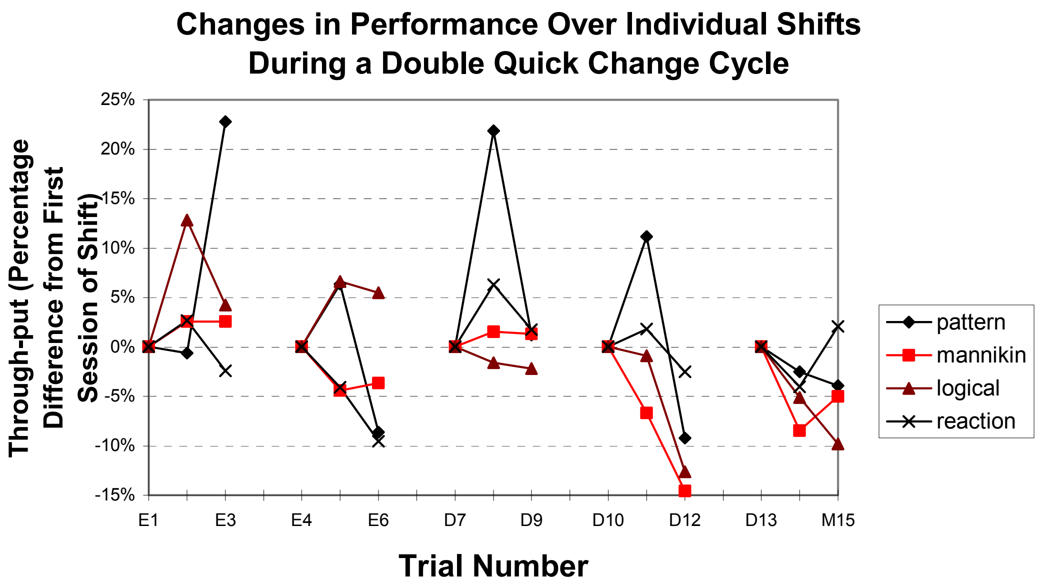
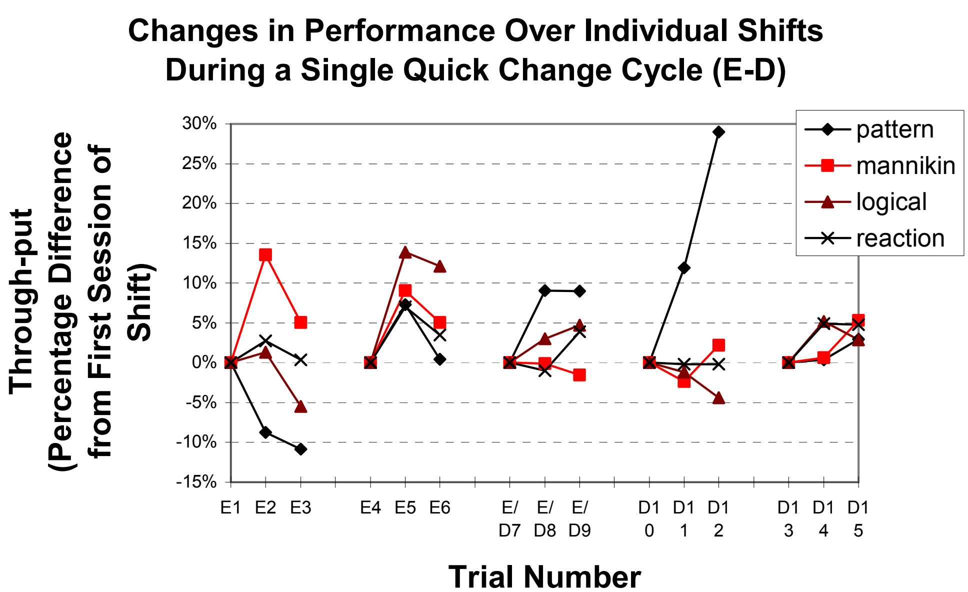


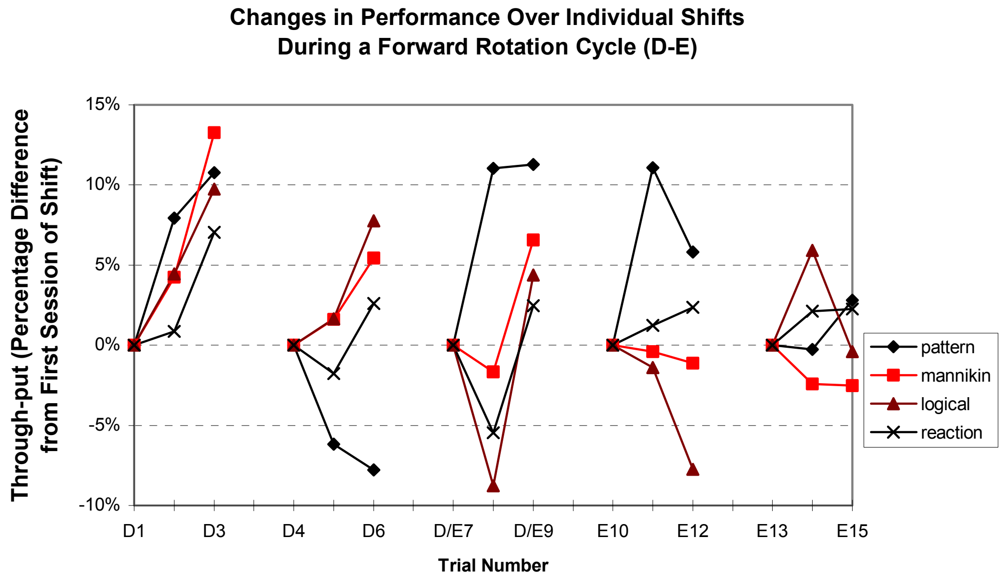
Figure 5.1.1-4



The decrements seen in the last two shifts of the double quick change cycle show that a possible acute sleep debt, combined with circadian effects may be affecting performance. Analysis of variance of the Shift differences (from shift to shift through all five days) shows a strong effect ($p<0.01$) indicating that these decrements across shifts may be a functional trend.

As can be seen in Figure 5.1.1-4, little progressive deterioration across shifts occurred and no “V” shaped pattern is evident in the single quick-change shift-cycle data. Figure 5.1.1-5 shows that there was some deterioration in some tasks over the forward rotationg shifts but that the magnitude was small and the task results somewhat inconsistent.

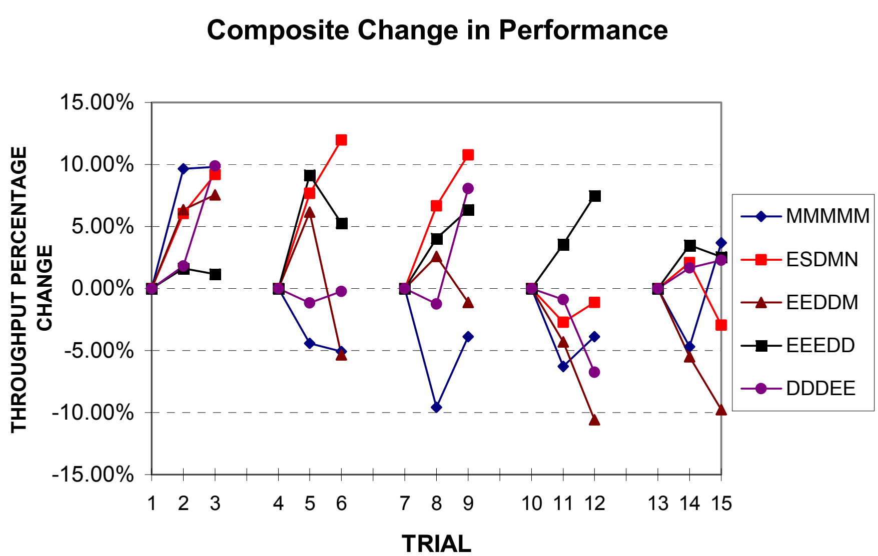
Figure 5.1.1-5



5.1.2 Composite Change in Performance for All Shift-Cycles

Figure 5.1.2-1 shows the overall performance change from the first trial of each shift.

Figure 5.1.2-1



In these data all tasks are averaged together. Generally the midnight shifts show the most consistent decrement between 5 to 10% starting on the second shift, although the double-quick-change shift schedule shows a greater decrement later in the 5-day cycle. Quick changes from evening to day shifts (see in the EEEDD and ESDMN shift-cycles) show performance increasing dramatically and steadily from the first trial of the day shift to the last trial of the day shift (within the shift). This may be indicative of a performance decrement at the start of the day shift as the body may still be in the sleep phase. As the day progresses, the performance improvement may be due to the circadian rhythms cycling into the peak period of physiological readiness for activity, matching the body's actual state.

5.1.3 Sleepiness, Activity and Fatigue Scales

Figures 5.1.3-1 to 5.1.3-5 illustrate the perceived sleepiness, activity and fatigue over the course of the shifts throughout the five days for the cycle. The graphs reveal a strong correspondence between fatigue and sleepiness. This indicates, among other factors, an honest response from the subjects. The fatigue and sleepiness scales also follow the expected patterns seen in the performance data. For midnights we see an increase in sleepiness and fatigue throughout the shift and a decrease in activity levels. Unlike performance data, no "V"-shape in the data is evident which indicates that although the controllers felt sleepy and fatigued at the end of each shift, enhanced motivation during testing probably led to the enhanced performance.

But the Gander and the Double Quick-Change data seem to indicate a later development of fatigue and sleepiness, and reduction in activity, than in the midnight shift. Also, the levels of fatigue and sleepiness were lower than those of the midnights group, and activity was higher for controllers in Gander and Moncton. For the Single Quick-Change little change is evident, however, it is noteworthy that sleepiness and fatigue were higher following the quick change to a day start. Perhaps the time of day for the early start contributed to this result. Relatively little change occurred for the forward rotating D-E cycle. Unlike other shift cycles, controllers working a days-to-evenings work cycle report the highest level of sleepiness during the first trial, suggesting their routine during days off may have resulted in poor adaptation to morning work. Many of those interviewed in Phase One self-reported that they found the early start on the day shift very difficult (i.e. they felt tired and lacking energy).

Figure 5.1.3-1

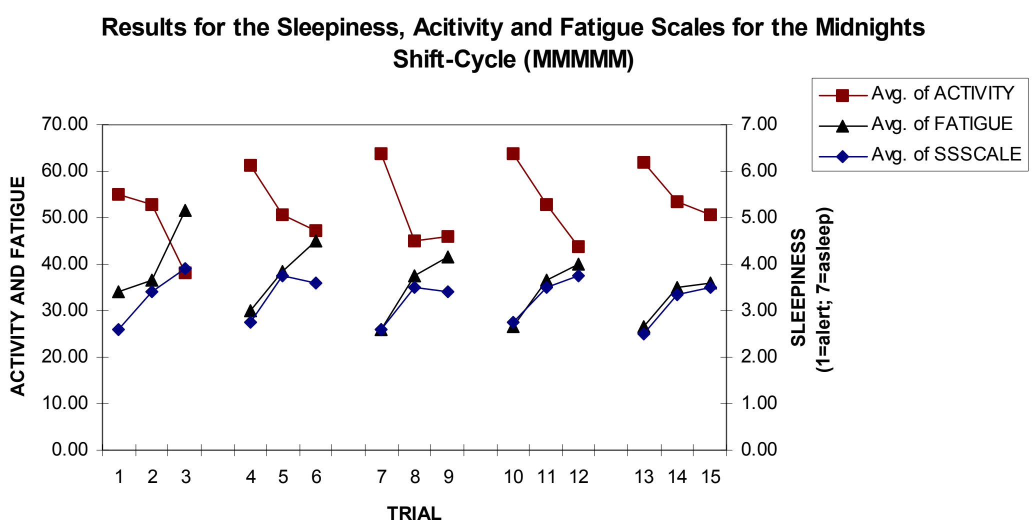


Figure 5.1.3-2

Results for the Sleepiness, Activity, and Fatigue Scales for the Gander Shift-Cycle (ESDMN)

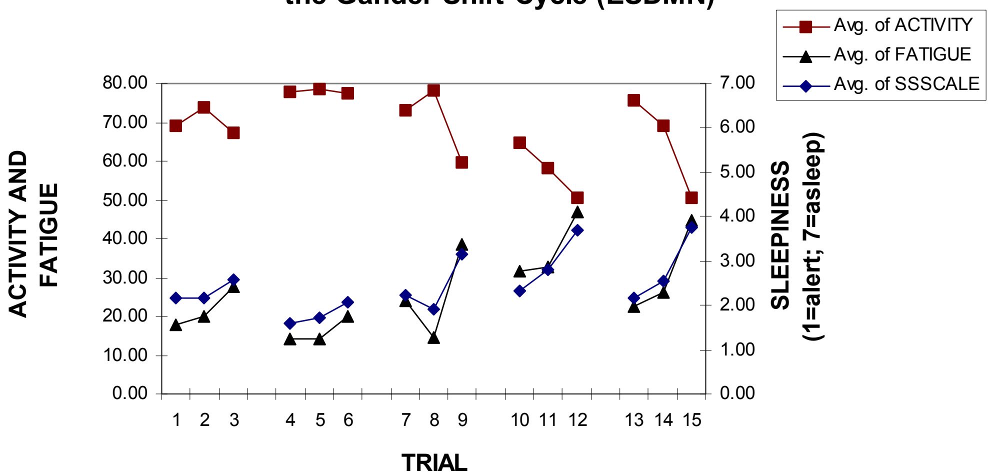


Figure 5.1.3-3

Results for the Sleepiness, Activity and Fatigue Scales for the Double Quick-Change Shift-Cycle (EEDDM)

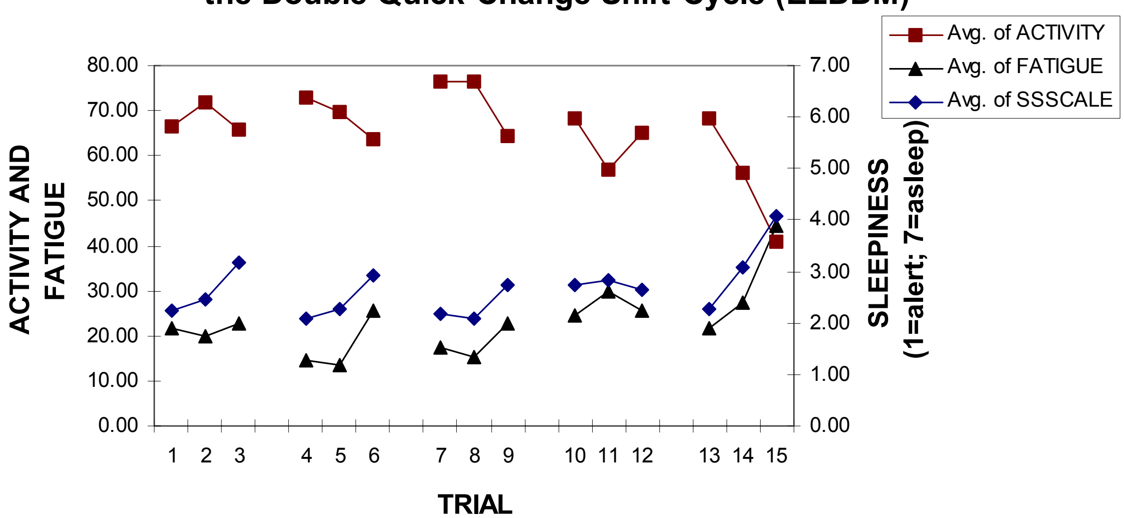


Figure 5.1.3-4

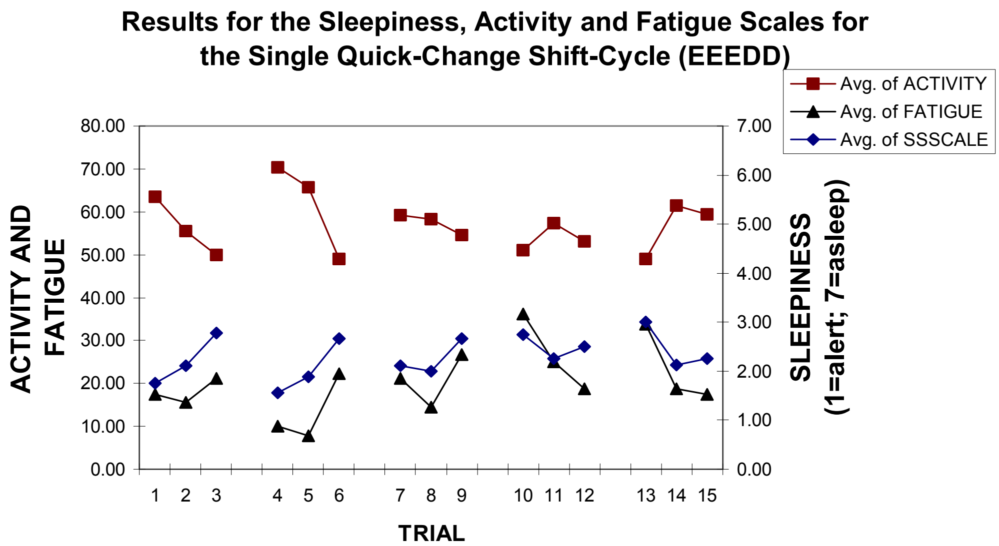
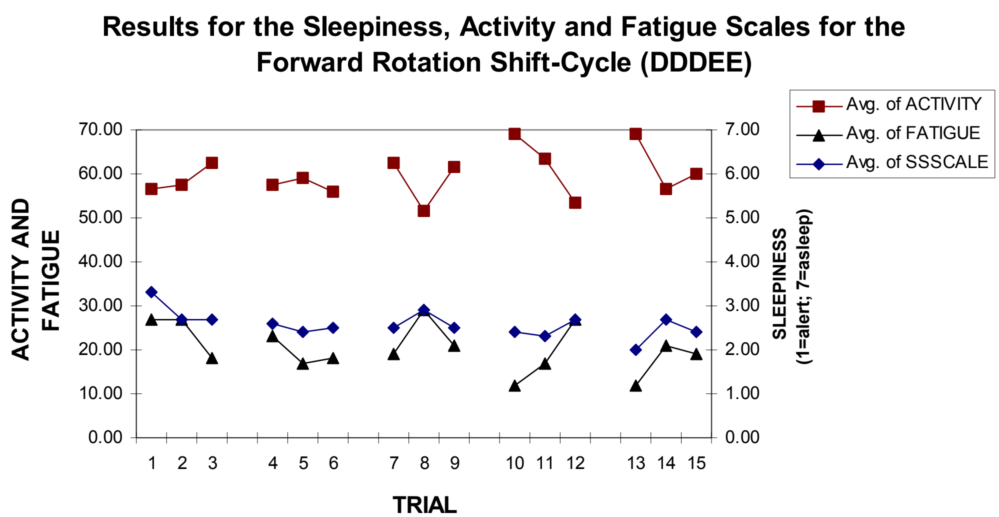


Figure 5.1.3-5



5.1.4 Performance and Age

The following graphs (Figures 5.1.4-1 to 5.1.4-5) illustrate the differences in performance for the younger versus the older controllers. Generally, older controllers do perform at lower levels than the younger controllers. However, it should be noted that this type of result is consistent with other data on experiments conducted using novel tasks, where older subjects indeed do show a decrement in performance (Salthouse, 1991). However, the air traffic control experience may more than offset the observed cognitive decrement, and may result in higher levels of actual job performance compared to less experienced controllers. But, it should be noted that higher levels of sleepiness (see Figure 5.1.4-5) are reported by the older controllers.

The older controllers may be having to work harder to maintain levels of performance, possibly dealing with more fatigue than younger controllers. Certainly, the difference is not large between the performance of younger versus older controllers, and only indicates a trend which should be considered in light of the physiology, sleep monitoring and log data. It is likely that less sleep and prior activity are factors in these declines and increased levels of sleepiness seen in the data for the older controllers. The trend may point at a need for more vigilance on the part of older controllers to ensure that they get their sleep and that they be aware of the effects of their cognitive state while working particularly disruptive shift schedules.

Figure 5.1.4-1

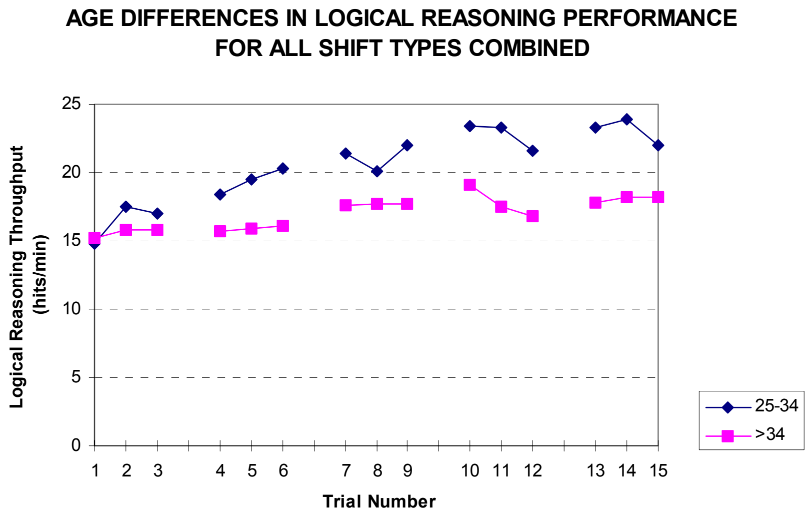


Figure 5.1.4-2

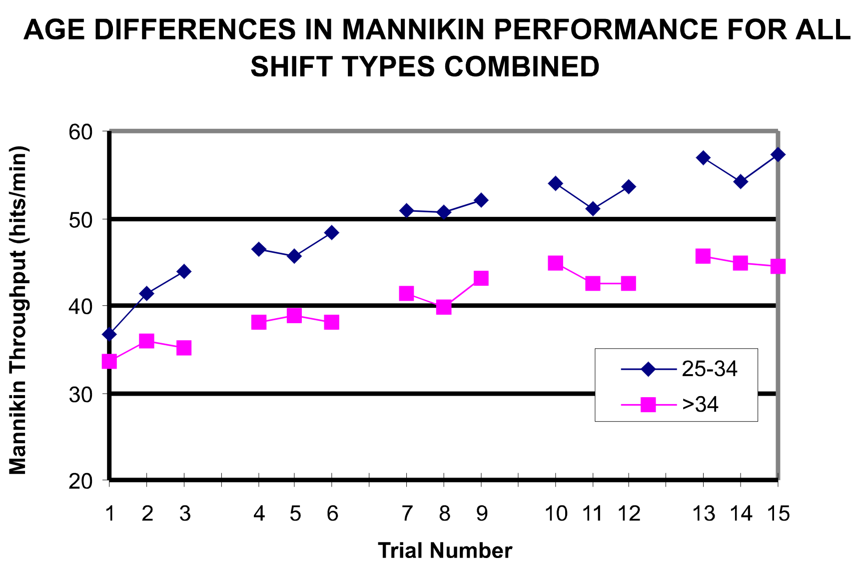


Figure 5.1.4-3

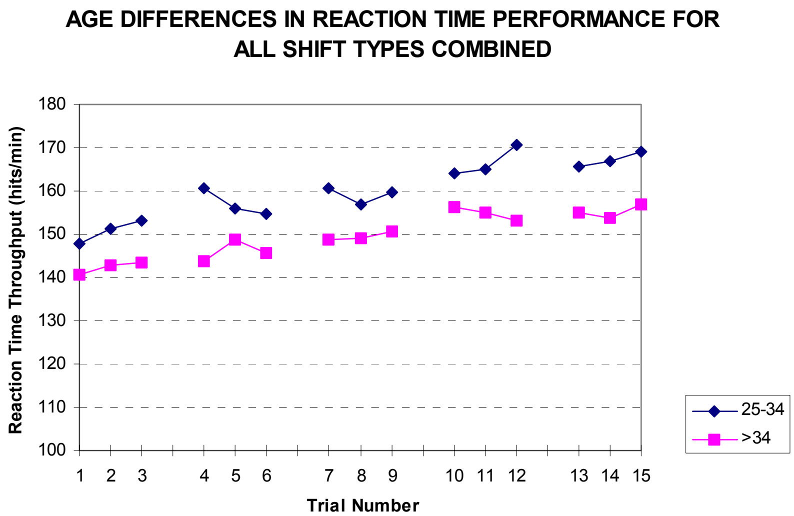


Figure 5.1.4-4

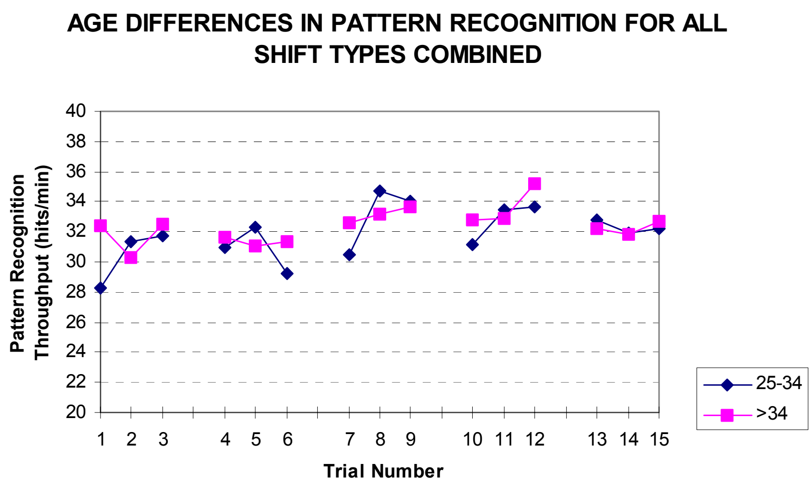
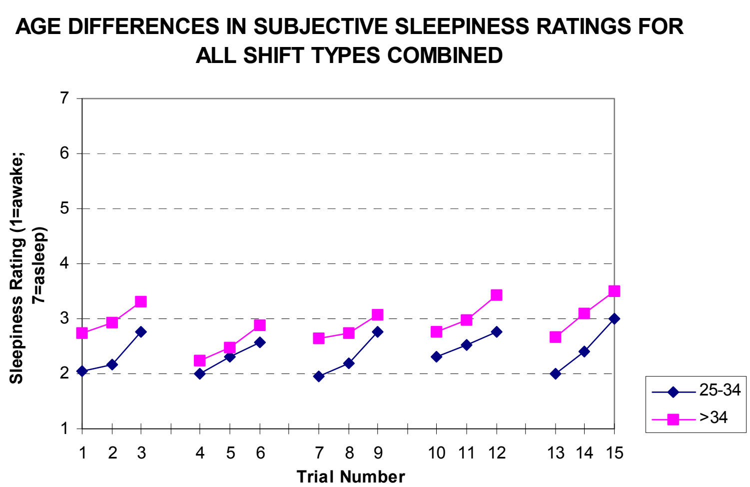


Figure 5.1.4-5



5.2 Results of Analysis of Polysomnographic Data

Specific data collected during the polysomnographic sessions were examined, including the following information for each of the three sessions for each controller:

- total time in bed,
- total sleep duration,
- sleep latency (measured for each sleep period),
- percent of REM and Slow-Wave Sleep,
- percent of all stages of sleep,
- sleep efficiency,
- arousals per hour,
- hypopneas and apneas per hour.

The following specific comparisons were conducted:

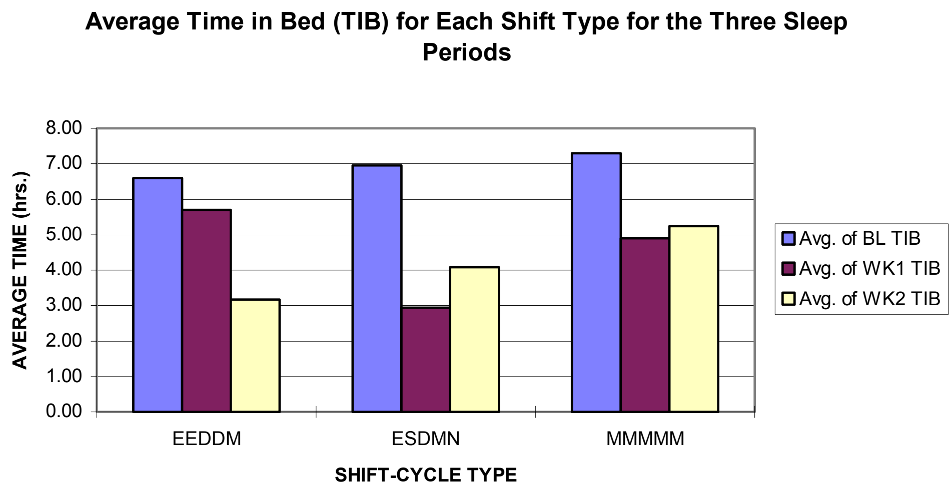
a) distribution of hours of time in bed for baseline sleep compared to work sleeps for each of the shift-cycles;
b) distribution of hours of total sleep for baseline sleep compared to work sleeps for each of the shift-cycles;
c) distribution of the stages of sleep for baseline sleep compared to work sleeps for each of the shift-cycles;
d) distribution of REM and slow-wave sleep for baseline sleep compared to work sleeps for each of the shift-cycles;
e) distribution of sleep efficiency and sleep latency for baseline sleep compared to work sleeps for each of the shift-cycles;
f) distribution of hypopneas, apneas, and arousals per hour for baseline sleep compared to work sleeps for each of the shift-cycles.

Please refer to figure 3.1-1 for the data collection schedule, explaining when the baseline, first work sleep and second work sleep were collected at each location.

5.2.1 Time in Bed

Time-in-bed (TIB) was measured to determine the sleep latency. All shifts had approximately the same amount of time-in-bed for the baseline measure (between 6.75 and 7.25 minutes). There were, however, significant differences between all shift-cycle types for the time-in-bed for the second and third work sleep periods. This is expected since the midnight-cycle (MMMMM) first work sleep is a day sleep, while the Gander (ESDMN) session for the first work sleep was during the evening, and the Double quick-change (EEDDM) first work sleep is a night sleep. The average time-in-bed for each shift cycle for each sleep period recorded using the polysomnographic data collection method is shown in Figure 5.2.1-1. According to the sleep recorded on the three days that controllers were monitored using the equipment, the midnight work cycle shows a slightly higher time-in-bed and actual sleep than in the other two work-cycles, with the exception of the EEDDM first work sleep. However, if the log data is used to represent sleep over the entire shift-cycle, midnight shifts show a markedly lower length of times-in bed, overall for the 5 sleep periods during the shift-cycle (see section 5.2.10 below).

Figure 5.2.1-1



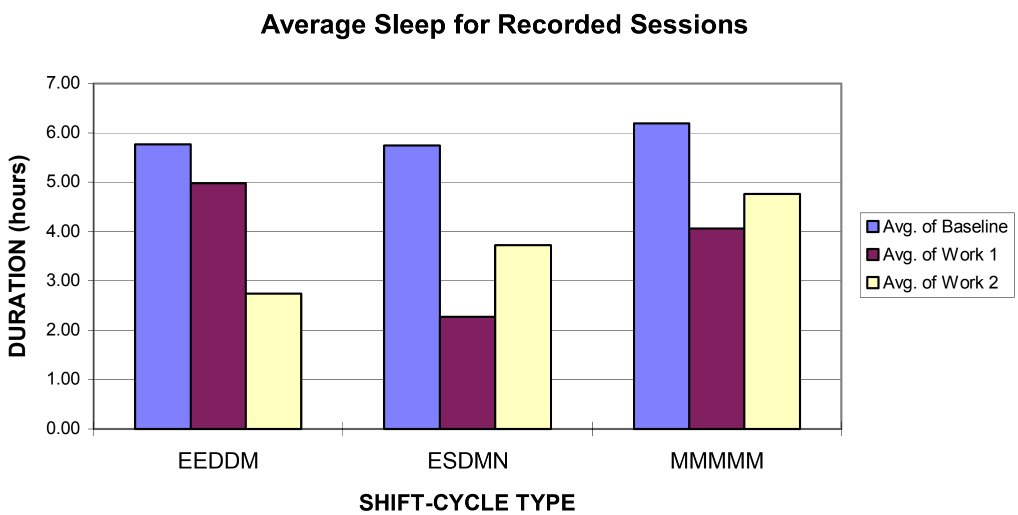
5.2.2 Total Sleep Time

The baseline total sleep is virtually the same for all of the shift-cycle types in the sample. The duration during the first work sleep, and during the second work sleep differ significantly for all shift-cycle types, as was seen for the time-in-bed described in the previous sub-section. The longer duration for the first work sleep in the double quick-change shift-cycle is more than twice the length as that for the Gander shift. The day sleep for the Double Quick-Change shift cycle subjects shows that this sleep period is poor for them, resulting in less than two hours sleep on average. This sleep period seems to be of reasonable quality, showing SWS and REM proportions similar to the baseline sleep, within the normal range. The short duration, however, results in an acute sleep loss which would affect performance if a controller was to work an overtime shift following this sleep period (e.g. an evening or midnight shift). The fact that performance decrements occurred during the midnight shift after this short sleep period, may indicate a direct relationship between reduced sleep and resultant poorer performance as the shift progresses.

The sleep recorded for each monitored sleep period for each shift-cycle is shown in Figure 5.2.2-1. The subjects working consecutive midnights averaged more sleep during the baseline and the second work sleeps than those working double quick-changes or the Gander shift-schedule. It is clear that afternoons or evenings are poor times to sleep. This time of day seems to result more in napping than actual sleep. The quality of this sleep is also affected, and is poor (see below in section 5.2.3).

A special note **:** the **overall amount of sleep** during the **midnight shifts** shown in the **logged** data was **lower** than that of the other shift-cycles, when taking into account all five work days. It appears that the average duration during the early day-time sleep period is consistently low, such that when compared to the overall average sleep duration experienced by controllers working other shift-cycles, controllers working midnights get **less** overall average sleep (taking all mean sleep periods for the group throughout the cycle and averaging them). Therefore, it is expected that there is a greater chance of **chronic** sleep loss occurring during five consecutive midnight shifts. Acute sleep loss occurs as a result of working the double quick-change and Gander shifts, due to the day shift to midnight shift quick-change, and the early start on the day shift. See sub-section 5.2.3 for a more detailed discussion.

Figure 5.2.2-1



The ranges and means for the sleep lengths for the three shift-cycles is shown in Table 5.2.2-1 below.

Table 5.2.2-1: Means and Ranges for Sleep Duration for the Three Shift-Cycles

Recorded Sleep Periods	EEDDM (W1=Night Sleep) (W2=Evening Sleep)	ESDMN (W1=Evening Sleep) (W2=Day Sleep)	MMMMM (W1=Day Sleep) (W2=Day Sleep)
Maximum Baseline Sleep	458.0	403.0	441.5
Minimum Baseline Sleep	289.0	238.0	260.5
Mean Baseline Sleep	346.1	338.6	367.4
Maximum Work Sleep 1	351.5	274.0	395.5
Minimum Work Sleep 1	254.5	22.5	149.5
Mean Work Sleep 1 *	298.6	135.29	251.27
Maximum Work Sleep 2	288.5	332.5	429.5
Minimum Work Sleep 2	25.0	147.5	151.5
Mean Work Sleep 2 *	164.6	224.29	298.23

* The difference between each mean is significant at $p<0.01$

Note that the worst time to sleep appears to be evening where minimal sleep periods of 22 to 25 minutes occur. The means for evening sleeps are also the lowest of all sleep periods.

When controllers were asked about sleeping in the afternoon they commonly replied that they always have difficulty sleeping at this time of day. A few controllers said that they had no trouble. These lucky few also mentioned that they recognised this sleep period to be a bonafide time to sleep. Most of the other controllers claimed that they usually just snoozed at this time, in front of the T.V. or on the couch after dinner etc. It is possible that both mental preparedness and the circadian rhythm influence this sleep significantly.

Day-time sleeps are marginally better than evening sleeps and tend to be almost as disruptive (see section 4.3.3 below). The best sleeps appear to happen if the controller can get to bed before 10:00. Most awakened between 12:00 and 13:00, so if they get to bed later, they obtain fewer hours of sleep. The midnight shift-cycle group slept more during their fourth day sleep (Work Sleep 2) than during their first day sleep (Mids Work Sleep 1) In fact their sleep times for the first day sleep (Mids Work Sleep 1) were similar to the sleep times for the Gander day sleep (Gander Work Sleep 2).

5.2.3 Amount of Sleep Loss

Table 5.2.3-1 shows the amount of sleep loss experienced by controllers working the 3 difficult shifts, comparing their recorded baseline means to their first and second recorded sleep periods during the shift-cycle. Note the magnitude of the difference in sleep duration between the sleep obtained on a day off (or equivalent such as an evening over-time shift worked on a day off - two controllers did this) and that of the first and second work sleep. The mean difference between sleeping on a baseline night compared with trying to sleep during the evening ranges between just over 200 minutes (Gander) and just over 180 minutes (Moncton) (see Figure 5.2.3-1) of lost sleep. Such sleep loss is only part of the overall sleep loss experienced by controllers during their shift-cycle. If the losses from the first work sleep and the work second sleep are added, the loss in potential sleep is now up to over 330 minutes. Add to this sleep lost during other shifts in the cycle, and it can be considerable. Though napping was evident, and sometimes went as high as an average of almost 70 minutes (for the subjects who were monitored for sleep), this napping does not pay back the sleep debt. Sleep durations of over 2-3 hours are the minimum amount of time needed to allow the body to begin to experience all of the stages of sleep, adequately. The sleep debt remains. Figure 5.2.3-2 illustrates the total sleep loss for the two monitored sleep periods.

Table 5.2.3-1: Mean Differences in Sleep for Three Shift-Cycles

Differences in Recorded Sleep Periods *	EEDDM (W1=Night Sleep) (W2=Evening Sleep)	ESDMN (W1=Evening Sleep) (W2=Day Sleep)	MMMMM (W1=Day Sleep) (W2=Day Sleep)
Mean of (Baseline - Work Sleep 1)	47.55	208.50	127.92
Min. of (Baseline - Work Sleep 1)	-30.00	90.50	23.00
Max. of (Baseline - Work Sleep 1)	127.50	372.50	259.50
Mean of (Baseline - Work Sleep 2)	181.60	120.75	85.67
Min. of (Baseline - Work Sleep 2)	84.50	25.00	7.00
Max. of (Baseline - Work Sleep 2)	372.00	255.50	267.00

* All differences are significant to p<0.01 level.

Figure 5.2.3-1

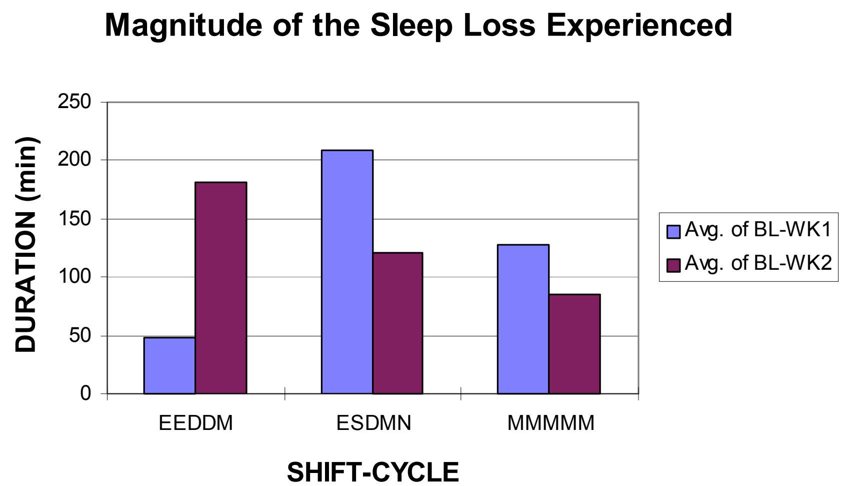
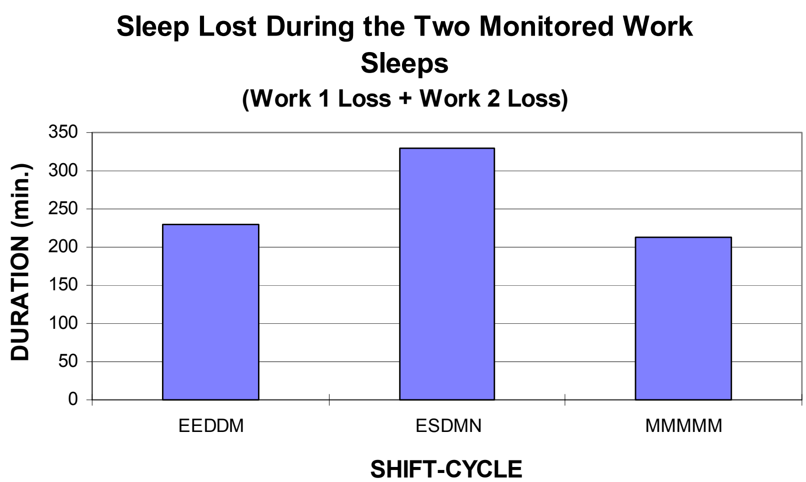


Figure 5.2.3-2



5.2.4 <u>Stages of Sleep</u>

Figures 5.2.4-1a & b show the contribution of the different stages of sleep for the midnight shift-cycle (MMMMM), Figures 5.2.4-2a & b show the contribution of the different stages of sleep for the Gander shift cycle (ESDMN), and Figures 5.2.3-3a & b show the contribution of the different stages of sleep for the double quick-change shift-cycle (EEDDM).

For the midnight group, there is more SWS (stages 3 and 4) during the work sleep compared to the baseline sleep with some increased REM during the second work sleep as well. For this group the need for restoration to repay the sleep debt seems to be more necessary. The Gander group also shows an increase in SWS compared with their baseline average. For the Double Quick-Change group there is a marked increase in SWS in the second (evening sleep) at the expense of REM sleep.

Figure 5.2.4-1a

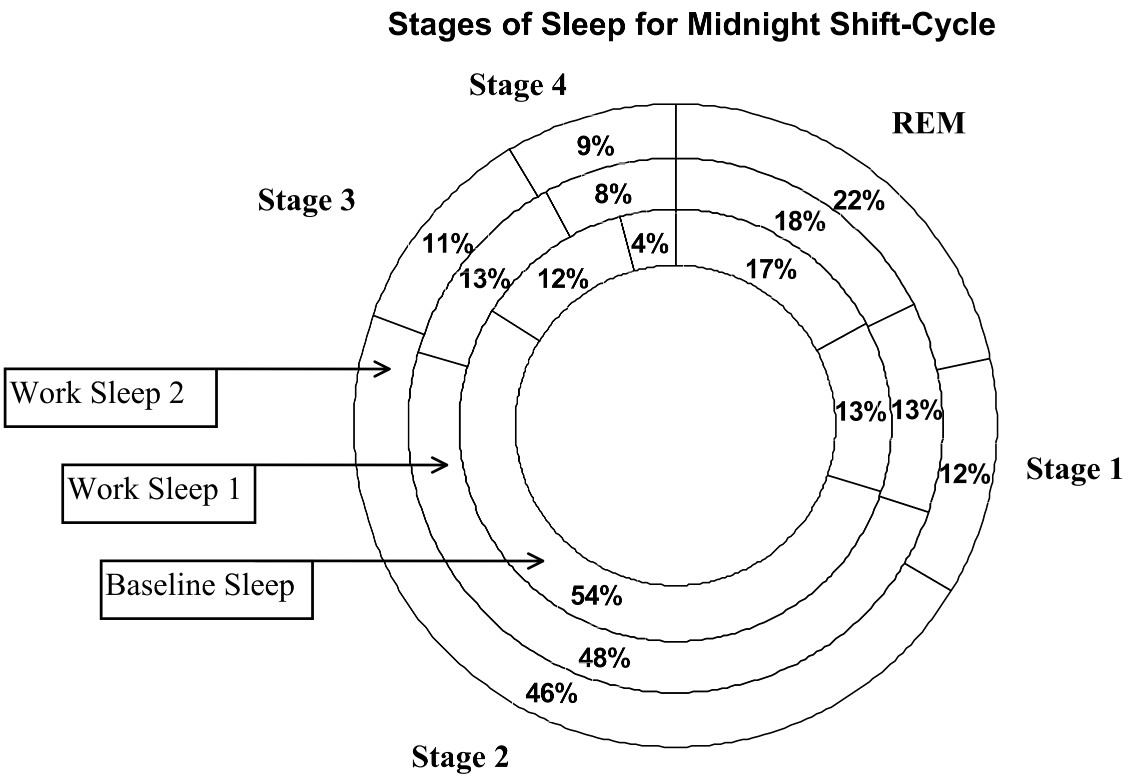


Figure 5.2.4 -1b

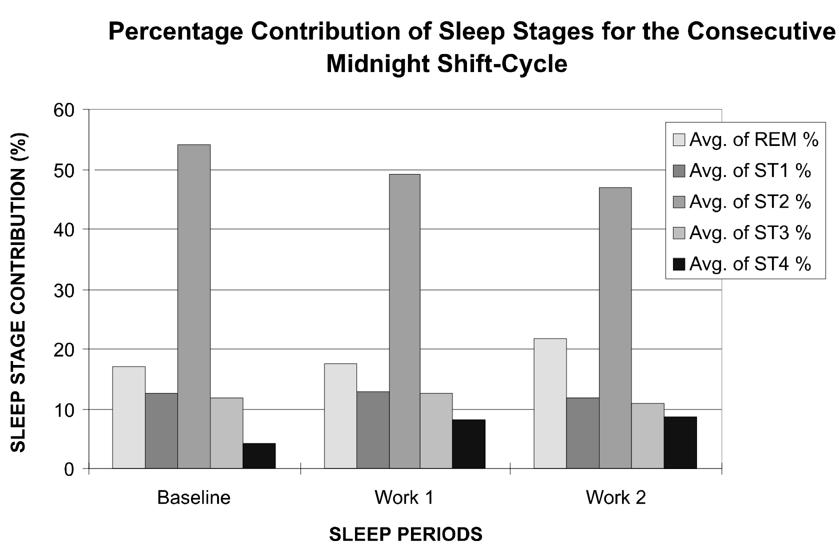


Figure 5.2.4-2a

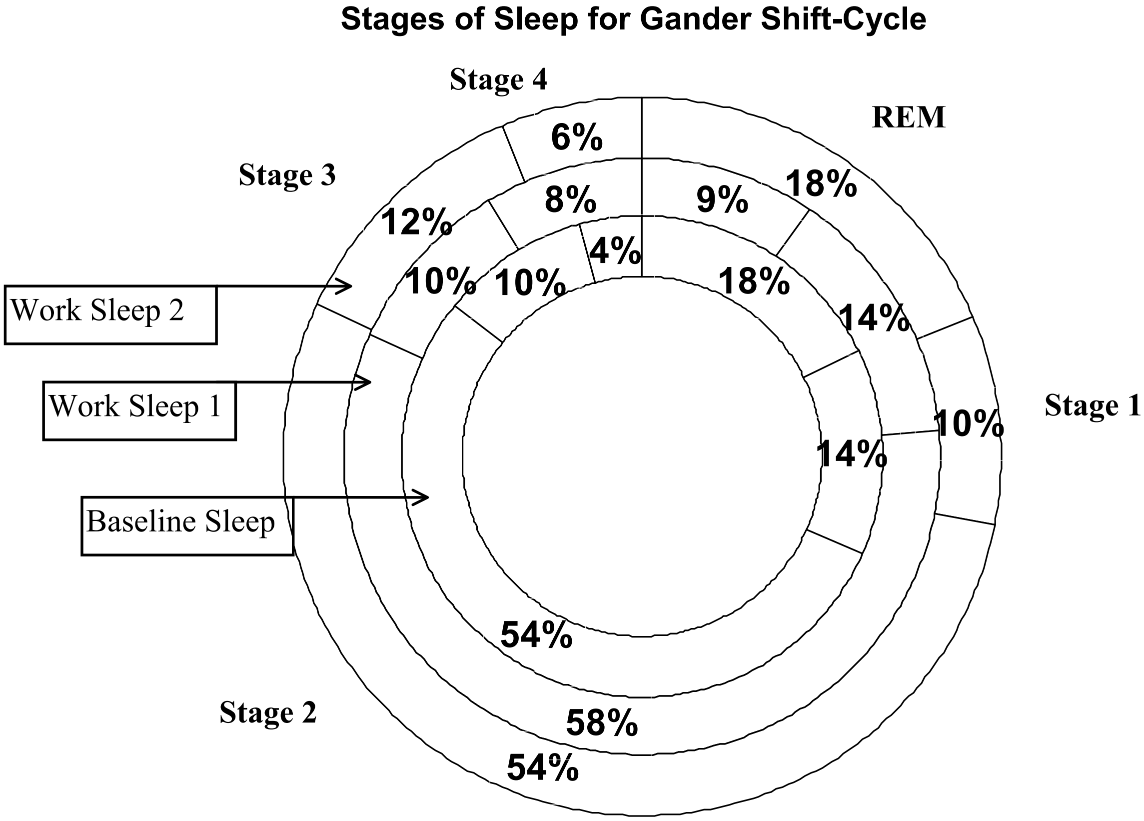


Figure 5.2.4-2b

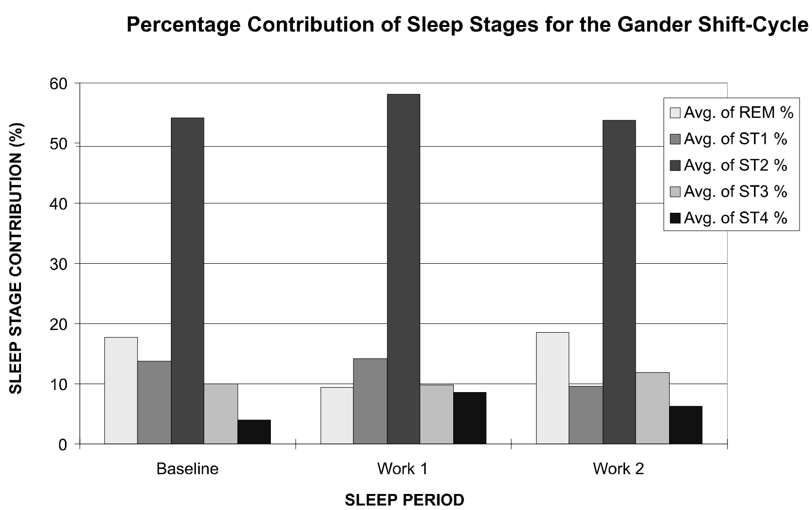


Figure 5.2.4-3a
Stages of Sleep for Double Quick-Change Shift-Cycle

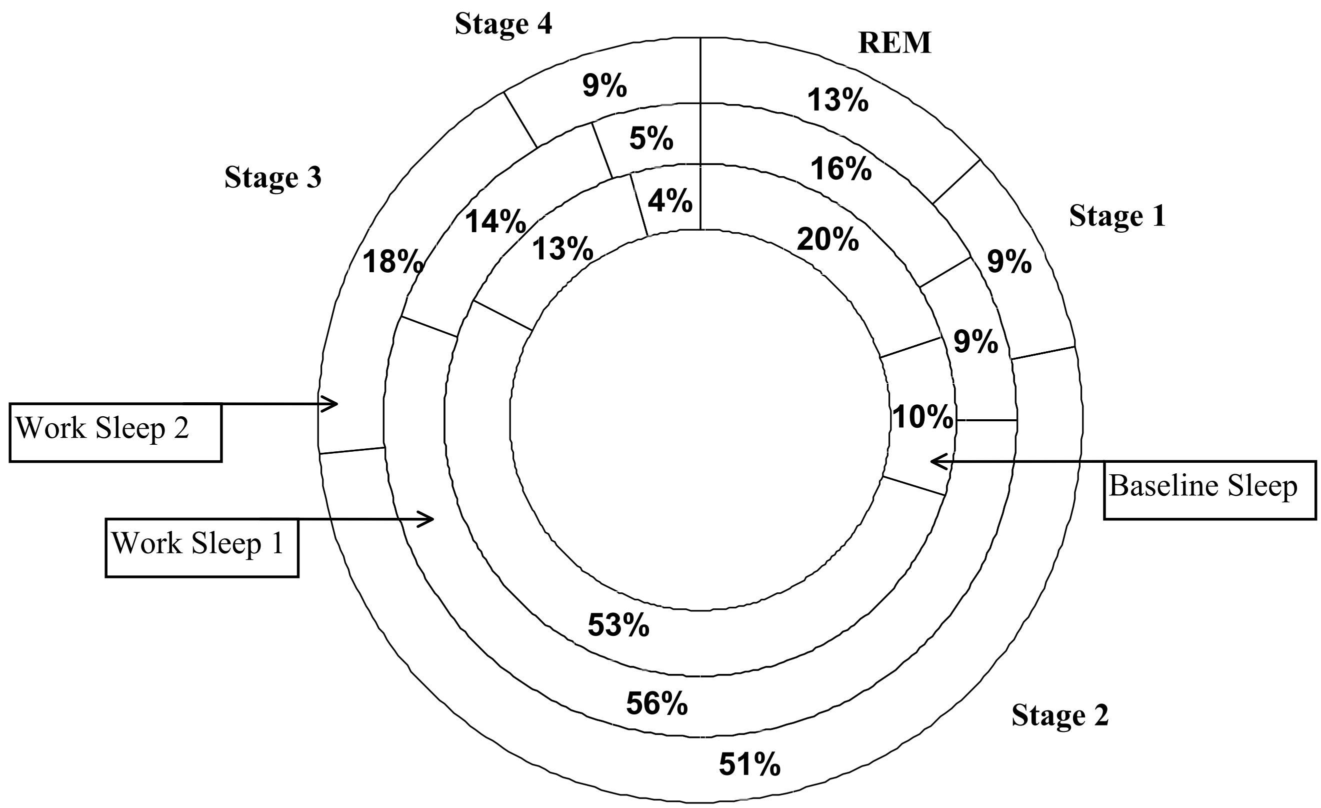


Figure 5.2.4-3b

Distribution of Sleep Stages for the Double Quick-Change Shift-Cycle (EEDDM)

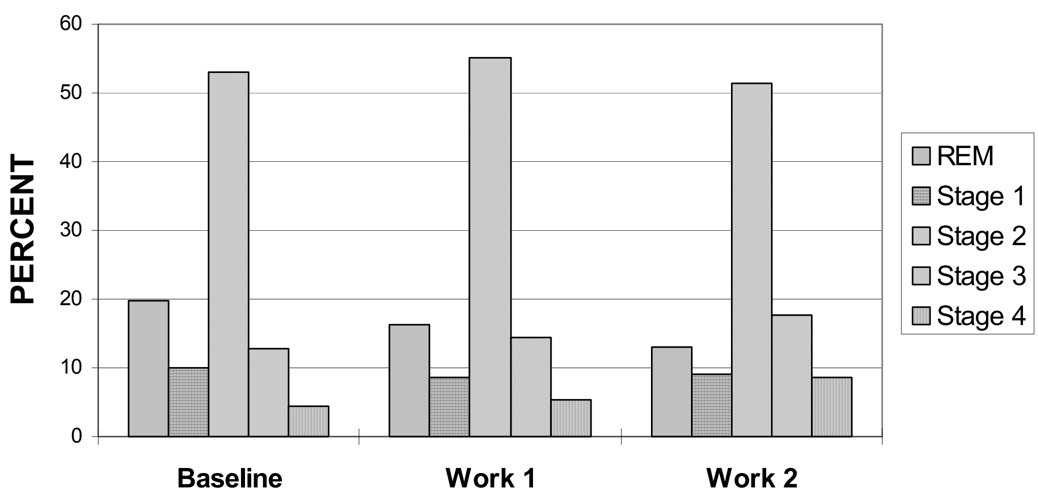


Table 5.2.4.-1 shows the mean percentage for the five stages of sleep for the three sleep periods which were monitored for all three shift-cycle types.

Table 5.2.4-1: Mean Percentage for the Five Stages of Sleep

Recorded Sleep Stages %	EEDDM (W1=Night Sleep) (W2=Evening Sleep)	ESDMN (W1=Evening Sleep) (W2=Day Sleep)	MMMMM (W1=Day Sleep) (W2=Day Sleep)
Mean Baseline REM	19.70	17.68	17.14
Mean Work Sleep 1 REM	16.30	9.33	17.49
Mean Work Sleep 2 REM	12.96	18.45	21.75
Mean Baseline Stage 1	9.89	13.80	12.71
Mean Work Sleep 1 Stage 1	8.65	14.14	12.73
Mean Work Sleep 2 Stage 1	8.97	9.63	11.82
Mean Baseline Stage 2	53.10	54.08	54.05
Mean Work Sleep 1 Stage 2	55.11	58.14	49.15
Mean Work Sleep 2 Stage 2	51.39	53.68	46.92
Mean Baseline Stage 3	12.81	10.05	11.83
Mean Work Sleep 1 Stage 3	14.36	9.81	12.51
Mean Work Sleep 2 Stage 3*	17.76	11.80	10.88
Mean Baseline Stage 4	4.40	4.03	4.16
Mean Work Sleep 1 Stage 4	5.42	8.49	8.06
Mean Work Sleep 2 Stage 4	8.64	6.28	8.56

* The difference between each mean is significant at $p<0.01$

5.2.5 Sleep Latency and Efficiency

Figure 5.2.5-1

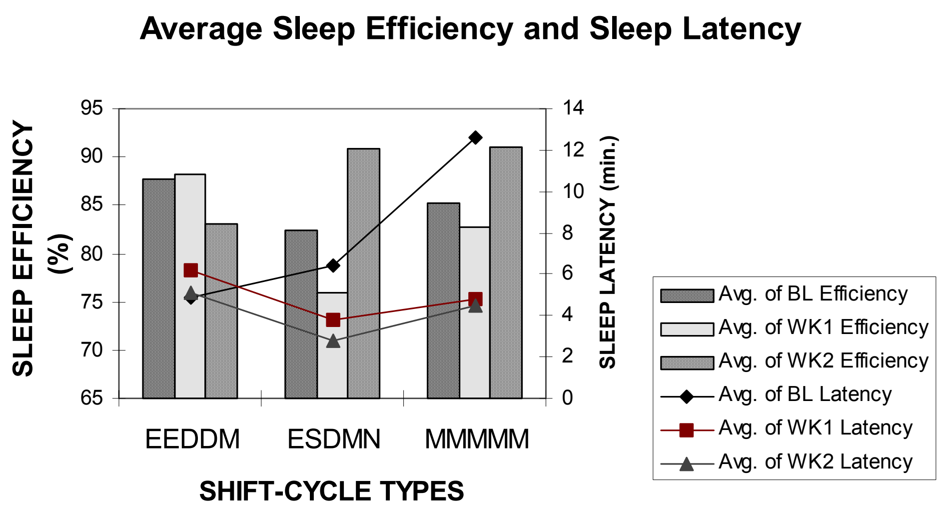
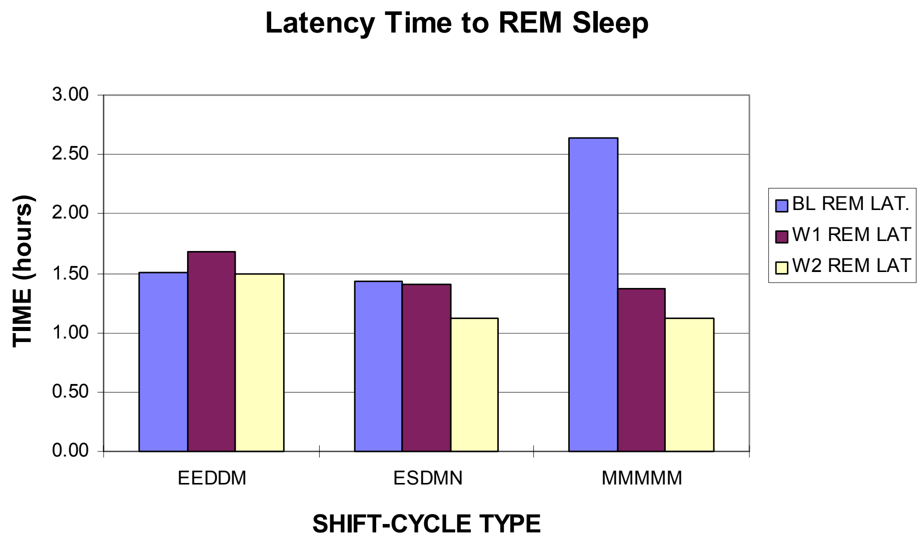
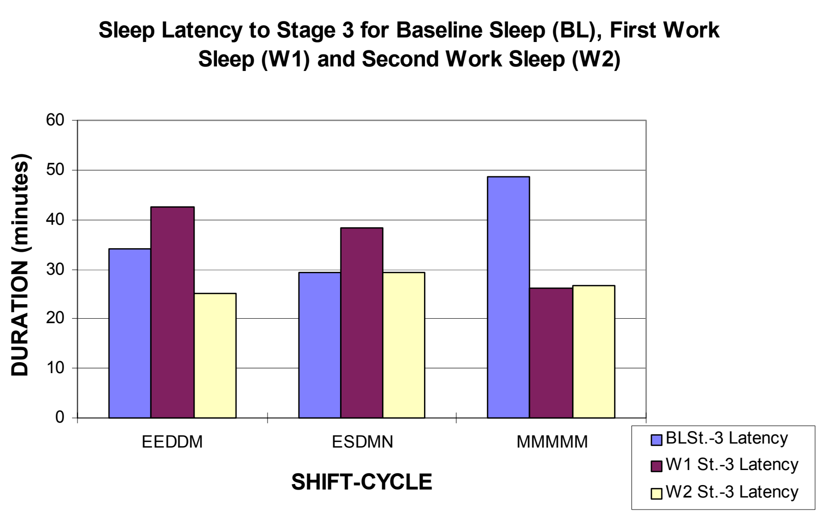


Figure 5.2.5-2



In terms of sleep efficiency, evening sleep tended to show the least sleep efficiencies across all groups. The sleep latency for the baseline sleep for controllers working the midnight shift-cycle is higher than that seen in the other shift-cycles but is still within the normal range. The decrease in the sleep latency time observed in the two day-sleeps monitored for the midnight shift-cycle group indicates that some sleep loss may have occurred. In fact because the REM onset (see Figure 5.2.5-2) latency for midnights is much lower for the two day-sleep compared with the baseline sleep (referred to as REM rebound), it is possible that the controllers may be making up for sleep loss. The Gander controllers also show a reduction in the sleep latency, but to a lesser degree, and do not show very much change in REM on-set latency, although there is a minor decrease during the day sleep.

Figure 5.2.5-3

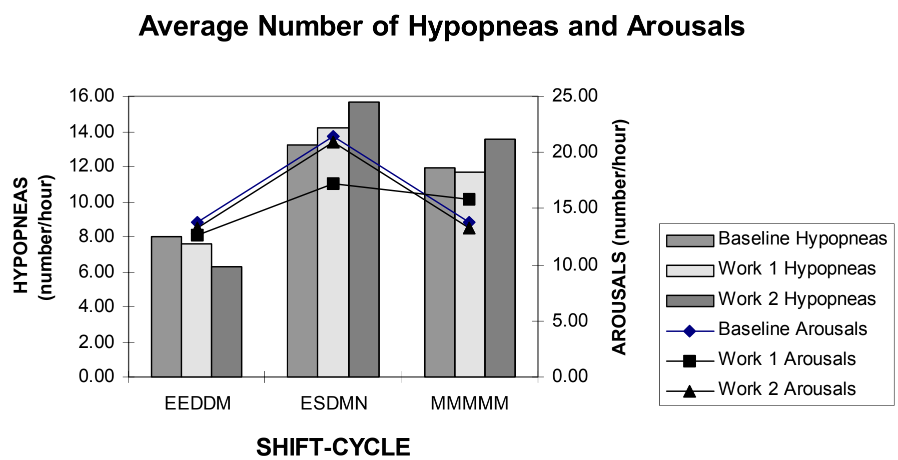


Sleep latency to stage 3 (Figure 5.2.5-3) indicates that the shorter durations for the evening sleep for the Double Quick-Change (DQC) sample, and the day sleeps for the Midnights shift-cycle controllers, may be a result of some sleep loss, and possible fatigue.

5.2.6 Hypopneas, Apneas and Arousals per Hour

Figure 5.2.6-1 shows the average number of hypopneas, apneas and arousals for the three groups. There are no real observed differences in the number of hypopneas, apneas or arousals per hour for any of the shift-cycle groups. The overall number for all groups is slightly higher than normal. This is probably due to the fact that the controllers were spending these sleep periods in unfamiliar surroundings.

Figure 5.2.6-1



5.2.7 Duration of Sleep for the Various Age Groups

Figures 5.2.7-1 to 5.2.7-3 illustrate the relationship between age and duration of the baseline sleep, work sleep 1 and work sleep 2, by comparing those controllers over 35 to those under 35 years of age.

Figure 5.2.7-1

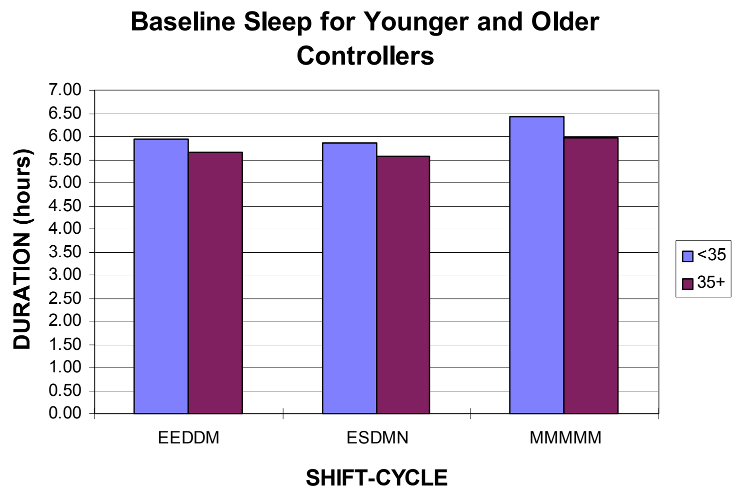
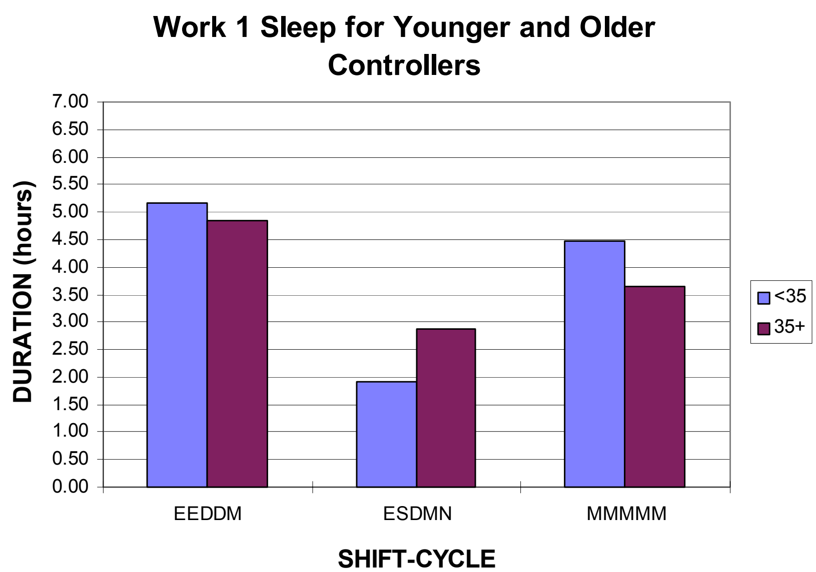


Figure 5.2.7-2

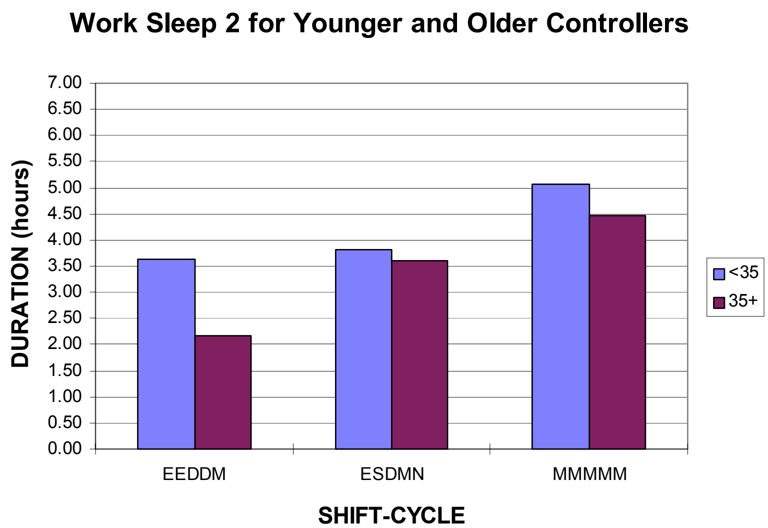


EEDDM	ESDMN	MMMMM
night	evening	day

Time of Day for Sleep

Figures 5.2.7-2 and 5.2.7-3 illustrate the duration of sleep for the first monitored work sleep period and the second monitored work sleep period for younger and older controllers. In all but one case, the older controllers get, on average, 30 minutes less sleep. The one case where this does not hold is in the Gander group where the older controllers managed to get almost one hour more sleep during the evening sleep (their work sleep 1). The reason for this difference from the other situations may be that the older Gander controllers have developed a better strategy for sleeping in the evening, or that they may be actually more tired than the younger controllers.

Figure 5.2.7-3



EEDDM	ESDMN	MMMMM
evening	day	day

Time of Day for Sleep

Note that for the evening sleep during the Work 1 sleep period, the older ESDMN (Gander) controllers sleep longer than the younger controllers, and for the day sleep they sleep less than the younger ones. Possibly, the younger controllers find it harder to allocate that time for sleeping and may not have developed the discipline to set that time aside.

5.2.8 Comparison of Log Sleep Record to Polysomnographic Record

Table 5.2.8-1 lists the average times for sleep as logged by the controllers and as recorded by polysomnograph during the three sleep periods which were monitored. Figure 5.2.8-1 illustrate the relationship between the sleep duration indicated in the log and the time-in-bed as recorded during the monitored sessions. Figure 5.2.8-2 shows the logged sleep durations on the left and the recorded times on the right for each pair of bars, for each shift-type. ***NOTE: The means for the recorded sleep varies from those data found in 5.2.1-1 earlier in the report due to the fact that three individuals (one from each of Toronto, Moncton and Gander) did not hand in logs and could not be included in the comparison.***

Figure 5.2.8-1

Comparison of Logged Sleep and Time in Bed

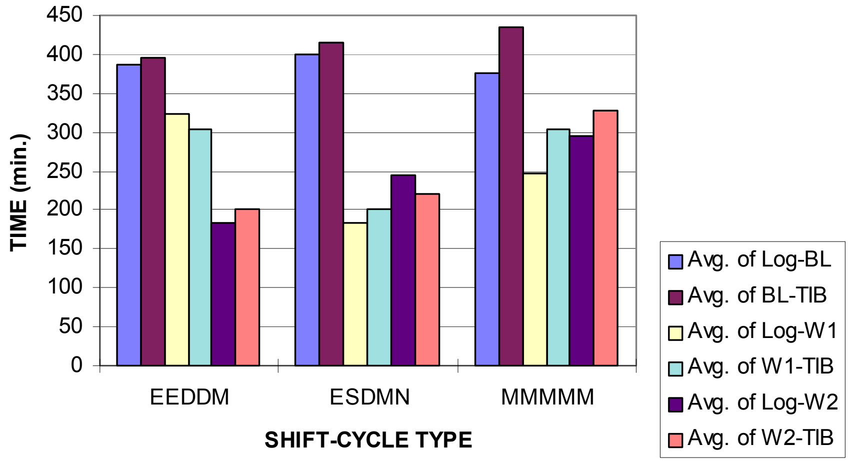
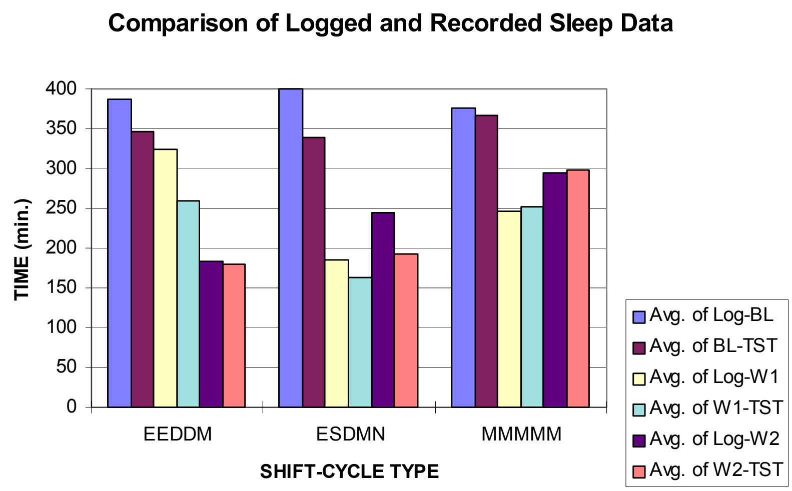


Table 5.2.8-1: Logged and Polysomnographic Recorded Sleep ***(see note above)***

Logged and Recorded Sleep Periods	EEDDM	ESDMN	MMMMM
Average of Logged Baseline Sleep	386.67	400.00	376.67
Average of Baseline Recorded Sleep	346.10	338.64	367.41
Average of Logged Work Sleep 1	324.00	291.43	246.82
Average of Recorded Work Sleep1	298.60	135.29	251.27
Average of Logged Work Sleep 2	183.00	244.29	294.55
Average of Recorded Work Sleep 2	164.55	224.29	298.23

Generally there was good correspondence between logged and objective polysomnographic data. The only differences are that the midnight controllers tend to have completed their logs more in correspondence with their actual sleep whereas the other controllers tended more to reflect their time-in-bed.

Figure 5.2.8-2



5.2.9 Logged Sleep Comparisons

The amount of sleep obtained during each day of the different shifts has been collected through the logs (see Figure 5.2.9-1). This data allows comparisons of sleep between the shifts, and the shift cycles. This information may shed light on the possibility of sleep debt and consequent fatigue.

Figure 5.2.9-1

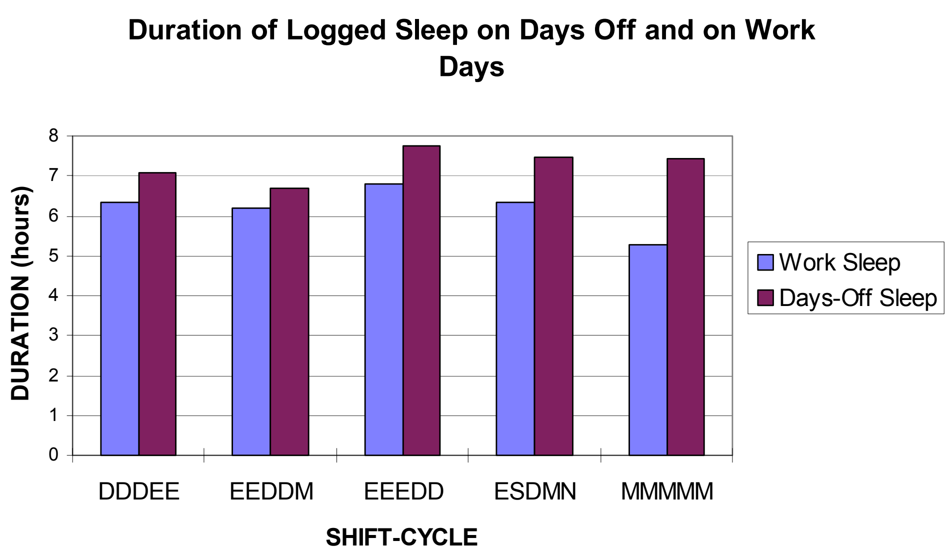


Figure 5.2.9-2

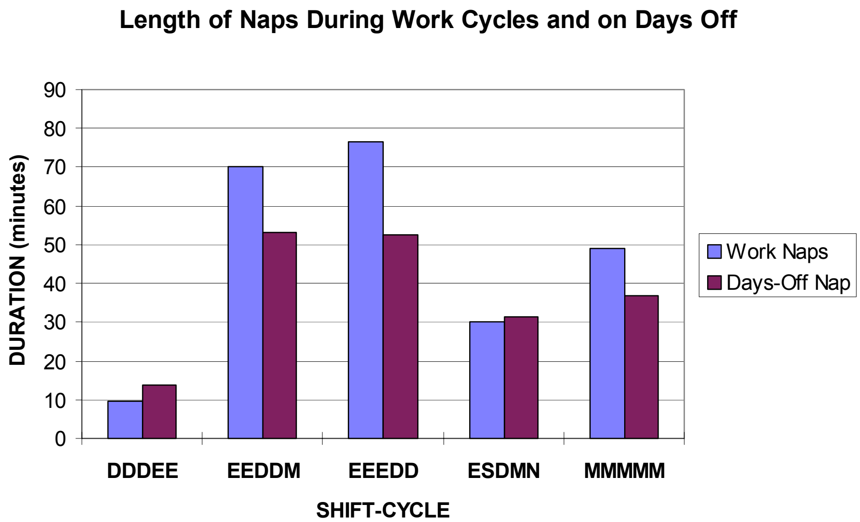


Figure 5.2.9-2 demonstrates clearly that the average daily duration of naps on the single quick-change and double quick-change shift-cycles, according to subjective logged data, is considerably longer than the other shift-cycle types. Some napping occurred during the midnight shift-cycle, but is almost half the average daily duration as that obtained by the SQC controllers. On days off napping was shorter in duration but still almost 75% as long as during the shift-cycle, and in the case of Days-Evenings and the Gander shift-cycle types, were slightly longer. The reasons for longer durations for the single and double quick-change shift-cycle controllers may include better opportunities for naps or a greater acceptance for napping (the groups' work cultures). Alternatively it is possible that these controllers also have a greater physiological need for napping to compensate for the shorter sleep durations during the quick change.

5.3 Physiological (EEG) Results

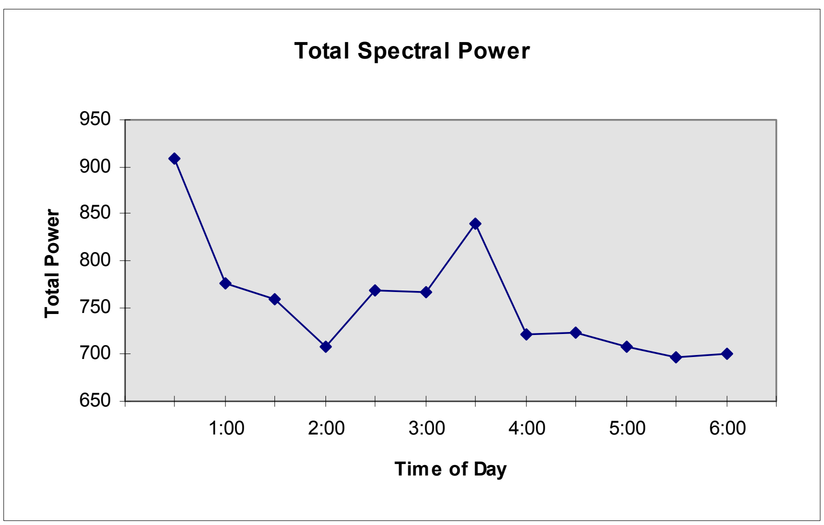
The results section will focus only on the data from the MMMMM shift-cycle and will focus primarily on the second night of data collection. The data loss in the study was substantial. Of the 8 controllers at Toronto who volunteered to participate in this part of the study, data were available for 7 for most (though not all) 30-min segments for the second data collection period (i.e., the fifth midnight shift). Additionally, data were available from 5 Toronto controllers for the first data collection period (i.e., the second midnight shift). For Gander, only 2 controllers out of 10 had scoreable data for the first data collection period (i.e., a midnight work period) and 3 controllers had data available for the second data collection period (i.e., a partial midnight shift from 2000h-0400h). For Moncton, only 3 controllers out of 8 had scoreable data with only 2 controllers providing data for each of the 2 work periods.

Given the data loss and the resulting small sample size in all settings, the exploratory analysis concentrated on the data from the second work period for the MMMMM shift-cycle controllers. In addition, the data are only reported in descriptive terms to look at trends in EEG data across the last midnight shift and descriptively assess whether any underlying changes in physiological state parallel subjective and objective data for the controllers for whom physiological data was available. Finally, it was decided that if these data revealed any interesting trends, the first work period for Toronto would be examined for specific physiological parameters to examine whether similar changes occurred during that work period (i.e., the second midnight shift).

As noted in section 4.3, the EEG data yielded a number of variables including the raw spectral power within each band, the relative power within each band based on the total spectral power for all frequencies, the mean frequency within each band, and the following 5 ratios: delta/alpha, theta/alpha, delta/beta, theta/beta, and (delta+theta)/(alpha+beta). The mean frequencies were calculated to assess whether the power within frequency bands systematically shifted across the midnight shift. The ratios were calculated because there is a significant amount of evidence to suggest that as drowsiness becomes stronger, the power in low frequency bands becomes more predominant relative to high frequency bands.

As can be seen in figure 5.3.1, total spectral power for the EEG signal across all bands varies across the night and generally decreases across the night. (The data in the following figures are the means for each 30-min segment starting from midnight until 0600h.)

Figure 5.3.1
Total Spectral Power During the 5th Midnight Shift for the Toronto Sample



To correct for changes in total power over the midnight shift, only relative changes were considered. These data revealed that the primary shifts in relative power occurred only in the delta and theta bands. These data are plotted in Figures 5.3.2 and 5.3.3.

Figure 5.3.2 shows that the power in the delta band (as a function of the total power in the EEG) initially declines over the early portion of the night and then begins to increase over the latter portion of the night. This decline toward less delta activity may be an artefact of unusually high levels of delta at the beginning of the night as controllers pass through what would normally be the first cycle of sleep at this time. Nevertheless, from the low level of delta activity, there is a general increase in delta over the remaining portion of the night.

Figure 5.3.2
Delta Power Relative to Total Spectral Power during the 5th Midnight Shift for the Toronto Sample

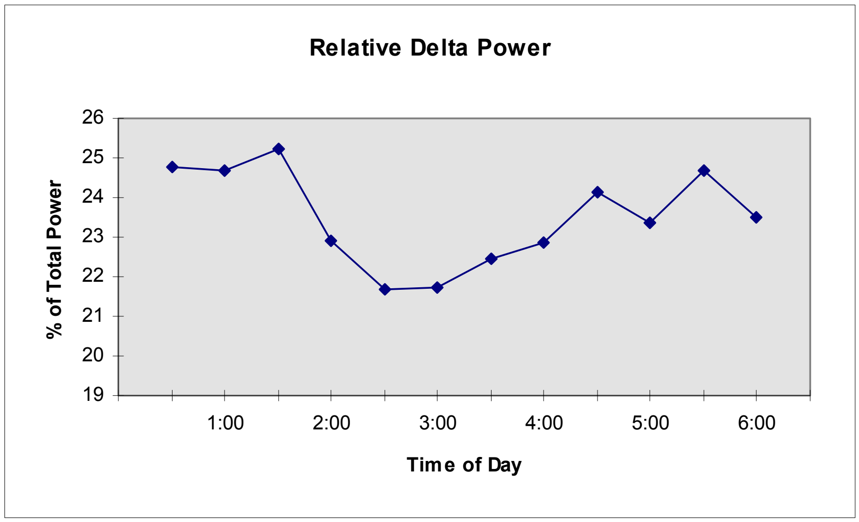
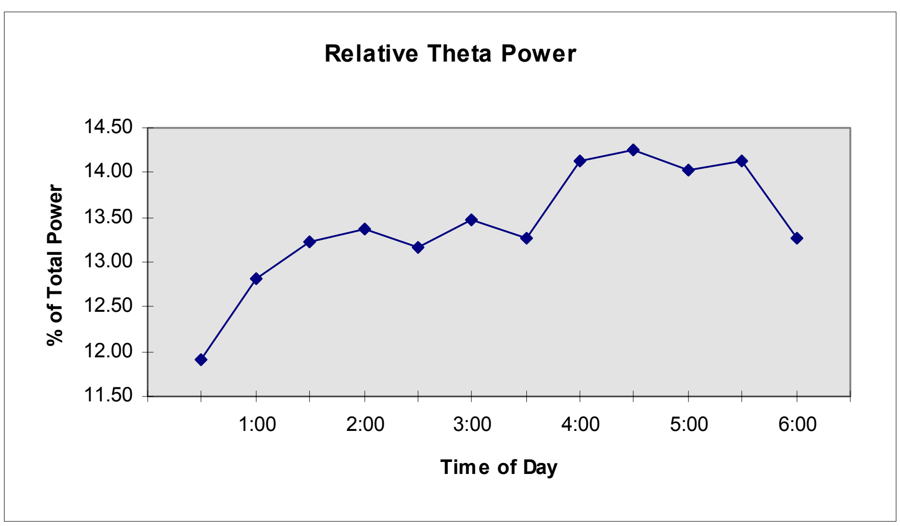


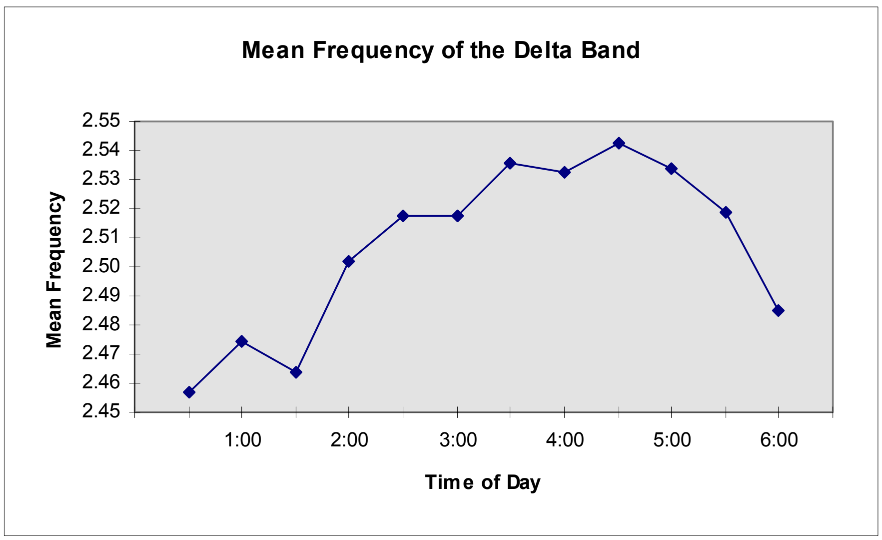
Figure 5.3.3 shows that the changes in relative theta power over the midnight shift. Clearly these data show a progressive and steady increase in theta activity as a function of enduring the midnight shift.

Figure 5.3.3
Theta Power Relative to Total Spectral Power during the 5th Midnight Shift for the Toronto Sample



Given the differences between delta and theta activity overnight, the possibility exists that the increase in relative theta activity in part occurred at the expense of power that was originally in the delta band. To examine this possibility, the mean frequency of power in the delta band was examined. These data are presented in Figure 5.3.4. These data show that when the drop in delta activity begins in figure 5.3.2, there is a consequent increase in the distribution of power within the delta band toward the theta band. These results suggest that the early increase in theta power may be in part responsible for the initial decline in relative delta power. Later in the night, however, the increasing theta power is accompanied by an increase in relative delta power and the distribution within the delta band is relatively stable.

Figure 5.3.4
Changes in the Mean Frequency of the Delta Band (reflecting a shifting Distribution of Power within the band) for the 5th Midnight Shift of the Toronto Sample



Together the above changes in delta and theta suggest, and support previous assertions in the literature, that there is an shift toward lower EEG frequencies as the night progresses. However, to confirm these data it must be clear that these changes occur consistently within epochs in contrast to changes in other frequency bands. To ensure that such changes were primarily occurring in the low, synchronous bands, these results were examined relative to the relatively asynchronous and stable beta band. In addition, the low frequency delta and theta bands were pooled and compared with the higher frequency bands. These data are shown in Figures 5.3.5, 5.3.6, and 5.3.7. Figures 5.3.5 and 5.3.6 show similar patterns to those already reported and indicate that these changes in delta and theta do not occur in asynchronous bands like beta. Figure 5.3.7 show the results for the more traditional ratio that is reported in the literature. This figure tends to reflect the delta changes to a greater extent for two reasons: a) the changes in theta relative to beta are relatively stable over the early part of the night so that the ratio changes are primarily a reflection of delta changes (theta relative to alpha remains relatively unchanged over the night), and b) the relative power in delta is twice that of theta, compared to the total power, so changes in delta predominate in the ratio.

Figure 5.3.5
Delta/Beta Ratio of Spectral Power during the 5th Midnight Shift for the Toronto Sample

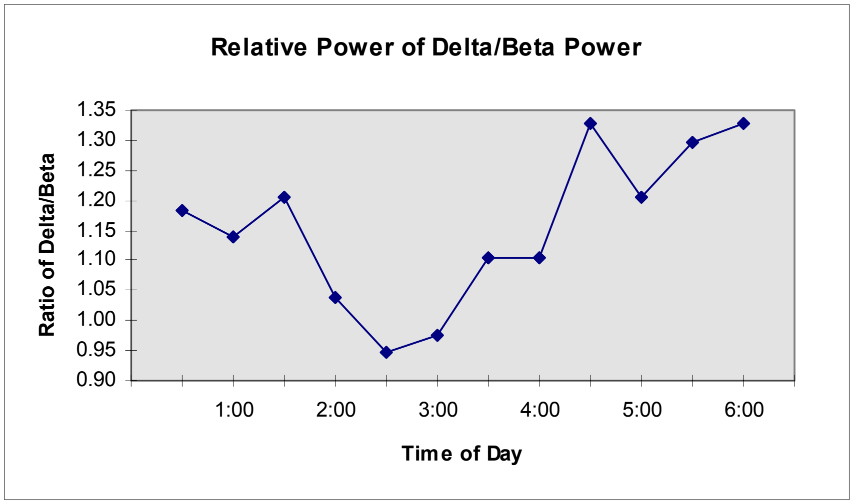


Figure 5.3.6
Theta/Beta Ratio of Spectral Power during the 5th Midnight Shift for the Toronto Sample

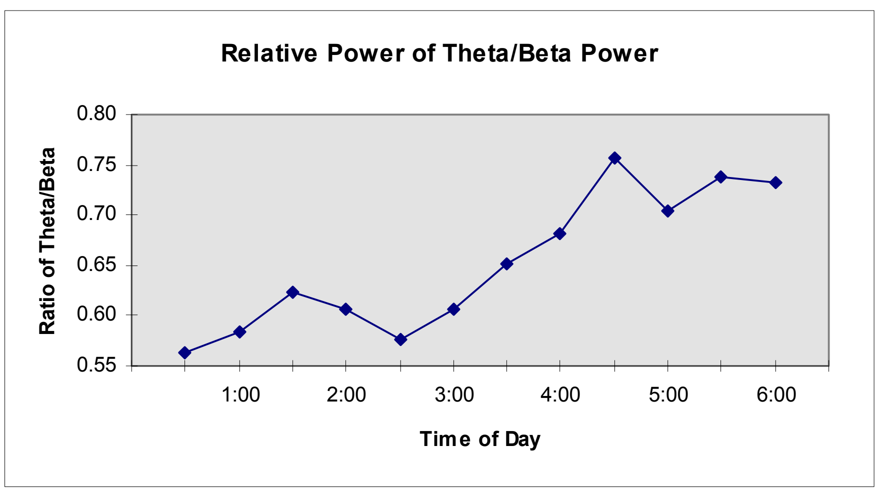
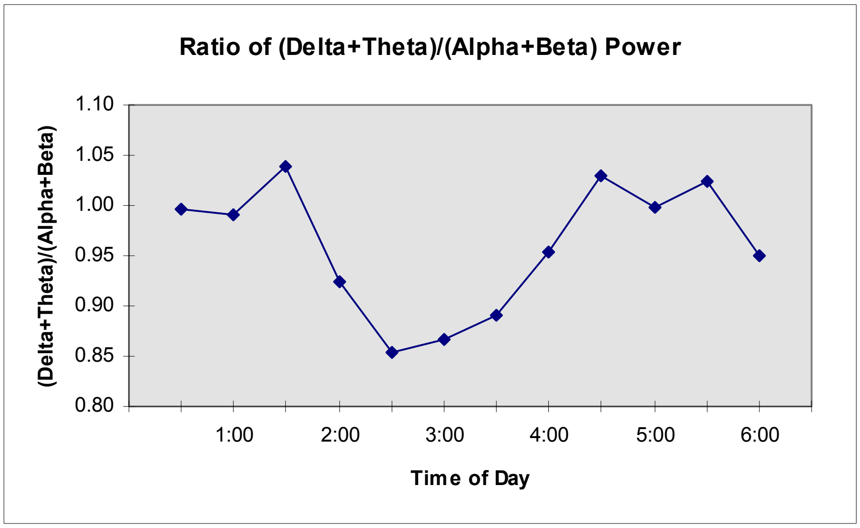


Figure 5.3.7
Relationship between Low (Delta and Theta) and High (Alpha+Beta) Frequency Activity During the 5th Midnight Shift for the Toronto Sample



The subjective and objective data from the test batteries were extracted from the performance results for only those controllers contributing to these EEG results. As was detailed earlier, subjective and objective data were gathered from controllers at the beginning, middle and end of the shifts. Figures 5.3.8 and 5.3.9 show the increases in both sleepiness and fatigue that were reported for these controllers overnight. These data appear to be consistent with the increase in low frequency EEG activity as the night progresses.

Figure 5.3.8
Changes in Self-reported Sleepiness During the 5th Midnight Shift for the Toronto Sample

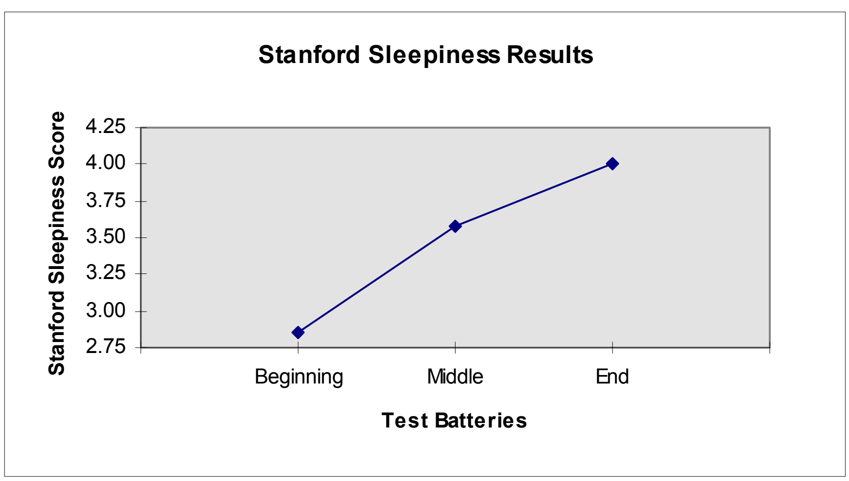
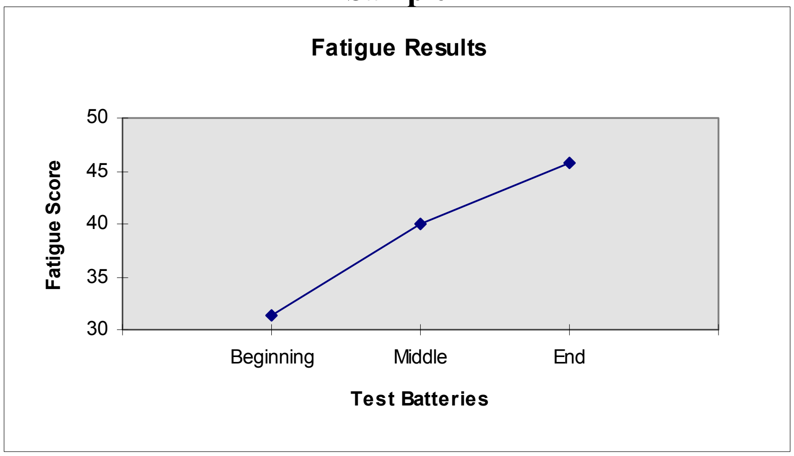


Figure 5.3.9
Changes in Self-reported Fatigue During the 5th Midnight Shift for the Toronto Sample



While the underlying physiological changes are consistent with the subjective responses of controllers the objective data requires somewhat more explanation. Consider the data from the choice reaction time and mannikin tests in the test batteries. These data are shown in Figures 5.3.10 and 5.3.11. As controllers become more sleepy and fatigued during the middle of the midnight shift, performance on these tasks deteriorates about 8% for the choice reaction time task and some 18% for the visual/spatial mannikin task. This is consistent with the changes in self-report data. However, there is an increase in performance to initial levels at the end of the shift which is inconsistent with the self-report data and the physiological data. This enhanced performance can likely be explained by the motivating effects associated with the end of the study. It must be remembered that most sleep deprivation studies have demonstrated that performance increases at the end of such experiments despite subjective and physiological data which would tend to indicate that performance should be even worse. These results have largely been interpreted as motivational.

Figure 5.3.10
Changes in Choice Reaction Time Performance During the 5th Midnight Shift for the Toronto Sample

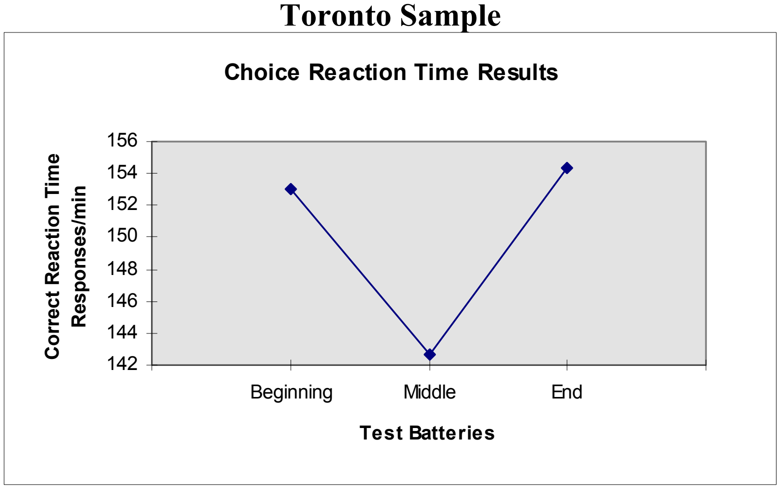
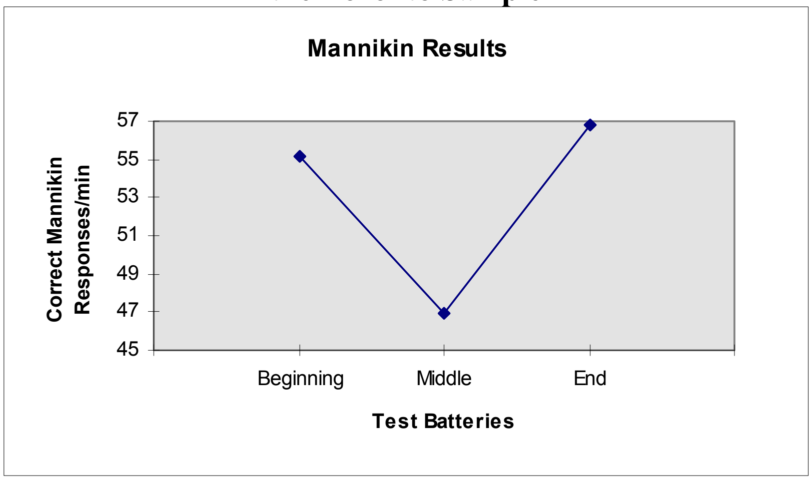


Figure 5.3.11
Changes in Visual/Spatial (Mannikin) Performance During the 5th Midnight Shift for the Toronto Sample



The first work period (e.g., the second midnight shift) of the Toronto controllers can now be considered. As stated earlier, data from fewer individuals contribute to these group data. Nevertheless, in terms of the trends identified in delta and theta activity, similar patterns were evident in this first work period. There were declines in delta activity during the early part of the night followed by increases in the latter part of the night with the distribution of power within the delta band generally increasing throughout the night. When these data were corrected on an epoch basis by looking at delta and theta ratios to beta, similar patterns still emerged. Figures 5.3.12, 5.3.13, and 5.3.14 show these results. Figure 5.3.12 shows the decline in relative delta power over the first 2 hours followed by an increase over the remainder of the night.

Figure 5.3.12
Delta/Beta Ratio of Spectral Power during the 2nd Midnight Shift for the Toronto Sample

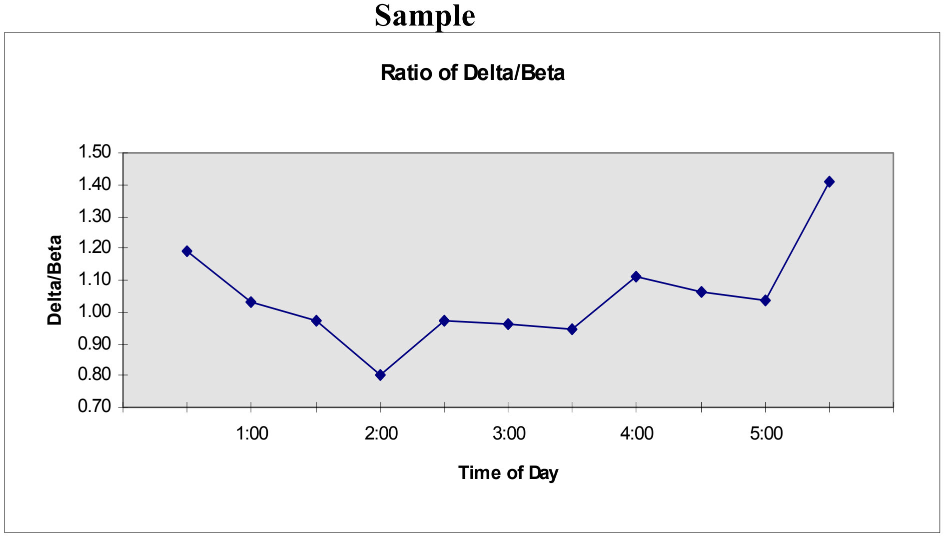


Figure 5.3.13 shows the gradual increase in relative theta power over the midnight shift similar to that observed in the 5th night.

Figure 5.3.13
Theta/Beta Ratio of Spectral Power during the 2nd Midnight Shift for the Toronto Sample

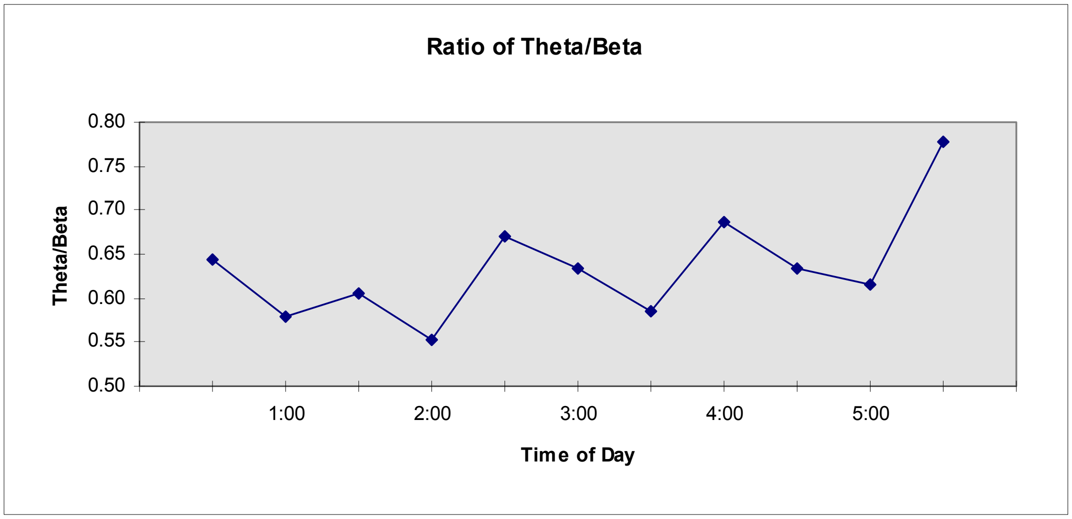
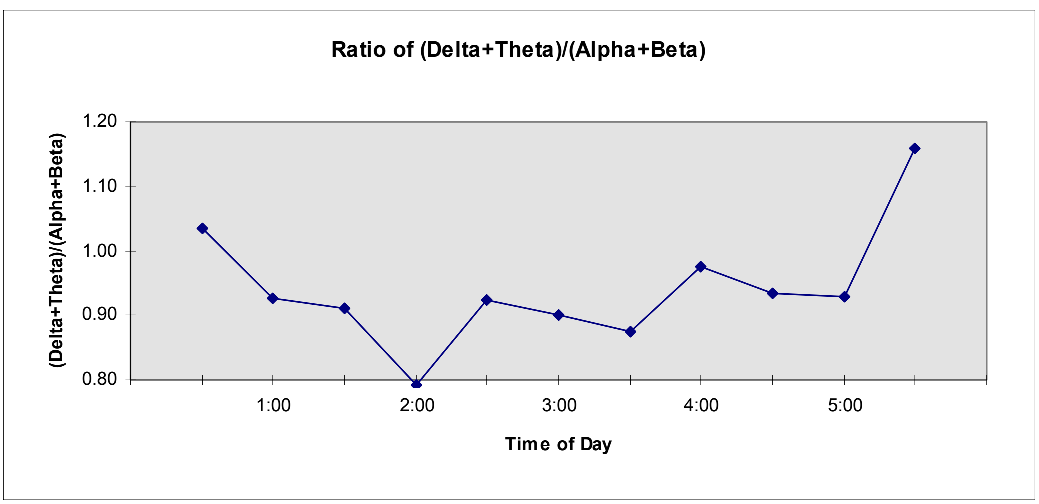


Figure 5.3.14 show the relationship between low frequency activity and high frequency activity. As expected from the earlier data, the change in delta activity dominates over that of theta activity.

Figure 5.3.14
Relationship between Low (Delta and Theta) and High (Alpha+Beta) Frequency Activity During the 2nd Midnight Shift for the Toronto Sample



The initial results from the 5th midnight shift at Toronto based on the data from the greatest number of controllers seem to be confirmed by the data from the 2nd midnight shift even though the sample size was much smaller.

Taken together the results of the physiological data support the interpretation that the subjective and objective changes in psychological state and performance occurred because of an underlying physiological change in state. These exploratory data suggest that this physiological change is initially characterised by an increase in theta activity in the EEG. This increase in theta is in part accomplished by power moving from the delta band to theta as reflected by decreases in delta activity initially. As the controller becomes more fatigued overnight, however, EEG changes suggest that there is a general increase in the lower synchronous activity in both the delta and theta bands relative to higher frequency activity.

Subjective measures of sleepiness and fatigue, along with the above physiological results indicate that controllers are working very hard to over-come sleepiness and the urge to sleep. The motivation to do well, as reflected in the performance data, is strong and likely puts some strain on controllers working very hard to handle the early morning flights as the day shift arrives. This scenario is played out every week-day and shows that controllers obviously do their best to carry on despite their physiological state.

5.4 Results of the Analysis of the Log Data

5.4.1 Meals, Snacks, Caffeine and Alcohol Consumption on Workdays

Table 5.4.1-1 shows the breakdown for frequency of meals, snacks, caffeine, and alcohol consumption for each shift-cycle type, during the work days only. Table 5.4.2-1 provides the breakdown for days off. Figure 5.4.1-1 illustrates the frequencies for the information in Table 5.4.1-1.

Table 5.4.1-1: Frequency of Meals, Snacks, Caffeine and Alcohol Consumption During Work Days

Shift-Cycle Type	Avg. # of Meals	Avg. # of Snacks	Avg. # of Caffeine	Avg. # of Alcohol
EDDMN (Gander)	2.05	0.77	1.86	0.94
EEDDM (DQC)	2.22	0.86	2.28	0.60
MMMMM (mids)	1.66	1.10	2.33	0.22
DDDEE	2.19	0.77	1.53	0.38
EEEDD (SQC)	2.20	0.48	0.94	0.25
Total	2.06	0.8	1.79	0.48

Figure 5.4.1-1
Daily Average Intake of Meals, Snacks, Caffeine and Alcohol on Work Days

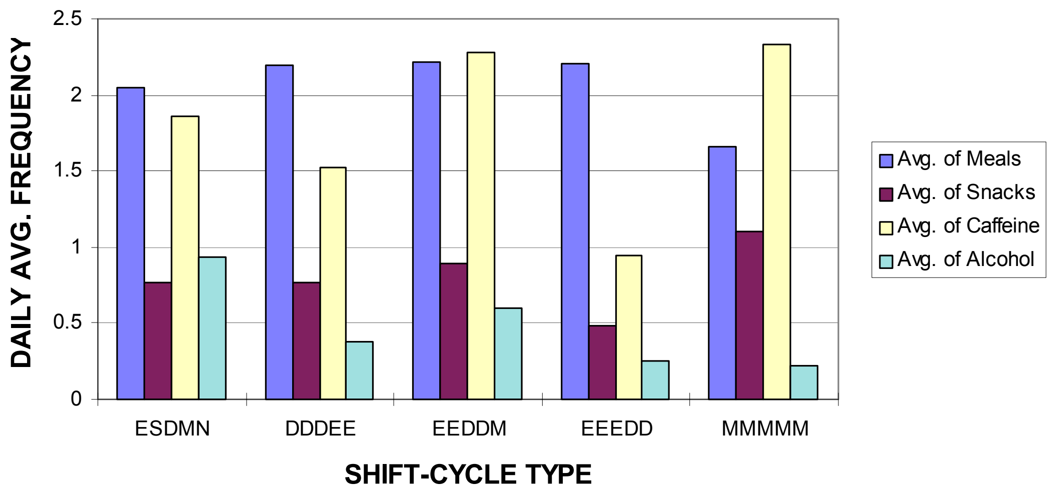


Figure 5.4.1-1 appears to support the observed and reported complaint that midnight shifts disrupt meals. This is discussed further in sections 5.4.2 and 5.4.3. Caffeine use on work days is common, though more is consumed by the controllers working the consecutive midnights, (MMMMM), double quick-change (EEDDM) and the Gander shift (ESDMN). More snacking occurs on midnights, probably to make up for missed meals. Alcohol consumption is lower on work days, as expected, though it is still used as a strategy to get to sleep and in some cases is consumed in the morning before bed. Since this is the controller's time to unwind after work it is understandable that this would be a natural time to have a drink before going to bed.

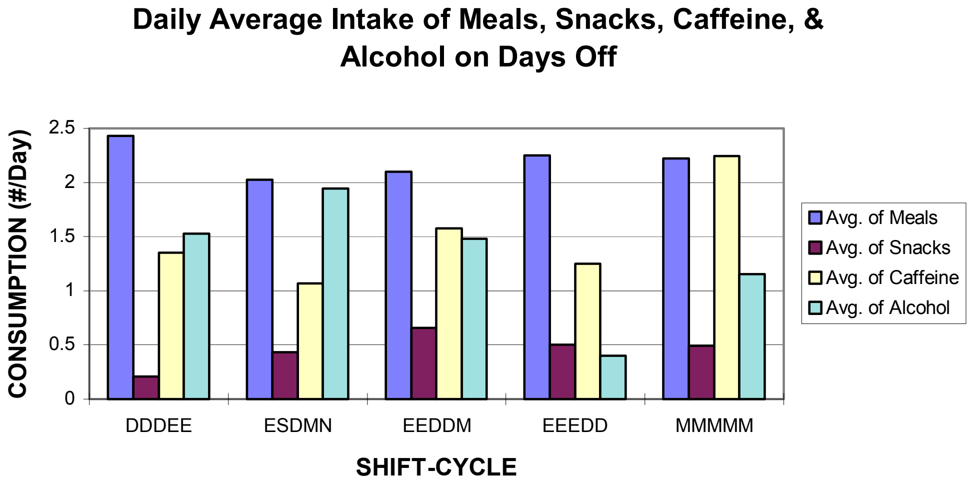
5.4.2 Meals, Snacks, Caffeine and Alcohol Consumption on Days Off

Table 5.4.2-1 shows the breakdown for frequency of meals, snacks, caffeine, and alcohol consumption for each shift-cycle type during the days off only. Figure 5.4.2-1 illustrates the frequencies for the information in Table 5.4.2-1.

Table 5.4.2-1 Frequency of Meals, Snacks, Caffeine and Alcohol Consumption During Days Off

Shift-Cycle Type	Avg. # of Meals	Avg. # of Snacks	Avg. # of Caffeine	Avg. # of Alcohol
ESDMN (Gander)	2.02	0.43	1.07	1.94
EEDDM (DQC)	2.10	0.66	1.58	1.48
MMMMM (mids)	2.22	0.49	2.24	1.15
DDDEE	2.43	0.21	1.35	1.53
EEEDD (SQC)	2.25	0.50	1.25	0.4
Total	2.2	0.46	1.5	1.3

Figure 5.4.2-1



Although caffeine usage is not high (1 to 2 servings during the shift), it appears to coincide with those shifts where higher levels of fatigue occur (see Figures 5.4.2-2 to 5.4.2-6). For example the first midnight shift is the hardest to get through for many controllers, as is the last. In fact, it was noted in the logs that most controllers consume most of their caffeine drinks during the first few hours of the shift, particularly when working midnights. Controllers working double quick-change shifts (EEDDM) self reported that the second day shift is difficult due to its earlier start time. It is surprising that the midnight shift does not result in increased caffeine usage for this group (EEDDM). It appears that the controllers in this study keep away from caffeine more than seen in other groups of shiftworkers.

Meals are taken more often on days off than on work days for the midnights controllers, while the number of snacks is reduced. Alcohol intake on days off is higher than on work days, and is noticeably higher overall for the Gander (ESDMN), midnights (MMMMM) and double quick-change (EEDDM) shift-cycles. It is interesting that days off alcohol usage is higher for controllers who work the more disruptive shift-cycle type.

Figure 5.4.2-2

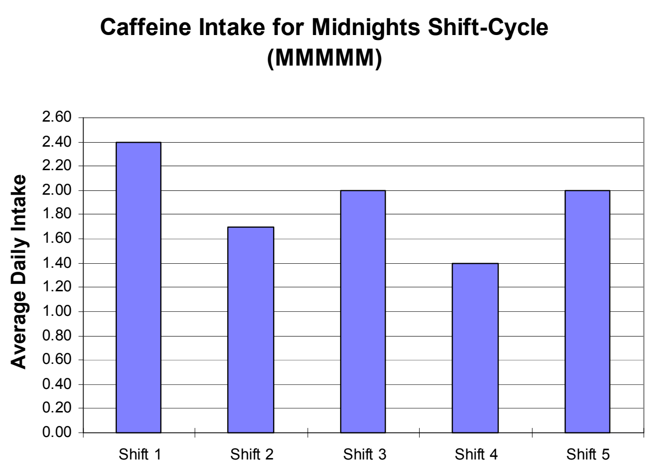
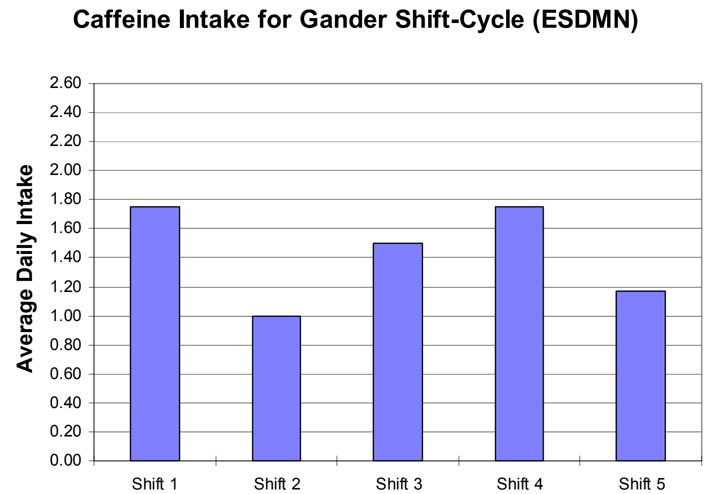


Figure 5.4.2-3



The first day back to work appears to cause controllers to increase their caffeine intake, with the exception of the double quick-change (EEDDM) and days-to-evenings shift-cycles (DDDEE), though it is as almost much on the first day for EEDDM controllers. The controllers working the EEDDM shift consume their greatest daily amount of caffeine while working the day shift (shift 4) prior to the midnight shift. The caffeine intake, as noted in figure 5.4.2-7, is lower during days off for all but the single quick-change shift-cycle.

Figure 5.4.2-4

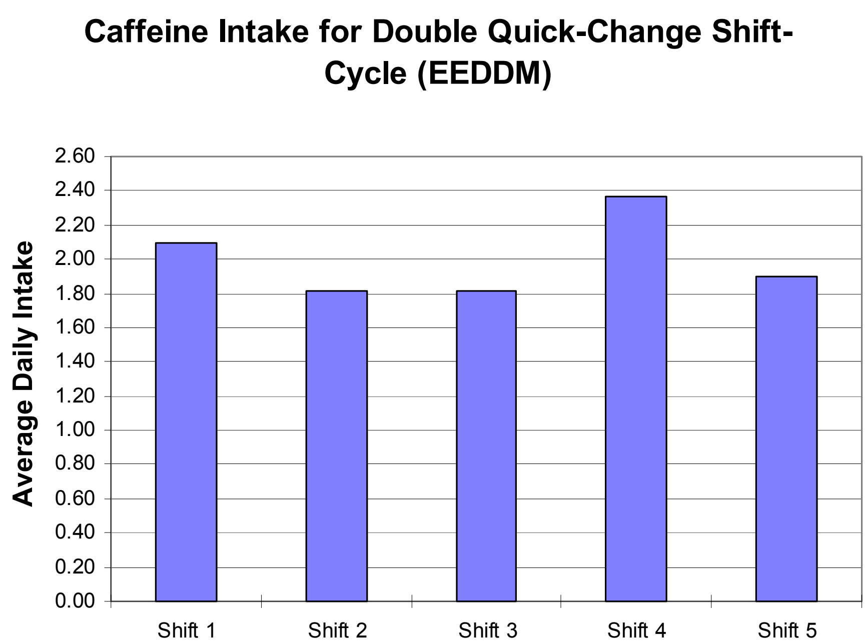


Figure 5.4.2-5

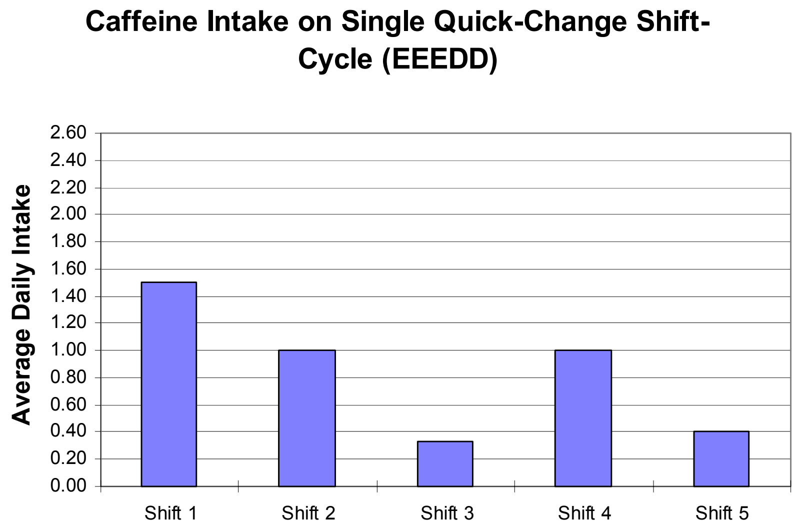
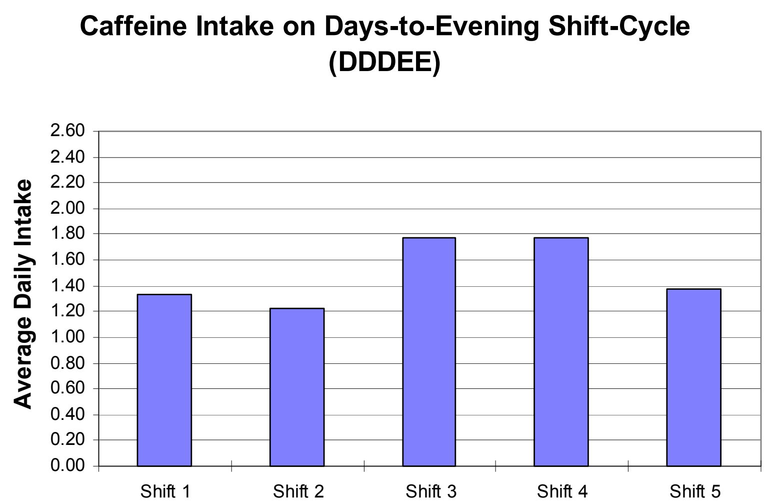


Figure 5.4.2-6



5.4.3 Frequency of Meals, Snacks, Caffeine, and Alcohol During Days Off Compared with Work Days

Midnight shifts generally tend to interrupt the regularity of meals as can be seen in Figure 5.4.3-1 below. Perhaps the timing of meals and the body's ability to digest food are out of sync. The frequency of the meals during the midnight shift-cycle is considerably lower than that of the other shift-cycles. Figure 5.4.3-2 illustrates the similarity in the number of meals and snacks occurring during the midnight portion of the shift-cycle. Interview data supports the contention that midnight shifts make eating properly very difficult. A systematic study of actual dietary intake and sleep patterns should be carried out for several different shiftworker populations. Such a study could examine the effects of the availability of appropriate nutritious food during the shifts, timing with family meals, prevalence of gastro-intestinal problems etc. The present log did not collect such information, in an effort to keep it brief.

Figure 5.5.2-7

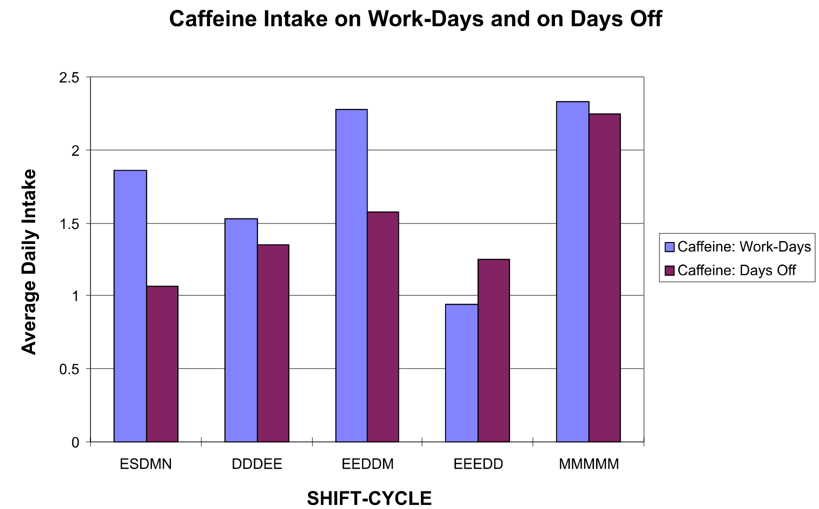
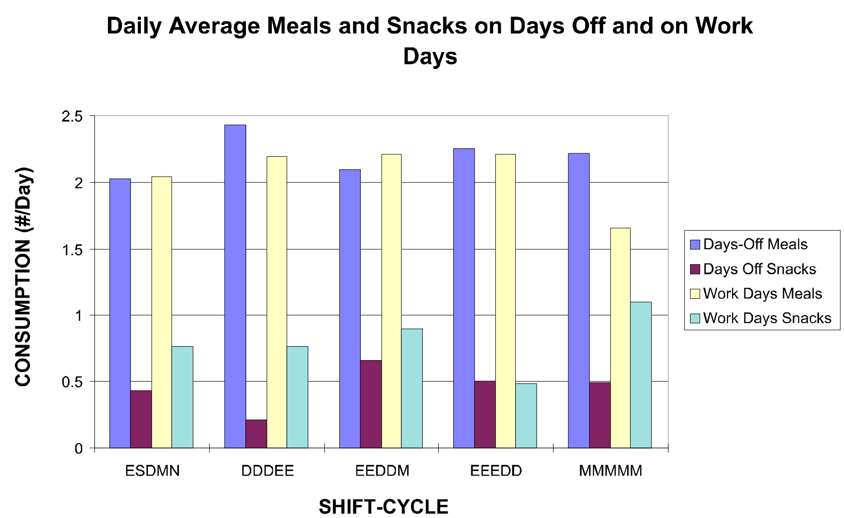


Figure 5.4.3-1



The time of the meal and its consistency is important for the regulating of the circadian rhythm and for maintaining health. Midnights make this very difficult and controllers showed that maintaining a routine is not easy to do on this shift. Though some controllers managed to eat at least one meal at the same time each day, they could not maintain their normal mealtimes. Most did have a meal sometime between 17:00 and 21:00, sometimes their only meal, and an earlier one between 13:00 and 15:00. Some controllers did manage to have their two meals at the same time each day when working the 5 consecutive midnights. Others had different times each day, some not even eating a meal and just snacking. Figures 5.4.3-2a to d illustrate this inconsistency over four of the five consecutive midnight shifts.

Figure 5.4.3-2

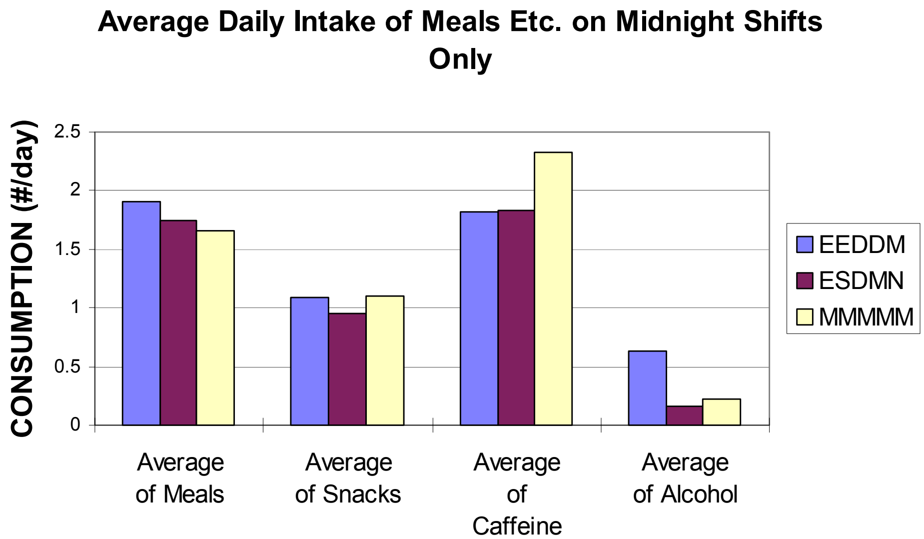


Figure 5.4.3-2a

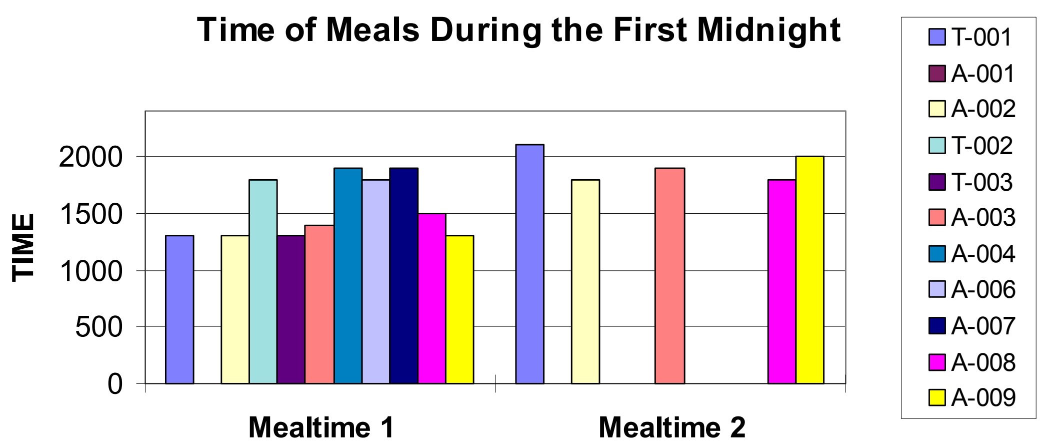
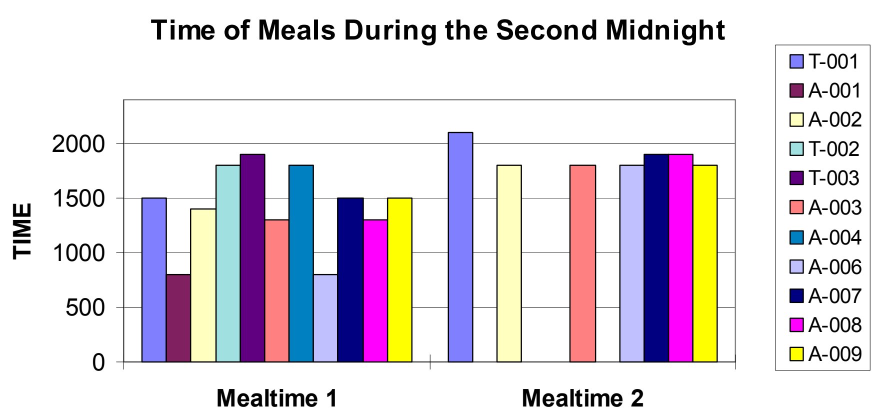


Figure 5.4.3-2b



Note in Figures 5.4.3-2a to d that there is a wide range of variability in times at which the meals occurred between individuals, and sometimes even for the same individual controller.

Figure 5.4.3-2c

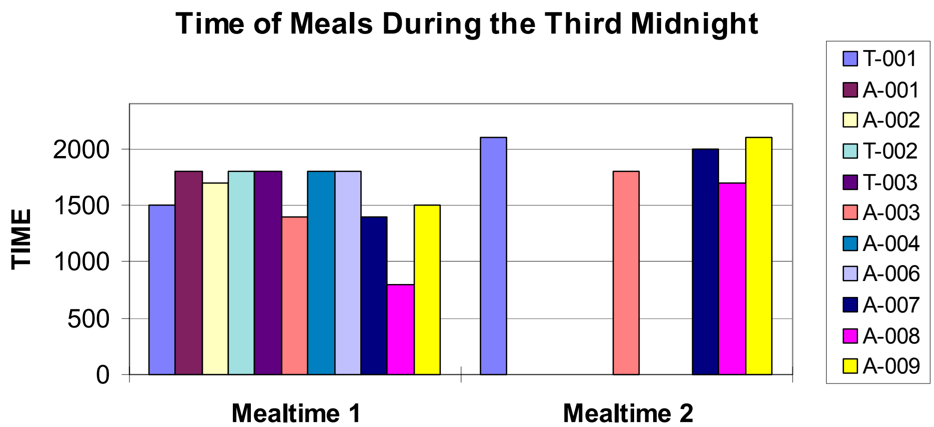
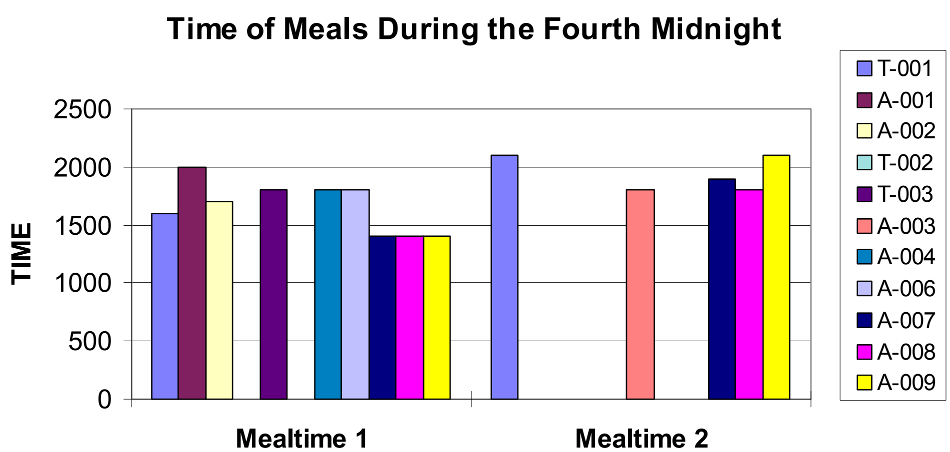


Figure 5.4.3-2d



5.4.4 Average Daily Hours on Activities During Work Days

Table 5.4.4-1 contains the breakdowns for the frequencies for various activities indicated in the log , for work days. Figure 5.4.4-1 illustrates the distributions for each activity type for each shift-cycle.

Table 5.4.4-1: Average Daily Hours on Activities During Work Days

Shift-Cycle Type	Avg. hrs. Exercise	Avg. hrs. Time Alone	Avg. hrs. Family/Friends	Avg. hrs. Dom./Errands
EDDMN (Gander)	0.29	1.72	2.74	1.91
EEDDM (DQC)	0.37	1.75	2.20	1.23
MMMMM (mids)	0.48	2.06	3.35	1.24
DDDEE	0.34	1.01	1.90	2.04
EEEDD (SQC)	0.60	1.96	1.20	1.10
Total pooled Average	0.42	1.70	2.28	1.50

Controllers working consecutive midnights spent more time with family and friends than those working the other shift-cycles, and also spent more time alone. The Gander controllers spent a greater amount of time on chores than the other controllers, and spent almost as much time with family and friends as those working midnights. The controllers working the single quick-change (EEEDD) had the highest amount of time on exercise, but also had the lowest time spent with family and friends and doing chores (errands and domestic duties such as taking care of children, house chores, etc.). Those working the forward rotation (DDDEE) spent the least amount of time on any of the activities, which indicates that they did not provide complete information.

Unfortunately, the log records were incomplete in some cases (not all hours of the day were accounted for) but other than the forward rotation group, this condition was similar for all shift-cycle groups The levels do, however, reflect the proportion of time spent on various activities, except in the case of the DDDEE group. Why this group kept less accurate records can only be speculated about, though working three days in a row may be particularly taxing and may have affected the controllers' motivation to complete the log.

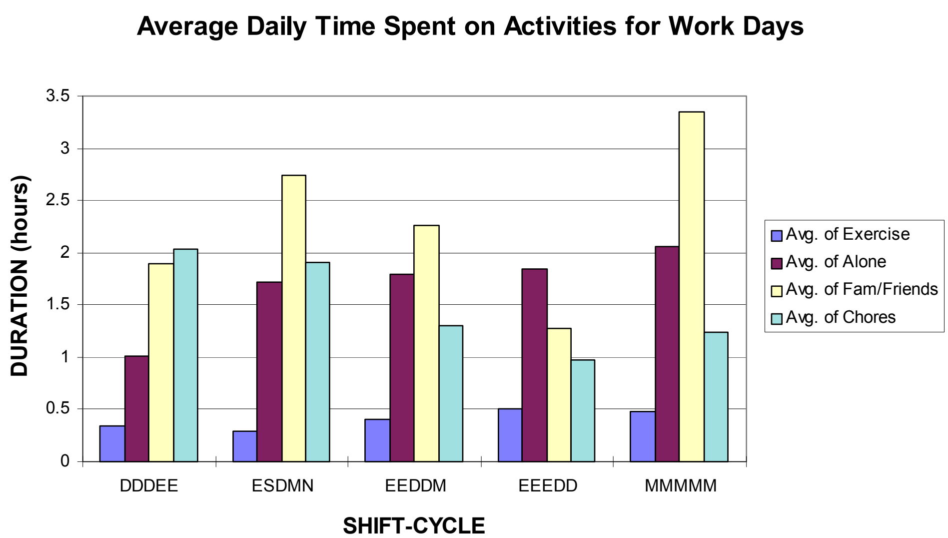
Generally, the distribution of time spent on activities can indicate how the time off from the shift can affect routine. If a controller is working midnights, he/she has a short time to carry out errands or do chores prior to the time when other family members or friends usually arrive home at the end of the work day. Hence, the time spent for the rest of the off-period will typically involve activities shared with family or friends.

On the other hand, evening shifts provide a greater opportunity for doing chores and spending time alone, but limits or eliminates the opportunity to spend time with the family or friends, who are at work, school etc., weekends excepted. Only in cases where a spouse, children, or other shiftworker friends are available during the morning and early afternoon hours, will the evening worker be able to socialise outside of work. The single quick-change

(EEEDD) shift-cycle involves three days where this situation occurs. The last two day shifts allow some time with family and friends.

The variety of the double quick-change shift-cycle (EEDDM) and the Gander shift-cycle (ESDMN) helps to allow controllers to engage in all activities, but may also be disruptive to any routine. However, the fact that meals are maintained during these shift-cycles in all but the midnight shift, indicates that some routine can be achieved. Midnight shifts do disrupt meal schedules and tend to reduce both the quantity and quality of meals, and the time of day in which they occur (see section 5.4.2 for a general description and section 5.4.3 for days off and work day comparisons).

Figure 5.4.4-1



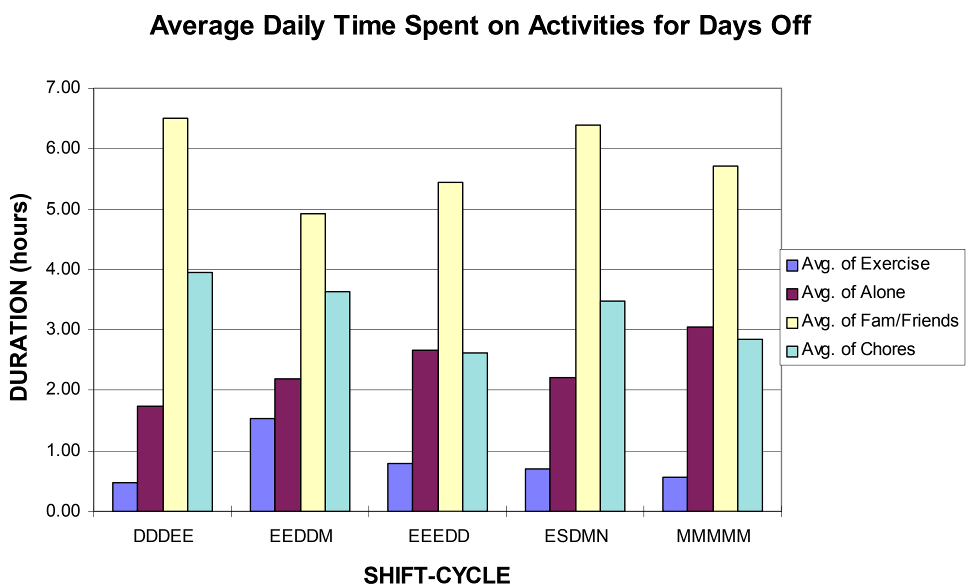
5.4.5 Average Daily Hours on Activities During Days Off

The distribution of time spent on specific types of activities is different on days off, compared to that of work days. First, all controllers indicated greater amounts of time on all activities, since they had more time available to them, as is expected (no time working). However, the ratios also changed. In fact they appear to be reversed. The controllers working the forward rotation (DDDEE) and the single quick-change (EEEDD) shift-cycles spent greater amounts of time with family and friends, the former spending the highest amount of time compared with the other shift-cycles. The controllers working consecutive midnights were no longer showing the highest amount of time with family and friends, but did spend the second highest. Those working double quick-changes (EEDDM) spent the least amount of time with family and friends, but spent higher amounts of time doing chores and on exercise.

Table 5.4.5-5: Time on Activities During Days Off

Shift-Cycle Type	Avg. hrs. Exercise	Avg. hrs. Time Alone	Avg. hrs. Family/Friends	Avg. hrs. Dom./Errands
ESDMN (Gander)	0.70	2.20	6.39	3.47
EEDDM (DQC)	1.54	2.19	4.92	3.64
MMMMM (mids)	0.58	3.06	5.72	2.84
DDDEE	0.47	1.73	6.51	3.94
EEEDD (SQC)	0.80	2.67	5.44	2.61
Total	0.82	2.37	5.8	3.3

Figure 5.4.5-5



5.4.6 Time on Activities During Days Off Compared with Work Days

Often one or two hours per day were unaccounted for. Unfortunately it is not evident what the time was used for. The comparison of trends in the data is more useful than actual amounts. Therefore, the following information should be considered in terms of trends rather than as absolute amounts of time spent. The data is best compared within each shift-cycle type to determine a trend unique to that shift-cycle type.

It appears that midnights provide more relative time to be with family and friends, and to be alone, but do not allow much time to do chores. Controllers working the single quick-change shift-cycle and the midnights shift-cycle spend slightly more time on exercises relative to the other activities, than those in the other shift-cycles, on work days (Figure 5.4.6-1). However, on days off (Figure 5.4.6-2), the days-to-evenings shift-cycle shows a higher relative level of time with families and friends, and the controllers on the double quick-change shift-cycle show more relative time on exercise. Perhaps the double quick-change shift-cycle prevents controllers from being able to fit exercise in, and, therefore, days off provide the opportunity to make up the lack. The Gander shift-cycle has the least differences between days off and work days.

The days-to-evening and the Gander shift-cycles seem to provide more time for chores, but the reason for this is unclear. The controllers on the midnight shift-cycle reported more of their time than did controllers working the other shift-cycle types.

Figure 5.4.6-1

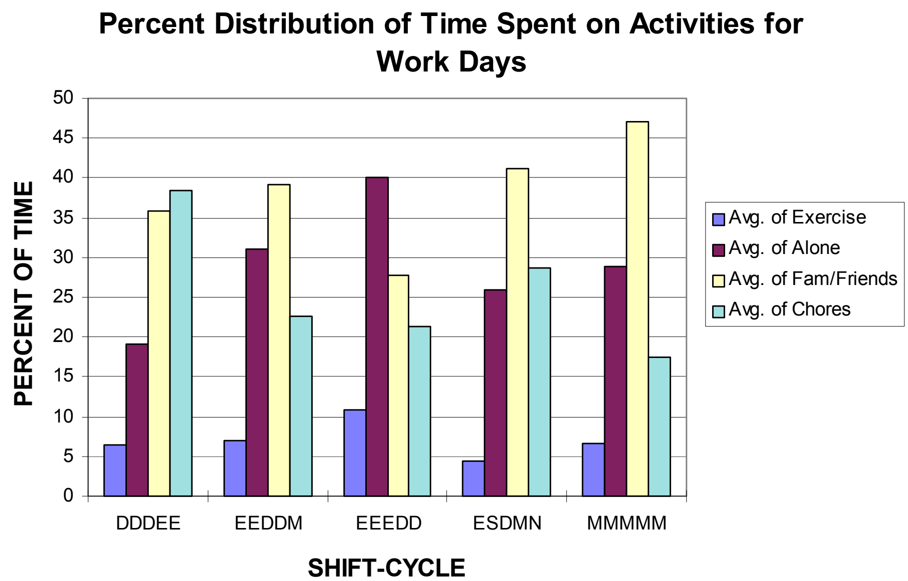


Figure 5.4.6-2

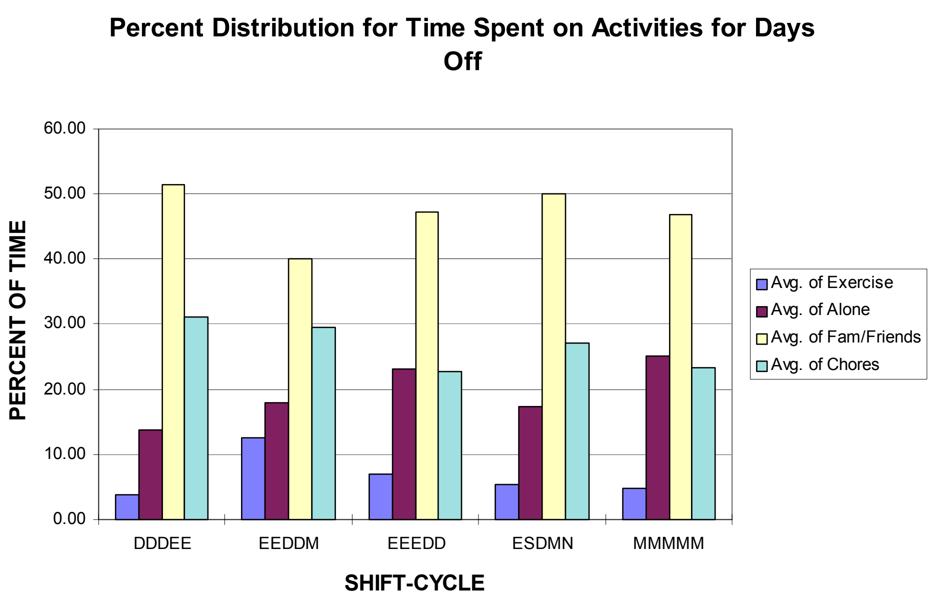
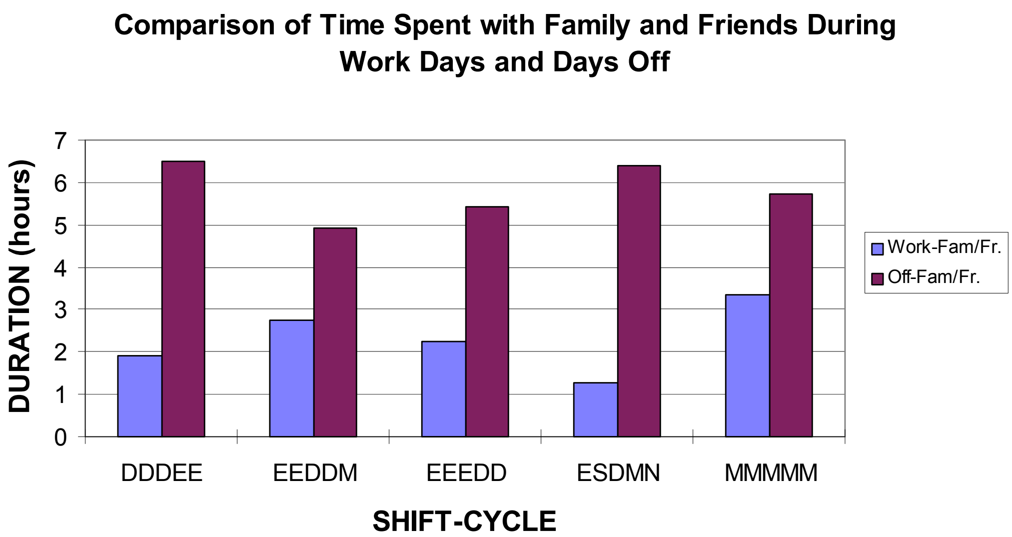
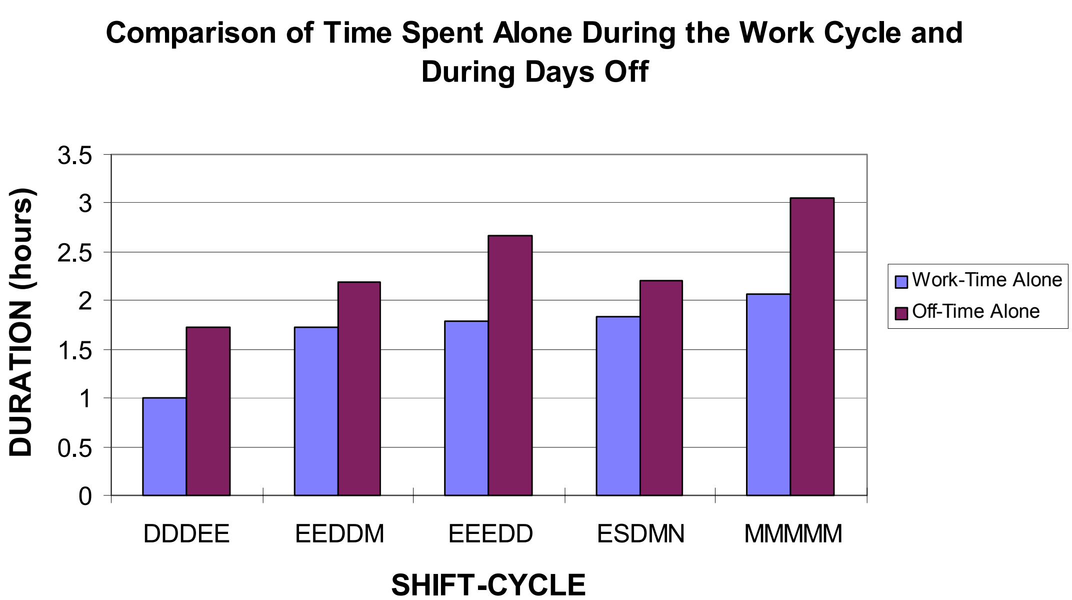


Figure 5.4.6-3



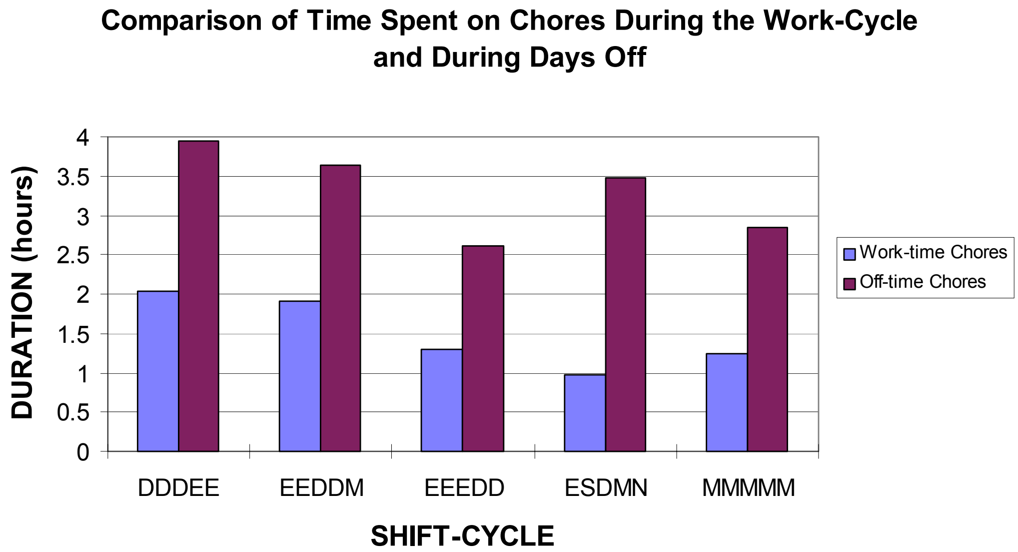
The amount of time spent on any activities was reported as consistently lower on work days. Also, there is variability in the length of time reported for all activities for all shift-cycle groups. This variability suggests that even on days off there are preferences for doing activities in varying amounts regardless of whether it is a work day or day off.

Figure 5.4.6-4



In some activities, for some shift-cycle types the trend for specific activities appears to be the same, though the magnitude is different (e.g. time alone increases at roughly the same proportion for each shift-cycle type [except for ESDMN]).

Figure 5.4.6-5



5.5 Melatonin Results

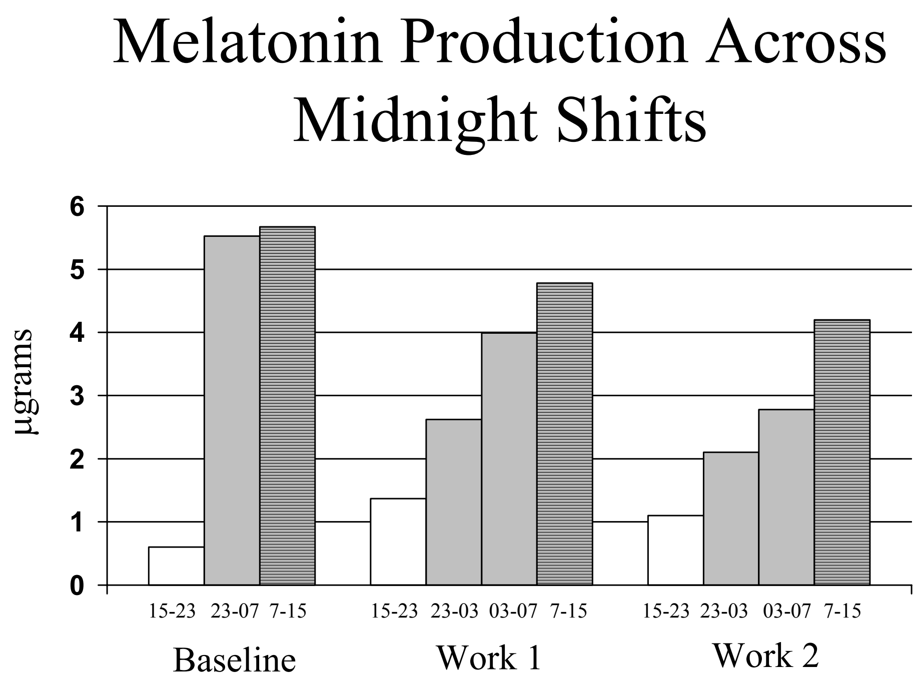
The results for the melatonin levels, measured in the urine collected during the 24 hour period around the sleep and work period that were monitored, show that the subjects did not shift their circadian rhythm. Figure 5.5-1 indicates that high amounts of melatonin are present in the over-night and early day-time samples. If the circadian rhythm had shifted across the consecutive midnights, then there would have been a decrease in 23:00 to 03:00 sample and an increase in the 03:00 to 07:00 sample. It is clear from the figures that there was no such phase shift in melatonin.

The Gander (ESDMN) and Moncton (EEDDM) controllers showed similar patterns in their baseline melatonin levels. There appears to be a considerable carry over into the early part of the next day (07:00 to 15:00 collection period), where melatonin levels are noticeably higher. Why this pattern occurs is difficult to explain, but may be due to the fact that those sleeping later would be providing their night-time sample in the early day-time collection period (07:00 to 15:00).

The Gander (ESDMN) evening sleep period prior to the midnight shift (second set of collection periods), appears to be normal in its distribution (highest during the double collection period in the middle - 23:00 to 03:00 and 03:00 to 07:00). However, the third set of collection periods shows a pattern similar to the baseline, although in smaller amounts. The Moncton (EEDDM) melatonin data for the second and third sets of collection periods appear normal. These two periods included a day shift and a midnight shift.

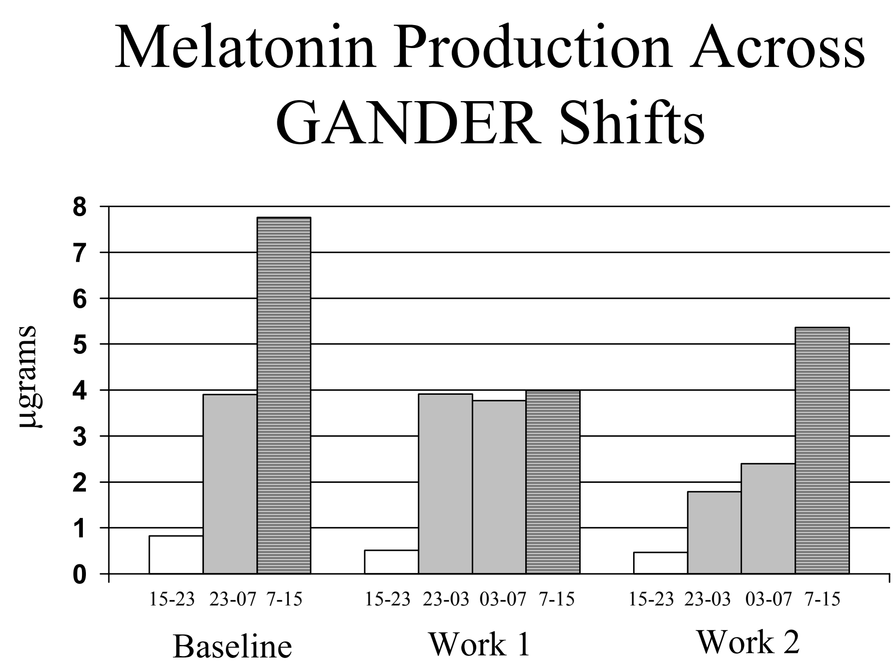
The Moncton and Gander baseline data and the Gander data for the second set of collection periods appear to be shifted to the morning, which was certainly not the pattern expected.

Figure 5.5-1



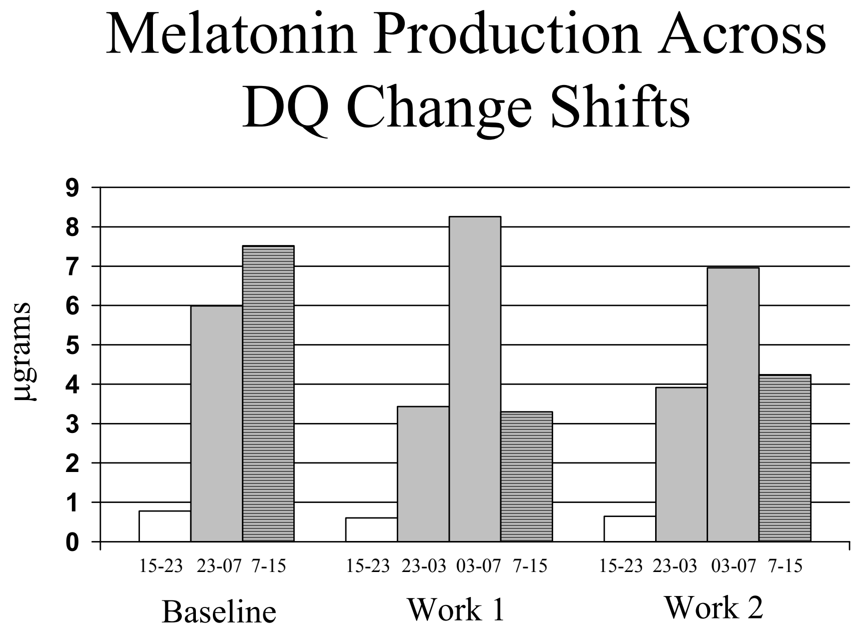
Melatonin Production Across Midnight Shifts
µgrams
6
5
4
3
2
1
0
15-23 23-07 7-15
15-23 23-03 03-07 7-15
15-23 23-03 03-07 7-15
Baseline
Work 1
Work 2

Figure 5.5-2



Melatonin Production Across GANDER Shifts
µgrams
8
7
6
5
4
3
2
1
0
15-23 23-07 7-15
15-23 23-03 03-07 7-15
15-23 23-03 03-07 7-15
Baseline
Work 1
Work 2

Figure 5.5-3



5.6 Overview of the Shift-Cycle Effects - Summary

This section provides an overview of the results for each Shift-Cycle Type. The results section is organised according to the type of shift-cycle worked. This way the focus is on the effects of the shift-cycle on the controller and on the interaction between the various factors (variables) examined in the study.

5.6.1 Midnight Shift-Cycle (MMMMM)

The midnight shift-cycle appeared to cause the following effects during the work cycle:

a) the middle part of the shift results in progressively poorer performance for cognitive tasks across the 5 shifts;
b) the last part of the shift in the morning leads to somewhat better performance;
c) reduced sleep overall according to log data (least amount for all shift-cycle types, overall) if all five midnight shifts are considered, but greatest amount of sleep on those days that were recorded sleep sessions, compared to EEDDM (Moncton) & ESDMN (Gander);
d) shorter naps than most of the shift-cycle types (except when compared to DDDEE);
e) shorter and poor quality sleep during first day sleeps, compared with the baseline and second day sleeps;
f) greatest amount of free time is spent attending to family, social and personal activities;
g) less time is spent on chores compared with the other shift-cycle types;
h) exercise second highest for all shift-cycle types;
i) meals are disrupted and average only 1.5 per day, and snacking is prevalent;

j) the physiology data indicates that micronaps and reduced alertness may be a potential problem during the midnight shift.

The midnight shift was generally more disruptive than any other shift. Even after five consecutive nights it was difficult for subjects to get a normal amount of sleep. In fact they incurred a sleep debt that was unlikely to be repaid during the shift-cycle (i.e. if any more shifts were to follow, like overtime shifts). Even during days off the entire off-period was used to recover from the midnights, catching up on lost sleep. Overall, the controllers working consecutive midnights lost the greatest amount of sleep, although the controllers working the Gander (ESDMN) and the double quick-change (EEDDM) shift-cycles experienced the least sleep during the two most difficult times of their shift cycle (see below in their respective sections). However, log data shows that the bulk of the sleep loss occurred during the last two sleep periods of the shift-cycle. Whereas, according to log data the controllers working consecutive midnights (MMMMM) accumulated more sleep loss over their entire shift-cycle.

Meals occurred at various times of the day depending on the time the subject woke up and the controller's other activities. Unfortunately it appeared that sometimes controllers had only one meal, or at best, two. To make up for the reduction in meal-times, controllers tended to snack more.

According to the melatonin results the controllers were not able to shift their circadian rhythm by the fourth work night. They appeared to be producing the same or even more melatonin during the times at which the melatonin level was expected to be high. Hence, no shift in circadian rhythms were found. Other influences must have been keeping the controllers on the diurnal schedule, such as low lighting in the centre and in the towers at night, bright light during the drive home and during the day (poor sleeping conditions or exposure to light during the sleep period).

Midnights did allow controllers to be around when their friends and family were home, and indicated more time on these activities. They had little time for chores (domestic or errands) and less time to be alone. In fact the most common meal of the day occurred during times with family and friends. The controllers working the midnights indicated the highest levels of caffeine during work, yet showed some of the lowest levels on days off.

Performance as measured with the computerised test battery showed that the controllers working midnights did do more poorly during the test at the midpoint of their midnight shift. They did the poorest at this time on reasoning and visual memory tasks (logical reasoning and pattern recognition). At the very end of the last shift of their cycle they appeared to be revitalised, and actually improved somewhat. Seeing the last of the tests and the end of their midnight shift-cycle likely improved their motivation to perform. Sleep deprivation studies often cite experimental effects where performance improves at the end of the study period (Angus and Heslegrave, 1985; Babkoff, et. al., 1985).

The EEG data collected during the midnight shifts indicate that there is a potential for micronaps and reduced alertness while on shift, as evidenced by increased Delta and Theta wave activity. Increased power levels in the Delta and Theta wavelength band is usually interpreted as the onset of lowered attention and a susceptibility to nodding off.

5.6.2 Gander Shift-Cycle Type (ESDMN)

The Gander shift-cycle type resulted in the following effects during the work cycle:

a) performance declines as much as 12% during some trials;
b) cognitive and psychomotor tasks are performed better toward the end of the evening, day and swing shifts;
c) cognitive tasks are performed more poorly in the middle of the midnight and night shifts;
d) perceptual and reasoning tasks were performed more poorly than psychomotor tasks;
e) second highest amount of sleep according to logs;
f) napping levels highest of all shift-cycle types;
g) evening sleep is very poor, and extremely short;
h) exercise levels the lowest of all shift-cycle types;
i) second highest amount of time spent with family and friends
j) third highest level of time spent on leisure activities alone, though all but the single quick-change (EEEDD) were very close to each other;
k) second highest amount of time spent on chores compared with the other shift-cycle types;
l) average number of daily meals is similar to the other shift-cycle types (except midnights), as are the average daily number of snacks.

The controllers working the Gander shift-cycle found the cycle taxing but workable. Their sleep was very poor when making the change from days to midnights, and they had poor sleeps during the day sleep between their midnight shift and the late-evening/night shift. The first part of the cycle is relatively easy to do since the day shift following the evening shift is actually a swing shift starting at around 09:30 in the morning. The third day of the cycle is a little more difficult, controllers having to work an early day shift (06:30). However, the fourth and fifth days of the cycle are the worst and cause acute sleep deprivation over those two days.

Meals are fairly regular and frequent during the first three days of the cycle, but become disrupted during the midnight and night shifts. Activities are also easy to fit in during the first three days, but like meals, this becomes disrupted by the last two shifts.

The controllers working the Gander shift showed improved performance on the test battery toward the end of each of the evening, swing and day shifts, but showed reduced performance toward the end of the midnight and night shifts. The same drop in the middle of the midnight shift occurred as in the midnights of the MMMMM shift-cycle.

5.6.3 Double Quick-Change (EEDDM)

The following effects were identified for the double quick-change shift-cycle type during work days:

a) performance declines by as much as 15% during some trials;

b) cognitive tasks get worse over the shift for the second evening, days and the midnight shifts;
c) cognitive tasks get better through the first evening shift;
d) tasks become worse during the 4th (day) shift and the 5th (midnight shift);
e) second shortest overall logged sleep period (next to midnights);
f) second longest naps (slightly less than Gander - both over 2 hours);
g) the evening sleep after day shift, prior to the following midnight shift, was characterised by a high percentage of SWS with very little REM sleep;
h) better than two meals, average, per day, though snacks are relatively high in number as well;
i) moderately restricted time with family, friends, and time alone;
j) reduced time spent on chores;
k) less time exercising than those on the midnight or backward rotating (single quick-change) shift-cycle types.

Controllers working the double quick-change shift-cycle managed to get reasonable sleep during the first two days of the cycle, but got progressively less and poorer sleep through to the end of the shift. The sleep between the evening shift and following day shift was shorter than the sleep during the baseline by 1 to 2 hours. Also, REM sleep is reduced in the quick-change sleep compared to the baseline sleep. The evening sleep between the day and midnight shifts was extremely short, and was characterised by a high percentage of slow-wave-sleep (SWS) with very little REM sleep. An acute sleep debt is incurred during the last two days of the cycle, as indicated by the very high sleepiness and fatigue toward the end of the last shift (midnight).

A progressive decrement in performance of the test battery occurs over the shift from the beginning, through to the end, for the last four shifts of the cycle.

5.6.4 Single Quick-Change (Backward rotating - EEEDD)

a) performance generally changed little over the shift schedule;
b) generally, sleepiness and fatigue increase toward the end of the evening shifts and start out high and decrease toward the end of the day shifts;
c) the longest average duration for main sleep period;
d) longest average nap duration;
e) second longest time spent on activities alone;
f) shortest amount of time on family, social or chore-based activities;
g) better than two meals, average, per day;
h) very few snacks;
i) longest average daily time spent on exercise.

Performance remains fairly consistent throughout the shifts, showing performance improvements in the middle of each shift. Also, sleepiness and fatigue fit the pattern, increasing from the beginning of the evening shift to the end, and decreasing from the beginning toward the end for the day shift. The single quick-change shift-cycle proved to be the least difficult shift as far as sleep is concerned. The controllers working this shift-cycle got more sleep overall and for each shift. The single quick-change shift seemed to disrupt sleep less than the other shift-cycles. Also meals were more regular and frequent, and less snacks were consumed. However, from a social point of view the shift allowed little time for family and friends, and more time for chores.

5.6.5 Days to Evenings (Forward-rotating - DDDEE)

a) cognitive performance on the day shifts showed declines in some tasks toward the middle of the day shifts and on the reasoning task on the evening shift after the change from days;
b) second lowest duration for average daily sleep (during work days and days off);
c) very little napping (during work days and days off);
d) highest amount of time spent on chores;
e) second lowest average duration for time spent with family and friends;
f) lowest duration for average time spent alone;
g) better than two meals, average, per day.

The controllers working the forward rotating shift seemed to suffer from the early morning start. Performance improves toward the end of the shift, and fatigue and sleepiness are higher at the beginning of the first two day shifts. A decrease in sleepiness and higher performance levels exist at the beginning of the third day shift when compared with the middle of this shift. The drop in performance and increase in fatigue and sleepiness during the middle of the third day shift may be indicative of building fatigue, though improvement does come at the end of the shift.

Meal frequency and regularity are good, more time is spent with family and friends than in most of the other shift-cycles, and more time is spent on chores than in the other shift-cycles. Sleep durations are low and very little napping occurs, possibly resulting in some level of sleep debt. Better sleep occurs toward the end of the shift-cycle.

6.0 CONCLUSIONS

Several major conclusions emerge from this study:

1. On average, significant sleep loss is experienced by most air traffic controllers working the 3 most difficult shift schedules, ranging from a mean of 47.55 minutes of sleep loss for the night-time sleep between the evening and day shift for the DQC group; and 208.50 minutes of sleep loss for the evening sleep during the day to midnight quick-change for the Gander group, not including additional sleep loss incurred on the other 3 work days.
2. Performance decrements of between 5 and 20% (for group data) occur as a result of both circadian rhythm and acute sleep deprivation effects.
3. Some individual controllers experience even greater performance decrements as a result of continuous midnights or multiple quick-changes, which lead to progressive deterioration in performance (from chronic sleep deprivation).
4. The evening-to-day shift-cycle, or EEEDD, was the only cycle that resulted in levels of sleep at or above the average.
5. Day shifts lead to some sleep restrictions.
6. Sleeping in the evening resulted in extremely short (<2.5 hours on average) and poor sleep, and was more like a nap than a major sleep period (considered to be any sleep greater than 3 hours) for most controllers.
7. Consecutive day-time sleeping results in chronic sleep loss.
8. Older controllers (>35 years old) get less sleep than younger controllers. Overall, half of the subjects were over 35, which is still a relatively young population. Therefore, age effects begin early, and affect a large portion of the controller population.
9. Meal frequency and regularity is severely disrupted by midnight shifts.
10. Social activities are reduced most by the evening-to-day shift-cycle (single quick-change).
11. Midnights leave little time for doing chores, but allow some time for family and friends.
12. Caffeine use was at normal levels but was higher during shifts where fatigue was evident.
13. Melatonin patterns indicate that **no** beneficial shift in circadian rhythm occurs during five consecutive midnights.
14. EEG patterns show that on **midnight** shifts, microsleeps and periods of inattention may be of concern, i.e., controllers appear to have difficulty remaining alert during midnight shifts. Other shift-cycles could not be evaluated.

6.1 Serious Sleep Loss

The controllers working the midnights (MMMMM), Gander (ESDMN), the double quick-change (EEDDM), and the days-evenings shift-cycles all experienced varying degrees of sleep loss which most sleep researchers would consider to be significant. The first three shift-cycles had sleep durations on certain days which were extremely short (less than 23 minutes), and in most cases were almost half of what could be conceived of as the normal sleep duration for the controllers. This is seen when comparing the baseline sleep durations with the day and evening sleep periods. Often the evening sleep period was less than half of the baseline.

Since the logs showed consistent sleep estimates compared to objective recorded sleep, logs can be used to estimate other sleep patterns. When sleep for days off was compared with sleep on the work days, sleep is significantly restricted. Controllers are, therefore, incurring a sleep debt during their shift-cycle.

6.2 Evenings to Days Shift-Cycle Optimum for Sleep

The evenings-to-days shift-cycle appears to provide the opportunity to get adequate sleep during the cycle. Unfortunately, this shift-cycle does not allow very much time with family and friends, particularly during the evenings portion. Some controllers slept-in late on work days prior to going in to work, leaving little time for other activities. Part of this pattern was due to staying up late after the evening shift prior to going to bed. This time was often spent alone watching television or reading, etc.

The superiority of the backward rotation of this shift-cycle over the forward rotating days-to-evenings shift-cycle (i.e. that it provides a greater opportunity for sleep) is in contrast to the expectations of the literature. These expectations are based on the assumption of circadian rhythmicity exceeding 24 hours and favouring a forward rotation. Clearly in this case, controllers had made behavioural sleep adaptations which provide greater benefit than the advantage of lengthening the circadian cycles.

6.3 Patterns of Performance, Circadian Rhythm and Sleep Loss

This study does not have the control of a laboratory study, leaving the data somewhat noisy. There is, nevertheless, a clear relationship between performance and time of day. Controllers perform more poorly during times when the body is set for sleep. This was observed during the midnight or night shifts at approximately 03:00 when the circadian rhythms are typically at their lowest. Similarly, early day shift performance is lower compared to performance later in the shift when the body's internal clock cycles to the peak of the activity phase. Also, performance following acute sleep loss (for quick-changes) appears to be poorer than at times following longer sleep durations.

6.4 Chronic Sleep Loss and Performance

The effect of chronic sleep loss is evident in the consistent dips in performance during the midnight shift, which are only partly due to circadian effects. The decrements seen in the midnight data, combined with the subjective sleepiness and fatigue scales, indicate that the controllers are becoming more fatigued as the shift progresses. Although this same pattern does not appear at the end of the shift-cycle, it is likely that motivational and adaptive factors may be affecting the performance and the mood in controllers at the end of the shift cycle.

6.5 Days-to-Evenings Result in Sleep Loss

It seems that the early start on day shifts results in sleep loss that is almost as severe as that found during the midnight cycle, the Gander cycle, and double quick-changes. Sleep durations during the day shifts were much shorter than on days off and during evening shifts.

6.6 Sleeping in the Evening is Difficult for Most Controllers

Very few controllers managed to get more than just a couple of hours of sleep during the evening sleep periods prior to their midnight shifts. This sleep was also characterised by reduced REM sleep and disproportionately higher levels of SWS, indicating that there was an increased need for restorative sleep which remains unsatisfied. The self-report by controllers revealed that many just napped in front of the television or on the couch after dinner. Only a few controllers actually planned their sleep and achieved near-acceptable levels of sleep during this period of the day. Awareness of sleep hygiene principles would appear to benefit controllers.

6.7 Consecutive Day-Time Sleeping Results in Chronic Sleep Loss

Sleeping during the day for five consecutive days results in a mounting sleep debt. Each day-time sleep averages about 4.25 hours, as compared to the average of 6.25 hours, a full two hours less. This level of sleep loss results in a significant sleep debt which the body must cope with more and more toward the end of the cycle as the debt builds.

6.8 Older Controllers Get Less Sleep

The logged and recorded sleep results showed that the older controllers (over 35 years of age) achieved less sleep (about one hour less) than those who were younger. This is consistent with other study groups and is likely reflective of the body's natural ageing process. It should be noted, however, that most individuals in this study sample were between 30 and 45 years old. Hence, relative to the general population, they are still quite young. Of course, even at 35, controllers do begin to feel their shiftwork more, and report that it is increasingly difficult to do shiftwork after the age of 35 (according to the Phase One results from this study).

6.9 Midnight Shifts Curtail Meals but Work Well for Social Activities

This study clearly shows that controllers find it very difficult to eat proper meals when working the midnight shift. With very few exceptions, controllers demonstrated very little consistency in meal-times, and missed several meals during the midnight shift. Also, the types of food eaten may not be optimum for the digestive system or for inducing alertness during the work-shift.

On the other hand, midnights provide opportunities for social interactions. However, there are no data in this study to determine whether this opportunity is a positive experience for controllers, their family and friends. The literature suggests that working nights can cause friction, particularly if the shiftworker is fatigued and becomes irritable (Knauth and Costa, 1996).

6.10 Evening Shifts reduce Social and Family Activities Considerably

The evening shift disrupts social and family activities, leaving time for them only late at night after the end of the shift, or during the morning. This means controllers who want to engage in social and family activities must plan morning get-togethers, usually with other shift workers, or encourage friends or family to remain awake late into the night.

6.11 Caffeine Use was Higher on Midnights, the Gander Shift and Double Quick-Change Shift-Cycles

Caffeine use by controllers was higher for those working shift-cycles that tend to cause more fatigue. This situation is not surprising, is consistent with that found in other studies, and indicates that controllers may be compensating for loss of sleep. The amount of caffeine consumed on days off was lower for all shift-cycle types except the days-evening shift-cycle. The levels were much lower for the Gander and double quick-change shift-cycles, while midnights showed only a slight drop. Controllers working consecutive midnights also showed higher levels of caffeine intake, generally, suggesting that these individuals may develop a lifestyle that incorporates caffeine to a greater extent because of the shiftwork. Such lifestyle changes may be detrimental to health in the long-term.

6.12 Melatonin Levels show that No Shift in the Circadian Rhythm occurs

The levels of melatonin collected in the urine showed that the circadian rhythms of controllers remained unchanged during all shifts and were similar to those for individuals keeping a normal diurnal sleep/wake schedule. This held true for all three groups included in this component of the study. This conclusion is most important regarding the midnight shifts, indicating that the controllers' bodies were still in a circadian state more conducive to sleeping than to being awake. Thus, workers do not appear to adapt to a midnight shift routine, as generally assumed by many controllers (from Phase One results).

6.13 Brain-wave Physiology (EEG Results) indicates Lower Levels of Attention on Midnights

The EEG data collected for some individuals working the midnight shift were analysed. The data show a shift in the power toward more slow, synchronous activity, primarily in the theta range of wave-length. This indicates that there is an increased probability that micronaps and periods of inattention across the midnight shifts may occur. The implication is that the controllers are working hard to overcome the urge to sleep during a good part of their midnight shift. Unfortunately, too little useful data could be obtained from the exploratory data collected in the Gander and Moncton.

7.0 DISCUSSION

7.1 Impact Of The Shift-Cycles On Sleep and Performance

7.1.1 Fatigue and Performance

This study focussed on how shift-cycles affect the quality and quantity of sleep, the degree of fatigue development from either chronic or acute sleep loss, and the magnitude of performance decrements. The results indicate that fatigue caused by either acute sleep loss or accumulated fatigue will result in some decrements in cognitive functioning, which in certain situations are significant contributors to poorer job performance. The added effects of the circadian rhythm worsen the decrement in cognitive functioning. Since the present results show that perceived fatigue and sleepiness are also related to these times of reduced cognitive performance, there is convergent evidence for fatigue being a major contributor to performance impairment in Canadian Air Traffic Control.

The decrement in cognitive functioning observed in this study (up to 20% for group means) is large enough to warrant action. Even though the workload may be extremely low at certain times, events can unfold where tough decisions must be made, very quickly, and information processed correctly in order to avert disaster.

There is also concern in situations where even a steady flow of reduced traffic may also be difficult for a controller who is sleep deprived, and who is working when his/her circadian rhythm is at its lowest ebb (i.e. when the body wants to go to sleep). Increases in traffic levels due to courier and other night-time activity may introduce more opportunities for taxing reduced cognitive resources. The controller's ability to handle decision-making and memory tasks impaired due to lack of sleep and the body's circadian rhythm. During the night the body is preparing itself to sleep, and temperature and heart-rate is declining. This state also affects the cognitive abilities, causing a decrement in performance. Low traffic levels considered (qualified) to be below the controller's normal workload limit, may be high enough to compromise performance in a non-normal working environment, i.e. controlling aircraft in the middle of the night.

The performance decrement observed during the middle period of the midnight shifts indicates that indeed the circadian rhythm is suppressing cognitive abilities. Such decrements may also be a function of building fatigue as controllers continue to experience short day-time sleep periods. This building fatigue is not consistent with the apparent "second wind" at the end of the shift-cycle, where performance actually improves. Such a result shows that there is more affecting performance than lack of sleep or circadian rhythms. Motivation and the controller's mental state at the time will influence performance levels and will affect mood. Still, controllers' subjective ratings for sleepiness and fatigue show a progressive increase throughout each midnight shift, while ratings of activity declined as the shift progressed.

7.1.2 Night-shift Effects

The night-time quality of the environment in which the controllers working consecutive midnights operate is a major factor contributing to performance decrements. The lighting levels are very low and sleep-inducing. There is a need for a complete comprehensive ergonomics assessment to determine how to increase lighting levels and still maintain a functional environment (no glare on screens, and design of workstations which are effective in a bright environment).

Activity levels during midnight shifts at centres such as Toronto and Moncton are generally low and the centres are extremely quiet, also contributing to the inducement of sleep. Around 03:00 when the testing is performed, the lowest ebb in the circadian rhythms also coincides with the lowest period air traffic at most facilities. It is possible that the stimulus of increased air traffic contributes to increased alertness and activity at the start and end of the midnight shift seen at the Toronto facilities.

Care should be taken when staffing a control centre during night-time operations. Although traffic levels may be considered low, the working environment, as in the midnight shifts, will affect the ability of controllers to perform their tasks. Without breaks, controllers will be further affected, since sedentary inactivity during the time when the body wants to sleep will contribute to a greater urge to nod off. A nap, or taking a walk and getting away from the workstation, particularly in bright light conditions, will help to suppress this drive to sleep. By not allowing such a break, controllers are put at risk since their cognitive abilities are reduced by a building fatigue and a lowered circadian rhythm. Their inability to offset these problems, because they must remain at their workstation, may lead to errors in judgement and other potential errors related to memory lapses or inattentiveness.

More active night-time work such as found in the Gander ACC, where air traffic levels are high, helps to alleviate the drive to sleep during the shift. Also, the opportunity for short naps, since staffing levels allow this, improve the controller's ability to remain attentive, and able to handle various cognitive tasks such as those involving memory, decision-making and perception. Bright lighting and day-like working environments enhance the effect. For Gander a sleep-inducing environment appears to be less a problem. Acute sleep loss, however, may be a concern, since the quick-change from the day shift to the midnight shift results in very little and even no sleep, contributing to the declining performance seen in the study results. This is clearly shown in the ratings for sleepiness, fatigue and activity given by the Gander controllers. Sleepiness and fatigue increase from beginning to the end of the last two shifts (midnight and night shift) while activity declines steadily.

The Gander controllers have the opportunity for naps at any time during the day or night, providing there is adequate staffing. This practice probably helps the controllers maintain alertness and good cognitive functioning during most of the shift, and helps to alleviate some of the sleepiness which may follow the poor evening sleep prior to the midnight shift. This practice may also be beneficial for other centres during the midnight shift, helping controllers to maintain their performance levels.
Unfortunately, decrements in performance still occur in the middle of the midnight shift, again likely due to circadian effects. Also, the decrements occurring at the end of the night

shift indicate that the level of acute fatigue caused by the reduced sleep periods in the evening and day-time, are still a problem.

Performance decrements occur at the end of the double quick-change shift-cycle, during the last day shift and the midnight shift. The effects of two day shifts in a row where controllers experience reduced sleep, and the poor evening sleep before the midnight shift led to reduced performance towards the end of these last two shifts.

7.2 Sleep Quality and Duration

The quality of sleep as measured by the percent contributions of REM and SWS, and the latencies to SWS and to REM, can illustrate whether accumulated fatigue is a problem, and whether the sleep period experienced is adequate to provide sufficient restoration for proper functioning during the next shift. Day sleeps for the controllers working the midnight shift-cycle showed increased SWS and REM sleep (after the first midnight shift and fourth midnight sleep). These sleep periods also showed shorter latencies to SWS and REM sleep. These results are consistent with the type of sleep experienced by individuals suffering mild to moderate sleep deprivation. If such a pattern were to persist for longer periods of time, such as more than five shifts, as would occur if overtime shifts were worked, chronic fatigue would become a problem. This would include following the last midnight shift with an afternoon shift or another midnight shift. Following this work schedule with a day shift would definitely result in severe sleep loss (debt), no matter how efficient a sleeper an individual is.

The quality of the sleep achieved by the controllers working the Gander shift-cycle is characterised by an evening sleep where SWS is increased by 20% over the baseline, and the REM sleep is decreased by half. This evening sleep was very short (less than two hours) and would be expected to have REM sleep reduced because of this short overall length. REM sleep occurs near the end of any sleep period, and a shortened sleep would likely be ended before the normal amount of REM could be achieved. The higher amount of SWS is probably an indication of a sleep-debt being repaid.

The day sleep for the Gander controllers also had 20% more SWS than during the baseline sleep, but they achieved the same level of REM sleep as the baseline. This sleep was on average about 3.75 hours, which is short enough to result in a serious sleep debt when combined with the significant sleep loss which occurs during the evening sleep the day before. Any overtime shifts following this day sleep period would almost certainly be affected by this sleep debt, and the controller working such a shift would be adding more stress to an already stressed body. The results of this study imply that controllers working their normal five day shift have already built up a sleep debt, and are in need of recovery sleep. The older the controller is, the more this restoration is required.

7.3 Interpretation of the Logged Activities

The logs revealed some very interesting patterns. Those working consecutive midnights not only had difficulty getting enough sleep, but also found that meals were severely disrupted. Trying to fit in a main meal for the day seem to be the only meal consistently taken. Other meals either did not happen, or were taken at different times from day to day. All controllers had their main meal before 22:00, none having any meal after this time. This is a useful strategy which helps to avoid stomach problems. Unfortunately, snacking is common on the midnight shift, including chocolate bars, potato chips and popcorn. Some controllers did bring pasta, fruit and vegetables, but these were the exception rather than the rule.

A similar pattern as seen in the midnight shift-cycle occurs during the midnight shift in the double-quick-change and Gander shift-cycles. Meals are skipped, snacks are more prevalent, and activities are affected. The main problem seems to arise from controllers being asleep during the times when meals are normally eaten. Also, since the midnight shift requires that controllers work at a time when the body does not digest food very well, many plan to have a single large meal a couple of hours before work. This is an excellent strategy but if this is the only meal of the day, the impact of the meal on the body is less than ideal. In fact, a better strategy is to have a well-balanced lunch shortly after waking up, then another main meal (dinner including the four main food groups: meat and poultry, dairy products, fruit and vegetables, and grain products).

Variability in mealtimes is high for some individuals, and there are a number of subjects who skipped meals altogether. This irregular meal schedule can hinder diet and the digestive system, causing various gastro-intestinal problems (Costa, 1996) among other ailments. The lack of consistency in meals also can lead to unwanted weight gain or weight loss. The consequence of these ailments and conditions is often poor overall health. Combine this with poor sleep and sleep loss, and health is further affected with cardio-vascular and other disorders (Costa, 1996). The rates for these diseases and disorders are higher for shiftworkers than for day workers (Costa, 1996).

Unfortunately, no longitudinal studies have been carried out to examine the actual impact of shiftwork on health compared with control groups. Studies conducted so far have been inconclusive and mostly show only slight differences in the age of mortality of shiftworkers compared to the rest of the population (lower for shiftworkers). Since shiftwork puts such a high level of stress on the body, the chances that it may shorten life seem high. It may be that the shiftworkers who are most affected by such stress have dropped out of the shiftworker population and joined the day worker ranks. In fact some studies do confirm this situation, showing that the inclusion of these individuals in studies does show a higher frequency of certain diseases among shiftworkers compared to day-time workers (Koller et. al., 1978; Frese and Semmer, 1986).

Caffeine intake during work was higher for many of the controllers working the midnight shift, though not unusual. Most stopped drinking caffeine before 03:00, recognising the need to allow the body to eliminate this stimulant before bed-time. Less caffeine was consumed by the controllers working the other shift-cycle types, but those working the Gander and double quick-change shift-cycle had levels which were almost as high as those working straight midnights. On days off most controllers drank almost half as much caffeine as during work shifts, though many of the controllers working consecutive midnights drank almost as much caffeine on days off as on work days. This heightened caffeine consumption may be a lifestyle by-product of shiftwork involving midnights. Controllers working days-to-evenings were an exception, drinking slightly more caffeine on days off.

Controllers working the midnight shift-cycle (MMMMM) reported that they spent most of their time with family and friends, and alone, with less time for chores. Perhaps the time of day for sleep and when they awake leaves little “convenient” time to do chores. Also, the waking time when not at work, is at that time of the day when family and friends are likely to be around. Contrary to this, those working days-to-evenings (DDDEE) reported much less time with family and friends or alone, and much more time on chores, while the Gander (ESDMN) and double quick-change (EEDDM) controllers had a more even distribution of time spent on all activities except exercise which was lower. The evening-to-days (EEEDD) controllers spent a proportionally longer time alone. Again these results reflect the times in which certain activities can be conducted, when it is most convenient to do them so that controllers must arrange them according to the shift they are working. As is expected a more even distribution of time spent on activities occurs in the mixed rapid rotation shifts. Unfortunately, such shifts may disrupt routine and make planning of activities with other people difficult.

7.4 Interaction of Shiftwork Variables on Staffing Levels

Reducing staff levels, either because of illness, vacations or low traffic volume (e.g. midnights) must take into account the variables that have been discussed throughout this report. Three potential problems arise from inadequate coverage - 1) poor performance from those controllers who are on the shift, resulting in a greater potential for operational errors; 2) reduced overall effectiveness of the system, resulting in the potential for system error; and 3) increased stress on controller health and well-being. The first two problems are the immediate results of short-staffed situations, whereas the third problem may not become apparent until later, when the supply of replacement controllers becomes lower than the demand.

One major concern with low staffing conditions is whether the operation can continue to function effectively and safely. If controllers are stressed from critically high work-loads, and are suffering from fatigue from working overtime or from continually high work-loads, the situation degrades even further. Add to this the effects of circadian rhythms, as is the case on the midnight shift, the potential for error and ineffectiveness increases.

High workload is a function of the task demands and the duration of sustained work. Controllers sometimes must work at a steady pace, maintaining vigilance and good conceptual functioning for hours at a time without a break. This situation becomes more common when staffing levels are reduced such as during the summer vacation period, when abnormal numbers of controllers are off sick, or during a midnight shift where reduced staff levels are the norm. Sustained workload will be a strain if sleep loss is an issue, or if the circadian rhythm is at its lowest.

Hence, long periods of controlling with no actual breaks in between, occurring with regularity over a number of shifts, combined with a building sleep debt and working at a time when the body wants to sleep, and characterised by fluctuating operational workload, are all conditions where the potential for error is increased. Those working strings of midnights face this type of situation all the time.

What can be done to improve this situation? A number of solutions are available, but they all cost, initially. However, these costs are only a fraction of the costs associated with accidents, incidents, reduced revenue through poor performance, and long-term health and disability costs. In the long run the system would achieve large savings from reduced time off, improved performance and safety, and better service. First, the improvement of sleep during those day-time sleep-periods which working midnights demands would help to reduce some of the fatigue. Second, allowing for naps and breaks during the midnight shift would improve performance, reduce fatigue caused by sustained work, and decrease the number of days off taken for illness. Reduced illness days would also reduce the need for overtime shifts. Third, providing a bright, active environment would reduce sleepiness and perceived fatigue. The dark, quiet mystique of the midnight shift in some centres and all towers is counter to the nature of the human body; thus performance is compromised and the body is somewhat confused.

The Gander centre is very active throughout the midnight hours and tends to be brighter than most centres. This is important to maintaining an efficient, effective operation. Part of the reason for activity being high is that traffic levels handled by Gander at night are unusually high compared to other centres. This does, in fact, help to induce greater vigilance and alertness than in the less busy centres. At these centres levels drop off to no traffic during some hours of the night. This lack of operational workload can lead to severely reduced vigilance and attention. At such moments controllers can suffer micro-naps (as our data suggests) and, in fact, do nod off. The inactivity will lessen the controller's ability to stay awake and alert. Unless alarms, radio talk or another controller pull the individual out of his/her reverie, the controller will not be able to respond appropriately.

Performing exercises at the workstation is recommended for all controllers, during any shift, to relieve tension and to promote blood flow through the limbs and to the brain. This type of exercise should include stretching and deep breathing. The same exercises can help to improve a controller's ability to stay alert and vigilant. In fact, a good twenty minutes of exercise during a break can rejuvenate a very tired and fatigued body after sitting for hours. For those who exercise regularly, this would be an excellent time to do it.

However, it cannot be stressed enough that the only intervention that has the potential for reducing cognitive performance decrements brought on by sleepiness in the long-term is adequate sleep. All other interventions provide temporary relief and a false sense of altered functioning.

8.0 RECOMMENDATIONS

Based on the study results, the following recommendations are suggested:

1. Stress the importance of sleep hygiene and sleeping strategies by controllers and management.
2. Shiftwork and sleep awareness training for controllers and their families should be developed and implemented soon.
3. Sleep hardiness training approaches should be evaluated for effectiveness and feasibility for the air traffic control environment.
4. Napping during midnights, or at least the opportunity for breaks, should be investigated and the impact researched.
5. A study of the severity of midnight shift inattentiveness in air traffic control should be considered, given the fact that many studies have identified this as a potential problem.
6. Meal planning, dietary information and scheduling strategies should be included in controller training.
7. A review of shift scheduling practices based on the effects of the circadian rhythm and the physiological limitations of controllers (e.g. overtime of any type immediately after the normal work-cycle should be avoided).
8. Investigate the impact of circadian effects and fatigue on staffing levels.

8.1 Sleep Hygiene and Sleeping Strategies

Getting the proper amount of sleep is an excellent way to promote both good health and effective performance. The building of a sleep debt not only makes doing your job tough, it also makes you more susceptible to disease and leads to your being in generally poor physical condition. Without the right amount of sleep, life just seems to drag on and it is difficult to look at day-to-day challenges in a positive manner. Many shiftworkers say lack of sleep makes them feel just plain miserable! Many spouses and families agree as indicated by the 50% higher divorce rate among shiftworkers. The present study indicates that many of the controllers working all of the shifts, but particularly the double quick-change, consecutive midnights and the Gander shift-cycles, do not get enough sleep. In fact, severe sleep debts are likely to have been built up by many of these controllers, to the point that both health and performance may be compromised. Their professionalism is probably the main factor in their success at persevering when the going gets tough.

Intervention programs for helping controllers to cope with shiftwork must include, as a main component, guidance on how to improve the sleeping environment and to prepare for sleep, what to avoid prior to sleep, when to sleep, and how to stay asleep. The problems facing most of the controllers studied in this research were their inability to take advantage of the times they had to sleep, and the fact that many sleeping periods are during the day. The former problem is related to personal scheduling of sleep/rest periods (i.e. trying to fit the sleep period into a busy day). The latter problem is a result of the disruption of the circadian rhythm (i.e. sleeping during the part of the day when the body wants to be awake).

Improving the sleep environment will help to induce sleep, even when their circadian rhythm suggests wakefulness as suggested by various authors (Folkard, 1996). Dark conditions produced by light-tight blinds, or blindfolds over the eyes, keep the ambient lighting down to night-time levels, helping the body to accept sleep more readily. Quiet is necessary to reduce distracting noises which tend to awaken a sleeping individual. A fan or white noise device can mask out most disturbing noises, along with air conditioning which allows the windows to be shut in summer, keeping outside noises from intruding on slumber. Keep phones silent and make sure people know a shiftworker is sleeping, so as not to disturb the sleeper.

Second, preparing for sleep must be routine and familiar, to take advantage of alternative zeitgebers, or stimuli, to entrain the body. Brushing teeth, getting the normal sleeping clothes on, reading a short while if usually done, and performing relaxation exercises if appropriate. This strategy must be done in exactly the same manner as when preparing for bed at night, even when it is an evening or day sleep. That way the mind and body are more likely to accept this as a proper sleep period, rather than just a nap.

Third, the controller must make sure that heavy meals, food that upsets the stomach, or caffeine are avoided too close to bed-time. Each person has a period of time in which caffeine is eliminated from the body. This amount of time is individualistic and varies from person to person. Also, alcohol prior to bed will not only disrupt the sleep period and compromise the quality and quantity of sleep achieved, but will also act as a diuretic and cause one to get up part way through the sleep. Making sure that these items are avoided will improve sleep considerably, and allow a controller to fall asleep more readily even during the day time. Furthermore, adding positive dietary strategies to any of the above techniques will increase the chances of sleep onset, such as consumption of small amounts of foods rich in proteins (including tryptophan) such as milk, chicken, almonds, and turkey an hour or so before going to bed.

Fourth, relaxation strategies such as autogenic training, relaxation exercises, meditation, reading, mild exercise, or any other means to relax the body and mind, all need to be investigated. There is a need for controllers to discover natural ways to relax which work for them to help them get to sleep.

8.2 Shiftwork and Sleep Awareness Training

It is recommended that the committee members (ATCOH Program, CATCA, Air Traffic Services, TDC, and Civil Aviation Medicine) develop a training program which will help controllers, supervisors, managers, and others in the operational end of the Air Navigation services understand what they can do to improve the shiftwork environment and to improve sleep hardiness and hygiene. This program should involve four components:

1. Development of the shiftwork countermeasures program itself;
2. Training for those who will be responsible for conducting the training sessions;
3. Conducting a set of pilot training sessions;
4. Evaluation of the effectiveness of the training.

The development of the shiftwork countermeasures program should involve input from all of the stakeholders who will benefit from it. Information gathering meetings should be held with ATCOHS, controllers (e.g. CATCA regional directors), and ATC operational management, which should be structured so that specific content and approaches for the training can be identified and defined. The initial draft materials for the program should be reviewed by the committee members. Using this input the training program could be designed and presented at a presentation meeting. Such a program should be supplemented by an easy-to-read primer that could be developed for all shiftworkers to explain the nature of sleep, circadian rhythms, shiftwork, and tips to counter the effects of shiftwork.

The training of those who would be responsible for conducting the training once it is approved, should receive instruction from specialists in shiftwork management. This instruction should benefit from experience with other existing shiftwork and fatigue countermeasures programs.

Pilot sessions for the training should be conducted to identify problems and information necessary to fine-tune the program. Following these pilot sessions participants should be asked to complete an evaluation questionnaire and could be interviewed for feedback on the training. This information should be analysed and the results used to improve the training program. The evaluation questionnaire should then be modified to be used to provide feedback about the training program from there on.

8.3 Evaluation of Sleep Inducement Training Approaches

Various approaches for sleep inducement training should be evaluated to determine the effectiveness of such approaches. Some of the candidates could be:

- Autogenic Sleep Training,
- Deep Relaxation Exercises,
- Meditation,
- Mild Exercise,
- Combinations of these.

Additionally, light therapy and melatonin therapy can be explored as methods for shifting circadian rhythms to aid both work and sleep requirements. The approaches could be assessed as a complete study or could be done separately and the data compared at a later date. The advantage to doing the work as a complete study is the continuity and consistency available when conducted during one time period and in the same surroundings, allowing for some control of external variables.

8.4 Napping and Breaks

Midnight shifts are particularly difficult to work for many controllers because they occur during a period when the body wants to sleep. The melatonin results show that no shift in the circadian rhythm occurs, which suggests that the controllers' bodies still want to go to sleep. This being the case, the controllers are having to constantly fight to keep awake. Older controllers may find this even more difficult since, generally, they get even less sleep during their day sleeps than the younger controllers (Gander's older controllers got more sleep during the evening sleep period). Since the sleepiness and fatigue felt during the midnight shift is one of the causes of declining performance over the course of the shift, taking a nap may be one of the strategies a controller could use to "bounce back". There is evidence available showing that short naps (about 20 to 40 minutes in length) may enhance performance (see Costa, 1996b for a review). The benefit of napping has been investigated for pilots by Rosekind et. al., (1994) where it was found that naps of 40 minutes in duration, preceded by a 3 minute preparation time, and followed by a 10 minute recovery time, resulted in considerably fewer micro-naps, and improved performance. However, the true benefit of short naps during difficult schedules is largely unexplored and research dedicated to the short and long term effectiveness of napping would be extremely valuable.

Providing controllers with opportunity to rest, take a nap, go for a walk, even get away to eat their meals, would improve their ability to stay alert and reduce the risk of making errors. The danger of toughing it out is that cognitive resources will be seriously hindered if the controller were needed to respond to an emergency. Also, if the controller must switch gears and begin to handle building traffic, such as during small rushes in courier activity, or during the beginning of the early morning rush, he/she will be less able to perform critical cognitive tasks effectively. Taking a nap part way through the midnight shift may reduce the effects of fatigue and circadian rhythm, leading to more reliable cognitive functioning.

It is recommended that napping strategies be investigated in a simulation environment where the duration, time placement, and quality of the nap can be compared to on-the-job performance, subjective feedback and post-sessions interviews, using controllers trained in napping strategies, and a control group. Moreover, simultaneous field studies with limited measures should be conducted to ascertain the effect under real world conditions. This approach might involve providing trained controllers with scheduled nap opportunities during their shift. They could be asked to participate in performance, sleepiness, and mood assessments at specific points during the shift. A control group that did not nap could be compared to the groups using the napping strategies.

8.5 Severity of Midnight Shift Inattentiveness in Area Control Centres and Towers

Further research on the severity of inattentiveness and sleepiness at night in control centres and towers is warranted by the findings of this research, and that of others (Stager & Hameluck, 1988; Redding, 1992; Schroeder, 1987). The approach might involve having controllers work in a simulated or operational ATC environment, while being monitored closely, and tested for performance four or five times over the night. Such a protocol should involve one researcher dedicated to checking monitoring and testing equipment, and recording traffic levels and control centre/tower activities. Equipment which can easily check the signal strength of leads, and which can ensure adequate calibration, must be available at all times to the researcher assigned.

8.6 Meal Planning

Meal disruption is a serious problem for most shiftworkers, such that maintaining a proper diet during the shift-cycle is difficult, and almost impossible during midnights. Planning meals so that they occur at optimum times during the day and night is one way to ensure a balanced nutritional intake. Controllers working midnights must try to regularise their sleep and wake periods, eating meals at the same time each day if possible. The best strategy involves eating a light meal immediately after arising from bed. A larger, main meal (i.e. full dinner) should occur a short while prior to going to work on the midnight shift. During the night while working the shift, the controller should have another light meal high in fibre, complex carbohydrates and some protein, but containing little fat. Typically fruit and vegetables, small portions of nuts, whole-wheat bread etc. provide easily digestible energy-packed nutrition during the midnight shift, when the body is less able to digest food. Heavy protein, fat rich foods are very difficult to digest during the midnight shift, and can lead to digestive and gastro-intestinal problems.

The development of a controller's shiftwork food guide could be one way to help increase awareness of the problem and its solutions. Provision of a food planning booklet such as those used in diet-control programs, but geared toward controllers, may help with meal planning. Other strategies might involve making fruit, vegetables and bread etc. available during the midnight shift.

8.7 A Review of Shift Scheduling

The best shiftwork strategy to improve the workers's ability to cope is to eliminate shifts which disrupt the body and sleeping schedules (e.g. quick-changes, midnights, etc.). However, working nights, for example, will always be necessary for any operation where 24 hour service is required. It is strongly recommended that changes in the shift schedule be considered first as a priority, followed by worker coping strategies.

An example of changes to be investigated is the case of working an overtime shift immediately after the normal work-cycle. This practice is pushing the envelope for most controllers, particularly older controllers, because it eliminates the recovery time necessary to prepare the body for going back to work. Continuing to work past the normal shift-cycle adds to an already serious sleep debt which is beginning to affect both health and cognitive performance. Furthermore, disruption of social and other off-work activities will worsen due to deterioration in mood and cognitive functioning. Long strings of overtime will result in the paying back of the sleep debt at the expense of time usually spent with family and friends, eating meals and engaging in hobbies, relaxation time etc.
Two full days of rest following the normal shift-cycle is necessary to recover sleep and to adjust to a change in the time of day in which sleep must occur. Following this two-day reprieve, overtime will be much easier to do and work performance is likely to be better.

8.8 Impact of Circadian Effects and Fatigue on Staffing Levels

Planning staff levels is difficult. Each day has different traffic, even if there are similar trends, and illness and unforeseen circumstances can remove planned resources often at the last minute. Running an operation at its most efficient staffing levels usually means that very little surplus staff is tolerated. Of course the down side to this is that the system will have difficulty meeting contingencies, and short staffing will result. Unfortunately, in a safety critical working environment, redundancy in system components is a given requirement, including the human side of the system. Without system redundancy, safety critical operations become open to unsafe and sometimes disastrous consequences.

It is difficult to maintain staffing levels which will comply with this requirement, particularly when operating 24 hours a day. When traffic levels are too low to justify the required redundancy, it is removed, as a means of maintaining efficiency. Safety, therefore, is entirely a function of the ability of the individuals responsible for each specific job. If that individual cannot meet the demands of the job, there is no one available to step in and take over, unless others can do that individual's job, as well as their own. The danger, then, is that during conditions where individual staff are stressed by fatigue, circadian effects, and sustained workload, such as working a midnight shift alone, their abilities are degraded, and there is no margin of safety, the chances of error are increased considerably. Furthermore, the likelihood of a failure to respond effectively to emergencies is seriously heightened.

It is recommended that these factors be included in planning staff levels. If surplus staff can be made available for contingencies, either through multiple job capabilities, such as supervisors familiar with all of the job types, or through training for multiple jobs, individual staff can step in to relieve individuals requiring a break due to fatigue, suppressed alertness caused by circadian rhythm or long duration. If this multiple training is not possible, then technological support should be considered to make job sharing possible. Finally, if no job sharing can be achieved, the only option available is to provide redundancy in all job specialities. Although this may be prohibitively expensive, the fact remains that the system must have the necessary redundancy required of safety critical systems. It is recommended that alternative shift schedule strategies be applied in order to optimise current schedules with respect to circadian, sleep and psychological factors.

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APPENDIX A : Example of an Individual Controller Shiftwork Profile

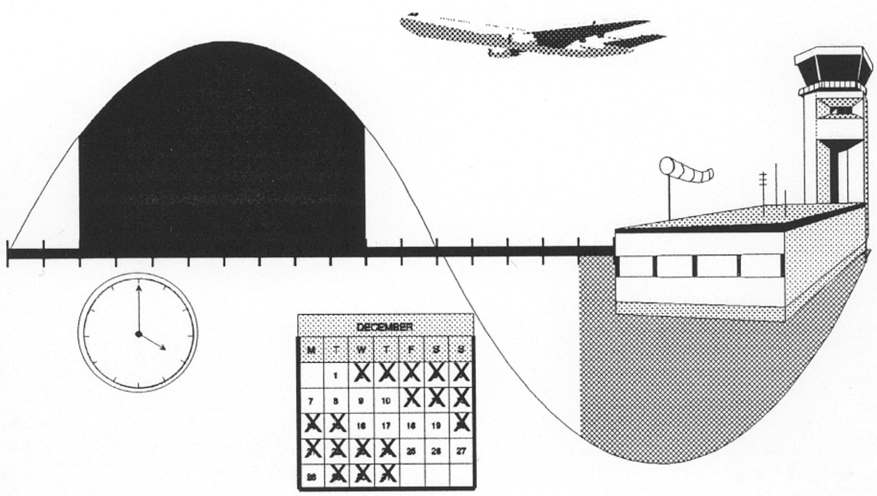
Rhodes & Associates Inc.
Human Factors/Ergonomics Specialists

Subject #: ______

INDIVIDUAL CONTROLLER SHIFTWORK PROFILE

Phase II

Study of the Impact of Shiftwork on Air Traffic Controllers



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DESCRIPTION OF THE PROFILE

The following report is a brief description of the results of your participation in the Air Traffic Controller Shiftwork Project. We have endeavored to provide the information we feel is of greatest interest to you. However if you have any questions regarding the results do not hesitate to call us at the number on the cover page, or send a facsimile of your question.

NOTE: *This profile is not a medical diagnosis. It is a report of your individual results from a research project, and represents only a snapshot of your sleep patterns and performance. The profile should be used only as information to help guide you in your decisions about sleep hygiene and a healthy lifestyle. This profile is completely confidential and exists only in trust with Rhodes & Associates Inc. and yourself. No other parties may have these individual results. Therefore, it is advisable that you not share this information with anyone other than close family.*

The profile is organized as follows:

1. Results of your three sleep sessions including:

⇒ a summary table showing
- total sleep time
- percent of slow wave sleep
- percent of dream sleep (REM)
- sleep latency (length of time to fall asleep)
- number of movement arousals per hour
- sleep efficiency
- sleep events worth noting (hypopneas and/or apneas)

⇒ hypnograms showing your whole sleep during each session

⇒ graphs showing proportion of sleep for the various stages of sleep

2. Results of your Performance Assessment Battery (PAB) Sessions

⇒ graph showing accuracy and time for all sessions for each test

HOW TO INTERPRET THESE RESULTS

Total Time In Bed

This is the total time you spent in bed from getting into bed until you rose at the end of the sleep session.

Total Sleep Time

This is the total amount of time you actually slept. Different people require different amounts of sleep. Total sleep time averages 6-9 hours, with older adults achieving less. If you get less than your required amount of sleep you may suffer sleep loss. This loss adds up each day, building up what is known as a sleep debt. This debt must be paid as early as possible or fatigue will result, affecting performance and mood.

Slow Wave Sleep

The type of sleep that restores you is called Slow Wave Sleep (SWS). This type of sleep is characterized by high amplitude, low frequency waveform called delta waves, and constitutes stage 3 and stage 4 sleep. In a normal sleep period an adult spends approximately 20% of their sleep time in SWS.

REM Sleep

Rapid Eye Movement (REM) sleep is your dream sleep which is thought to be necessary for maintaining positive mood and attitude. Some researchers believe that people find that they tend to be less happy and less motivated to complete tasks when REM sleep is restricted. Although this does not affect performance directly, it may lead to some performance decrements over time. It may also affect satisfaction levels with work and leisure activities. REM sleep typically contributes about 15 to 20% of sleep under normal conditions.

Sleep Latency

Sleep latency refers to the length of time it takes to fall asleep (i.e. achieve Stage 1 sleep). The normal durations for sleep latency is between 10 and 20 minutes. If you fall asleep in a shorter time, you are likely experiencing some fatigue due to lack of sleep, or as a result of disrupted sleep. Certainly shiftwork may cause either or both of these problems.

Sleep Efficiency

Your sleep efficiency is an indicator of the proportion of your time in bed which was actual sleep. The higher your efficiency is (percentage) the less times you awakened or had your sleep disrupted. However, since a short sleep latency period will contribute to a higher sleep efficiency, caution must be used in interpreting sleep efficiency results. Results where sleep efficiency is less than 80% are indicative of poor sleep.

Movement Arousals

A movement arousal is a brief moment of awakening that lasts for only a few seconds or fraction of a second. Some movement arousals are a natural part of the sleep cycle. However, frequent and consecutive movement arousals, as happens when suffering from sleep apnea, or due to the effects of alcohol or caffeine, result in a fitful and unrefreshing sleep. Typically less than 20 arousals per hour of sleep is considered normal.

Hypopneas and Apneas

Hypopneas and apneas are respiratory events which usually occur when the muscles at the opening of the windpipe relax. This relaxation sometimes causes constriction of the opening resulting in decreased air flow (hypopnea). If the airway becomes completely closed and all air flow is cut off this respiratory event is called an apnea.

Hypopneas are generally less severe than apneas and normally occur during certain sleep stages. Up to 10 respiratory events per hour of sleep is considered normal. However, hypopneas may develop into apnea after having alcohol or other substances that relax the muscles of the throat. Frequent hypopneas and/or apneas disrupt sleep and often cause daytime fatigue.

GENERAL FACTS ABOUT SLEEP

Normal sleep cycles in approximately 90 minute periods. When a person falls asleep, he/she progresses through stages 1,2,3,4 of sleep then usually returns to stage 2 for a few minutes before entering Rapid Eye Movement (REM) sleep.

The first REM period of sleep is usually very short, while the first period of Slow Wave Sleep (SWS) is usually the longest. Later in the night, SWS periods become shorter and fewer, while REM periods increase in length and in number. The presence of significant amounts of SWS in the last third of the sleep period is often a sign of sleep restriction and/or an accumulated sleep debt which a person is trying to "pay off".

It is important to note the effect of age on the sleep cycle. For reasons which we do not yet understand, our brainwaves decrease in amplitude throughout our lifetime. Since SWS (delta waves) have a specific amplitude criteria, older adults typically have significantly less SWS than younger adults. Older adults often never reach Stage 4 sleep.

Other reasons for marked decreases in amount of SWS include the presence of a sleep disorder (e.g. sleep apnea) which prevents a person from reaching deeper stages of sleep. Persons with sleep disorders often arise feeling unrefreshed and experience continued daytime fatigue.

SLEEP SESSION RESULTS

A) Summary Table

This table contains a summary of the most pertinent information about your sleep sessions. The table contains data for your three sleep sessions Baseline, first work sleep session (Work 1), and second work sleep session (Work 2):

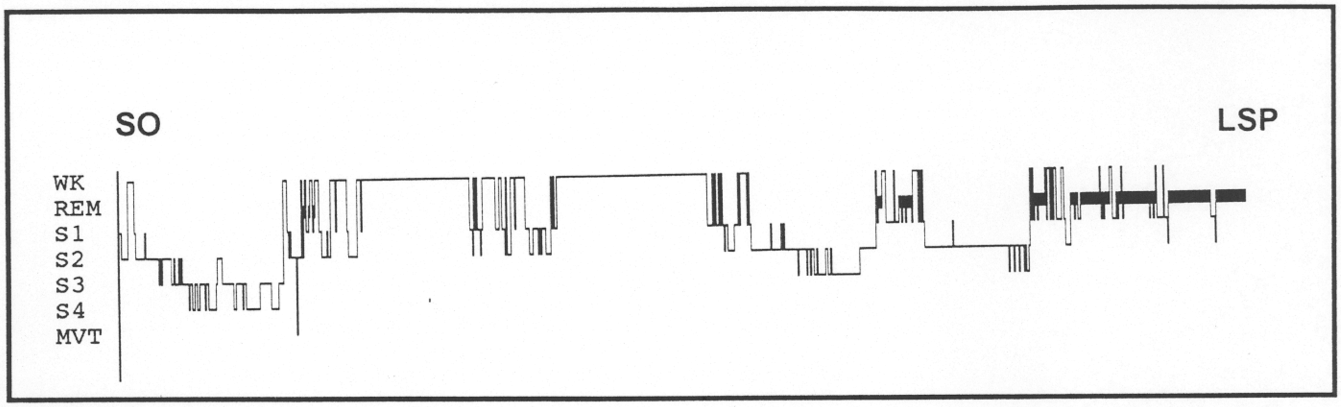
Sleep Item	*Baseline*	*Work 1*	*Work 2*
Time in Bed (min.)	444	224	266
Total Sleep Time (min.)	294.5	204	246
Proportion of REM Wave Sleep(%)	21.7	25.5	20.1
Proportion of SWS Sleep (%)	21.4	22.1	19.5
Sleep Latency (time to fall asleep) (min.)	0.5	0.5	4.5
Sleep Efficiency (%)	66.3	91.1	92.5
Movement Arousals (number/ hour of sleep)	48.9	22.4	16.3
Sleep Events ⇒ hypopneas (number/hr. of sleep)	17.5	16.2	17.6
⇒ apneas (number/hour of sleep)	0	0	1

B) HYPNOGRAMS

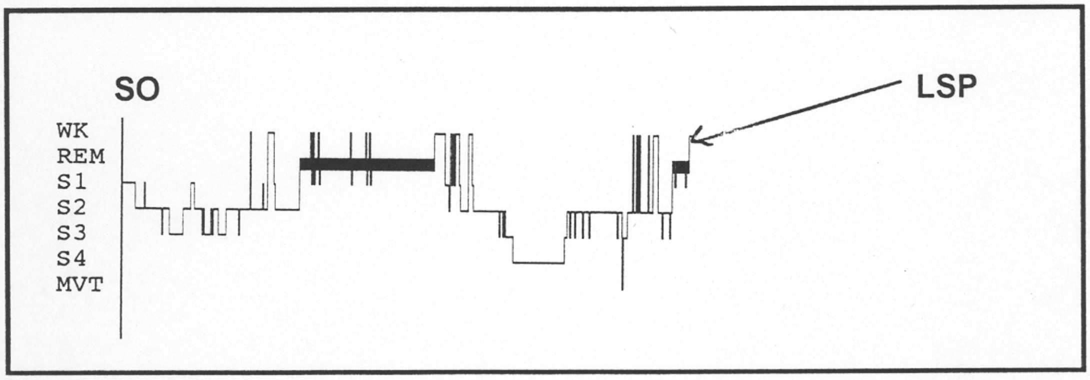
The following diagrams (hypnograms) show the progression of your sleep during each sleep session. A hypnogram is a diagrammatic representation of a person's time in bed. It reads from left to right and shows how you progressed from a waking state through the various stages of sleep. The graph shows your sleep as you progress from waking (WK) to stage 1 (S1) to stage 2 (S2) to stage 3 (S3) to stage 4 (S4) and back up through the stages to waking, repeating this cycle many times through the sleep period. REM (dream) sleep is indicated by a darker, thicker horizontal bars. SWS (the deep, restorative sleep of stages 3 and 4) is marked by the most downward points in the graph. Times when you wake are the highest points in the graph. SO is sleep onset while LSP means Last Sleep Period. MVT means movement time.

HYPNOGRAMS

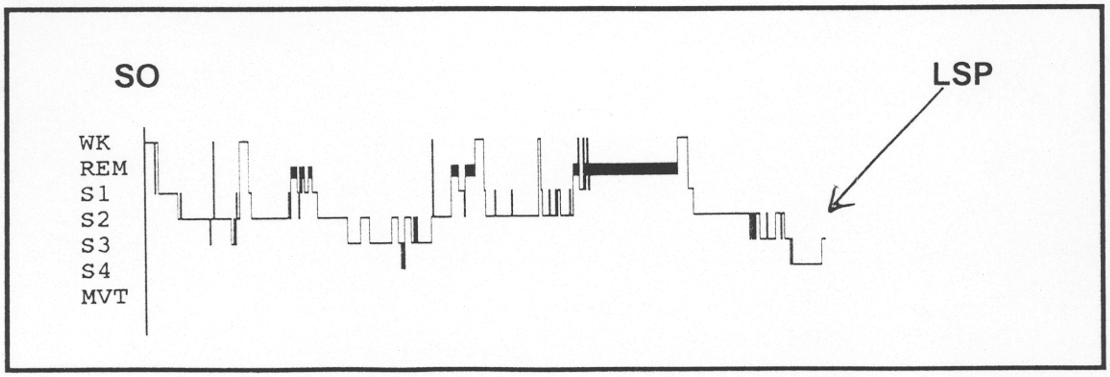
Baseline Sleep



First Work Sleep



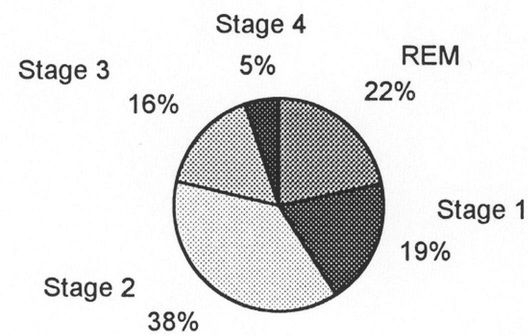
Second Work Sleep



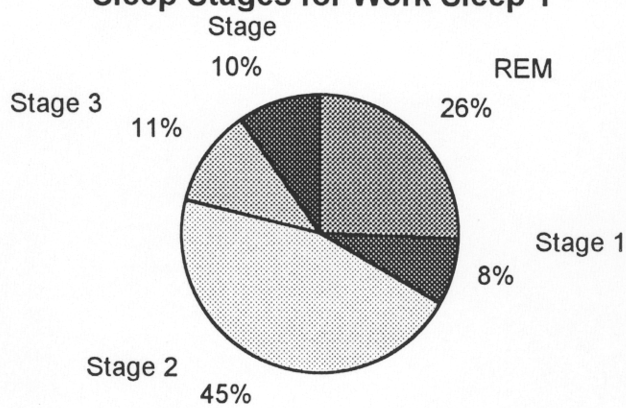
C) SLEEP STAGES

The graphs below show the total proportion of sleep for each stage of sleep achieved.

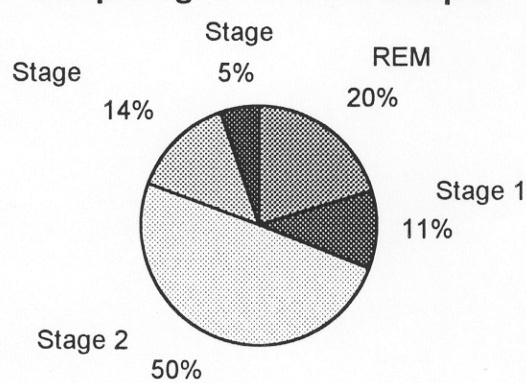
Sleep Stages for Baseline Sleep



Sleep Stages for Work Sleep 1



Sleep Stages for Work Sleep 2



RESULTS FOR THE PERFORMANCE ASSESSMENT BATTERY

The results of your performances during each of the test sessions are shown in the following graphs. Please note that these are your own personal results and can not be compared with other participants since the tests are sensitive to individual differences and conditions at the time. The study is interested in only changes in performance for individuals from test to test. We are looking for patterns in such change to determine the effects of work shifts on the individual.

ACCURACY

The accuracy measures are the percent of correct responses to the total number of responses. Accuracy is represented in the charts below as a bar graph.

TIME

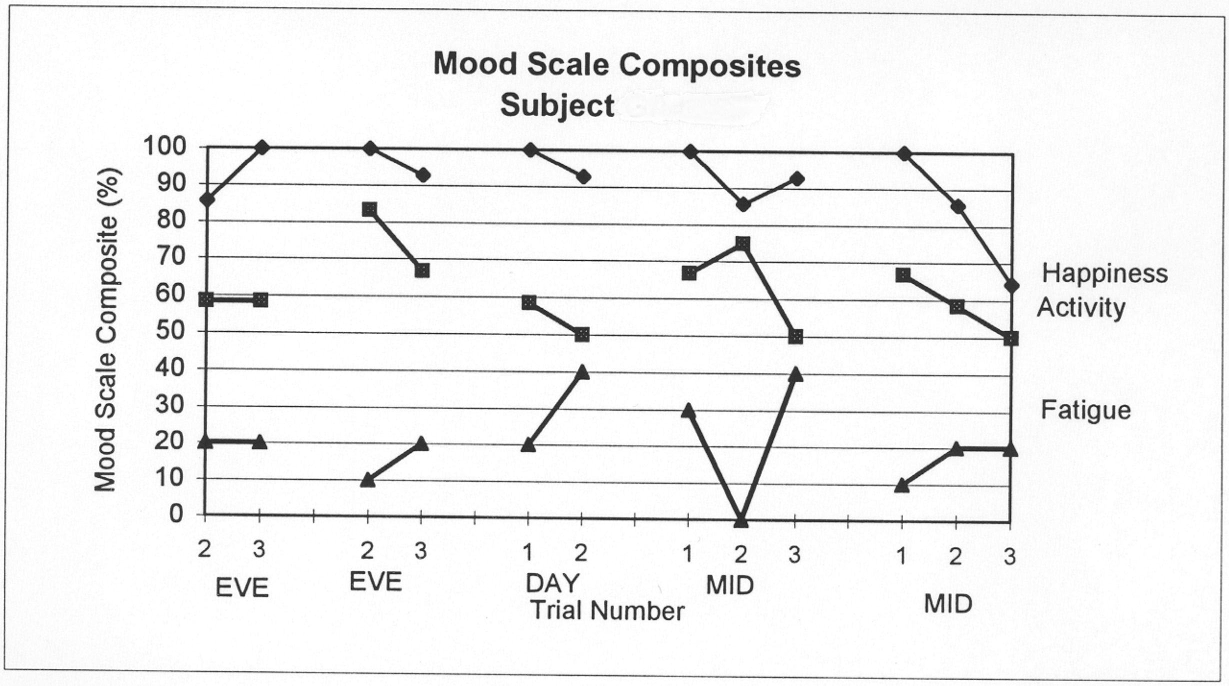
The time measure is the number of responses/minute, and is represented in the charts below as a line graph.

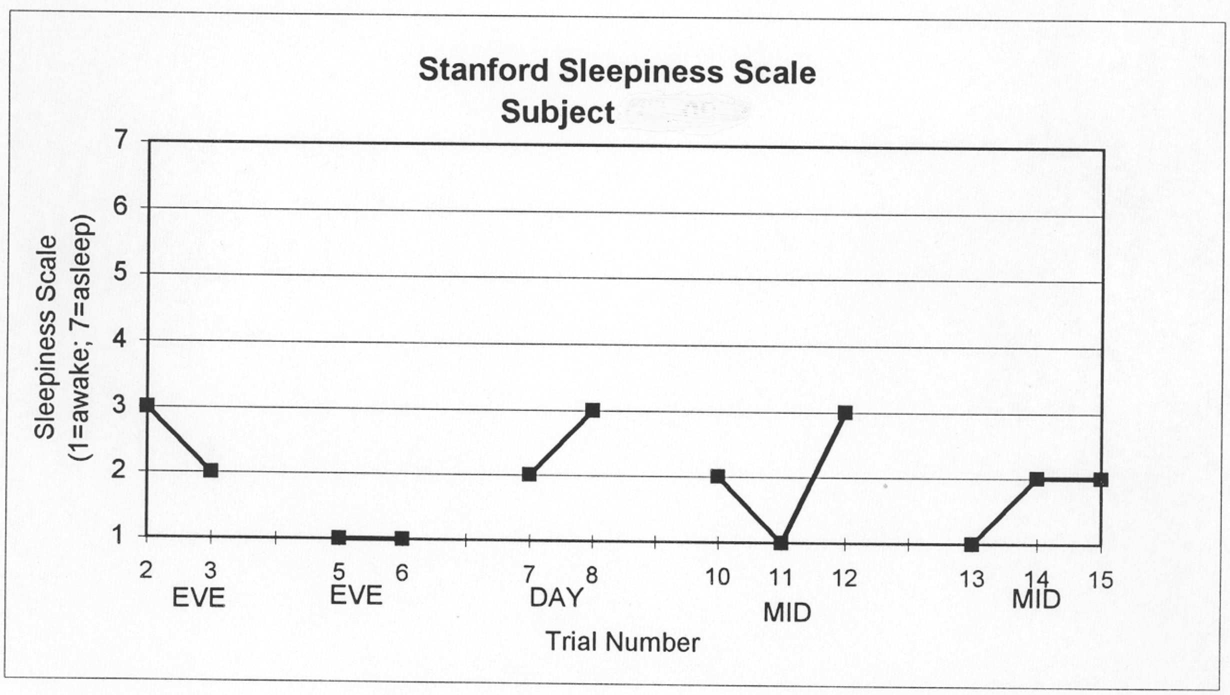
Test Results

The graphs are presented as follows:

1. Mood Scale
2. Sleepiness Scale
3. Pattern Recognition Test
4. Logical Reasoning Test
5. Wilkinson Reaction Time Test
6. Manikin Test

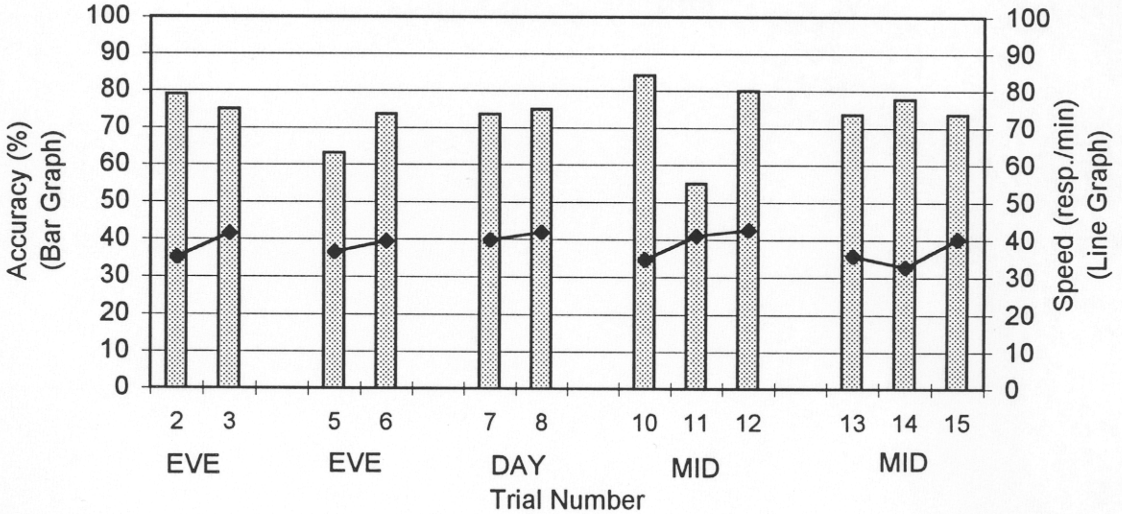
Subject


Mood Scale Composites
Subject
Mood Scale Composite (%)
100
90
80
70
60
50
40
30
20
10
0
2 3 2 3 1 2 1 2 3 1 2 3
EVE EVE DAY MID MID
Trial Number
Happiness
Activity
Fatigue

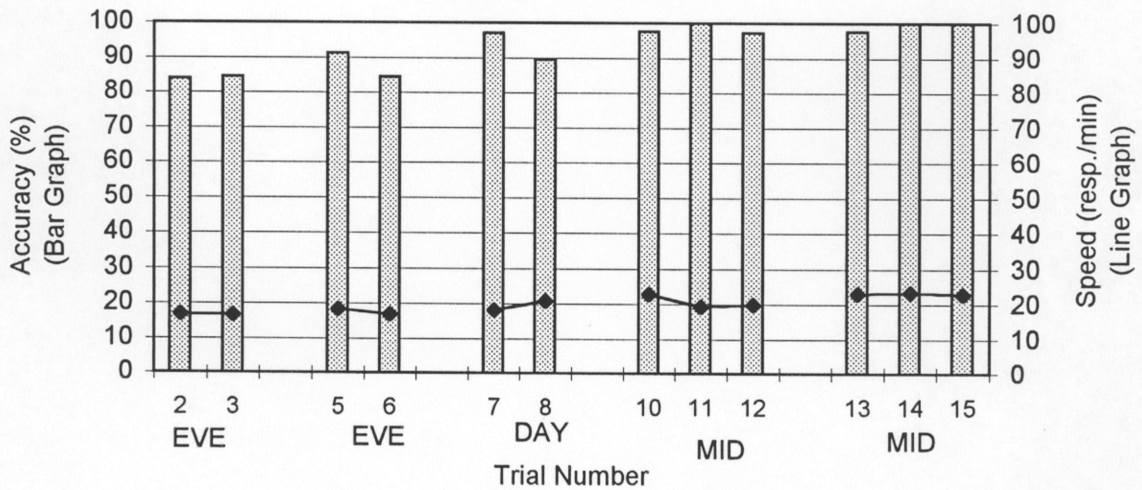

Stanford Sleepiness Scale
Subject
Sleepiness Scale
(1=awake; 7=asleep)
7
6
5
4
3
2
1
2 3 5 6 7 8 10 11 12 13 14 15
EVE EVE DAY MID MID
Trial Number

Subject

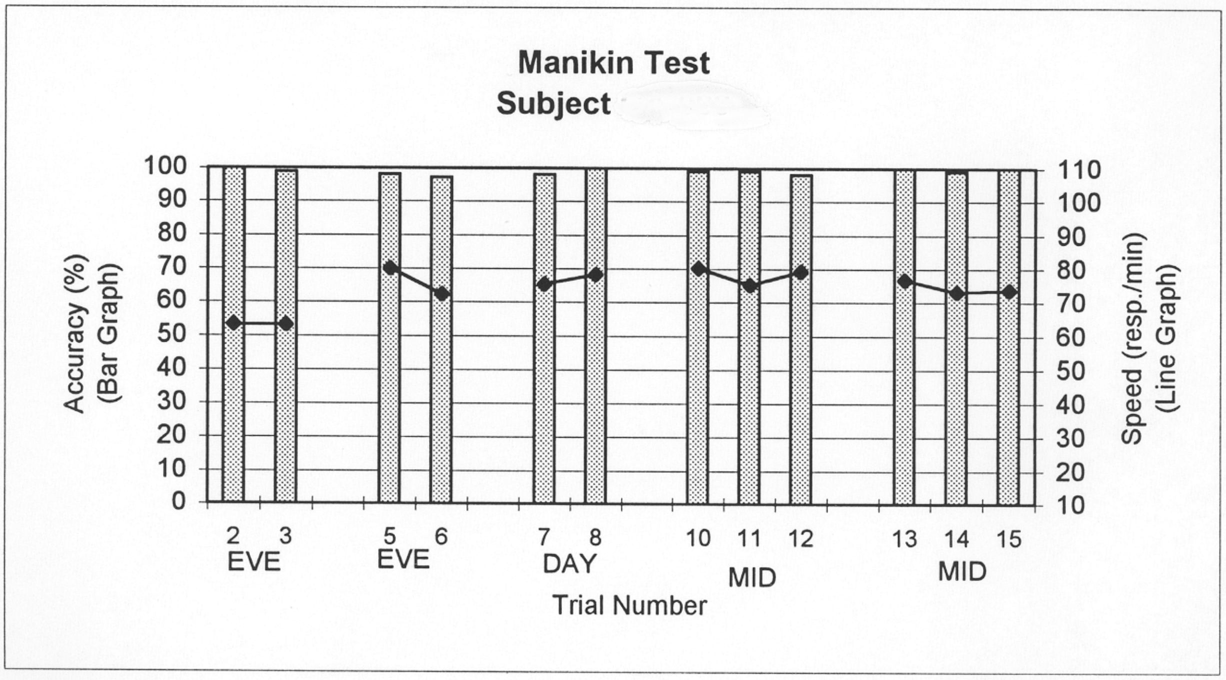
Pattern Recognition Test
Subject

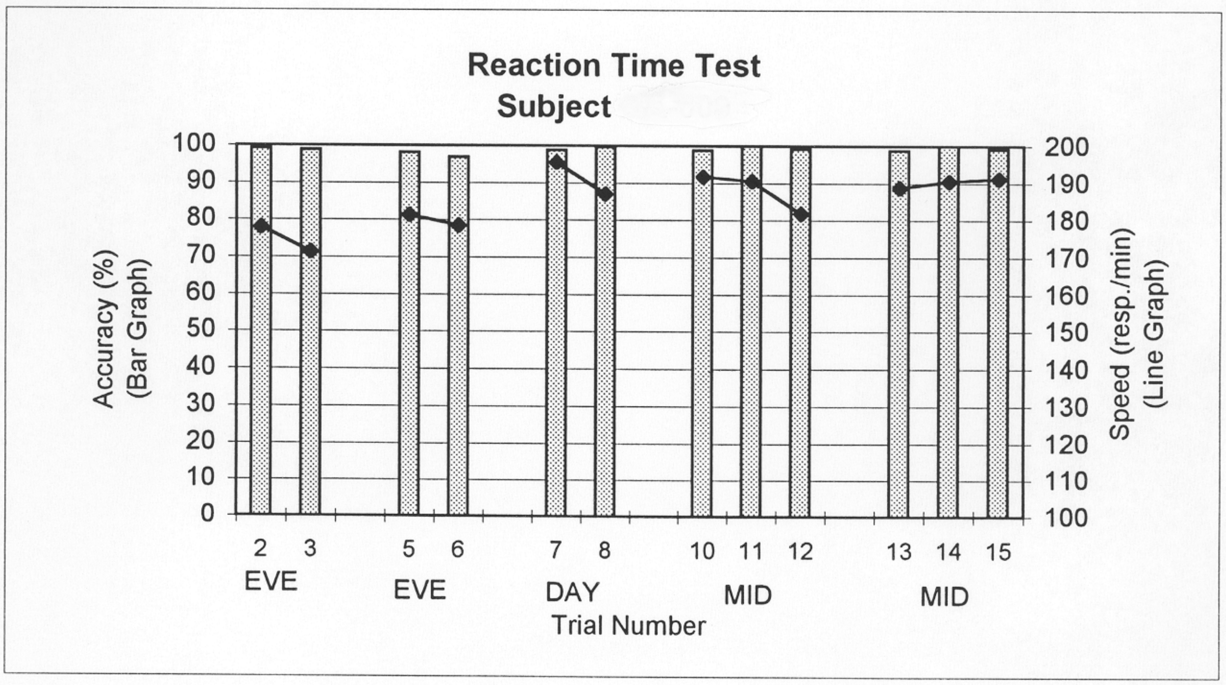


Logical Reasoning Test
Subject

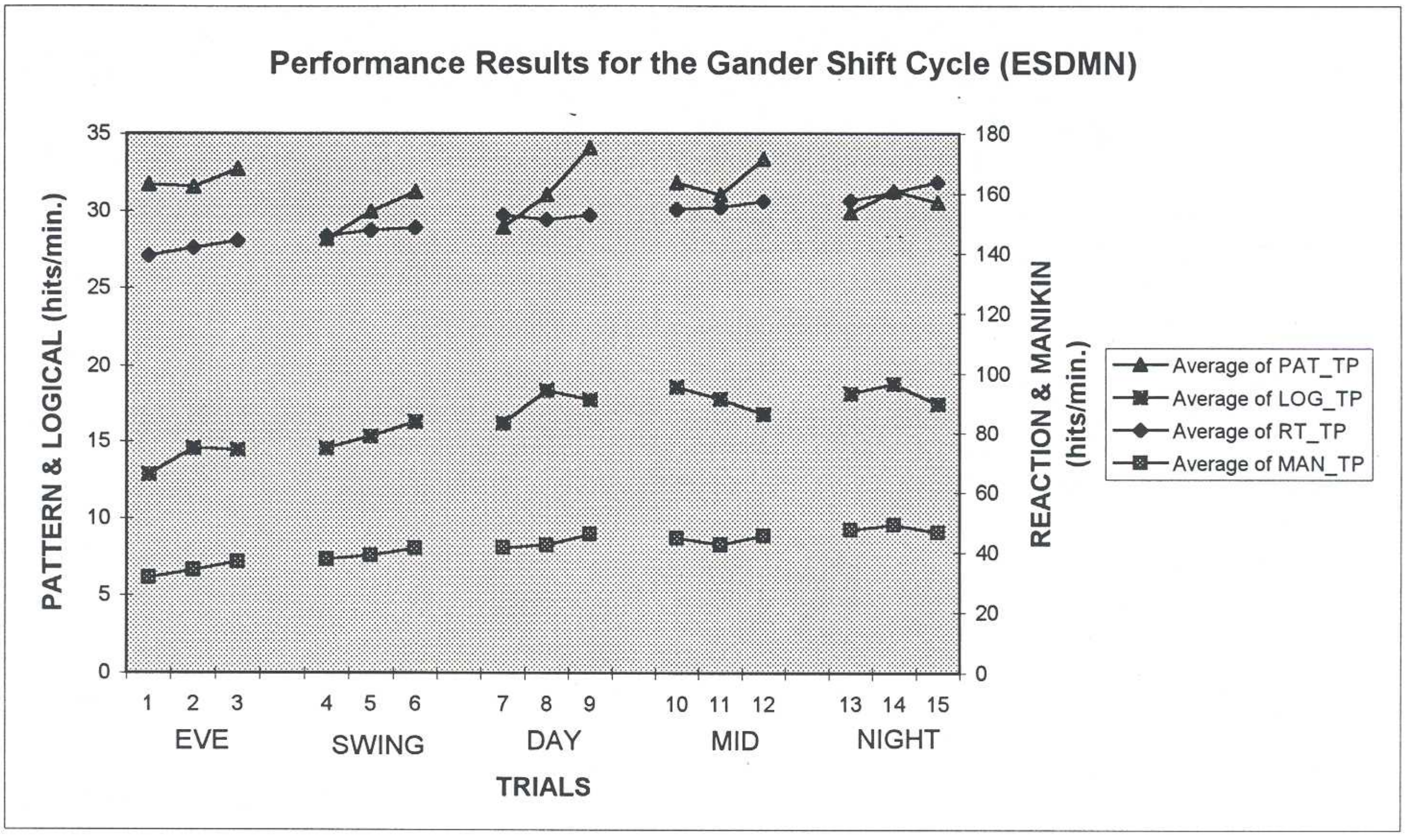


Subject

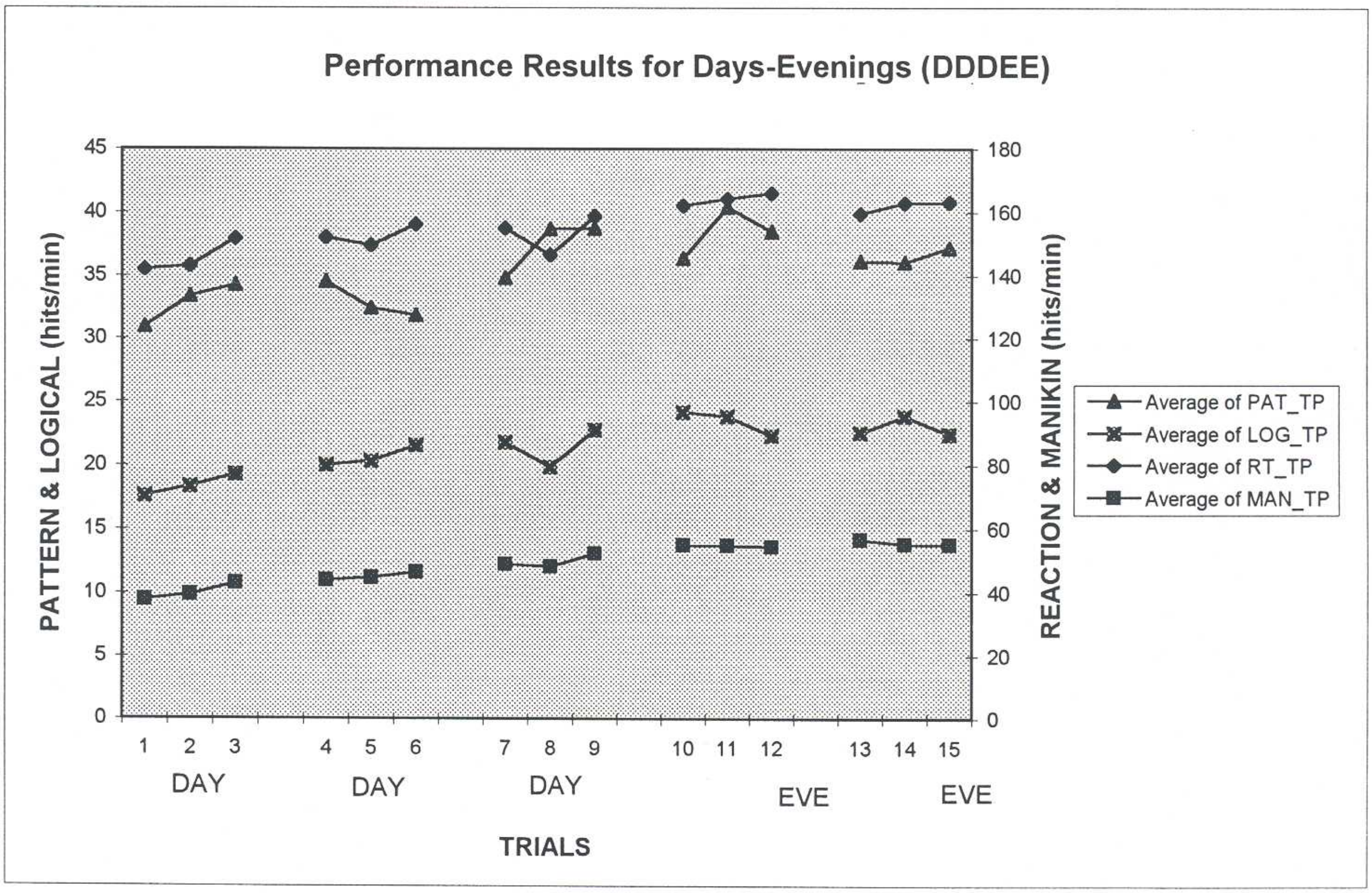

Manikin Test
Subject
Accuracy (%) (Bar Graph)
Speed (resp./min) (Line Graph)
100 90 80 70 60 50 40 30 20 10 0
110 100 90 80 70 60 50 40 30 20 10
2 3 5 6 7 8 10 11 12 13 14 15
EVE EVE DAY MID MID
Trial Number


Reaction Time Test
Subject
Accuracy (%) (Bar Graph)
Speed (resp./min) (Line Graph)
100 90 80 70 60 50 40 30 20 10 0
200 190 180 170 160 150 140 130 120 110 100
2 3 5 6 7 8 10 11 12 13 14 15
EVE EVE DAY MID MID
Trial Number

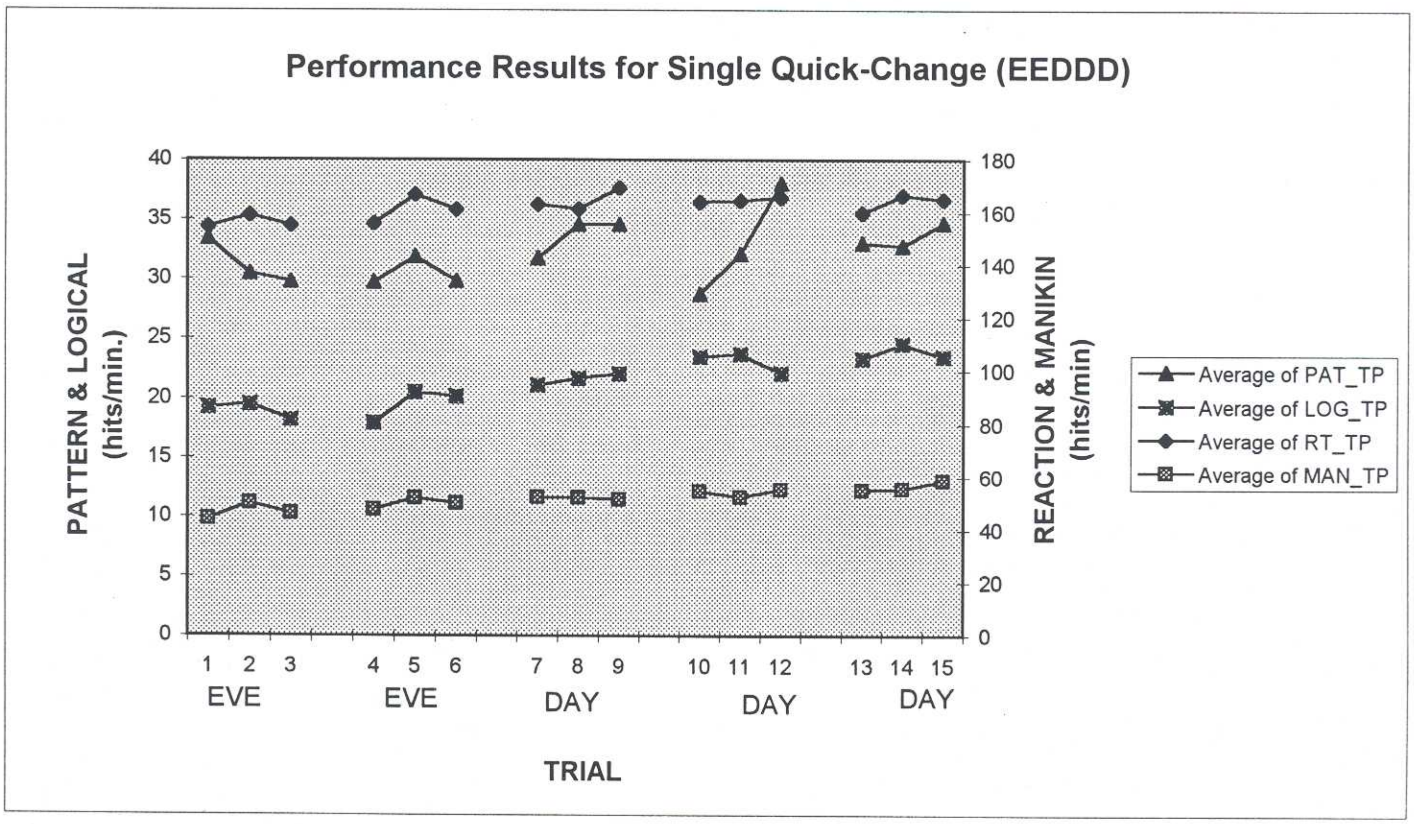
APPENDIX B: Performance Results for All Shift-Cycles (Absolute Through-put Values)

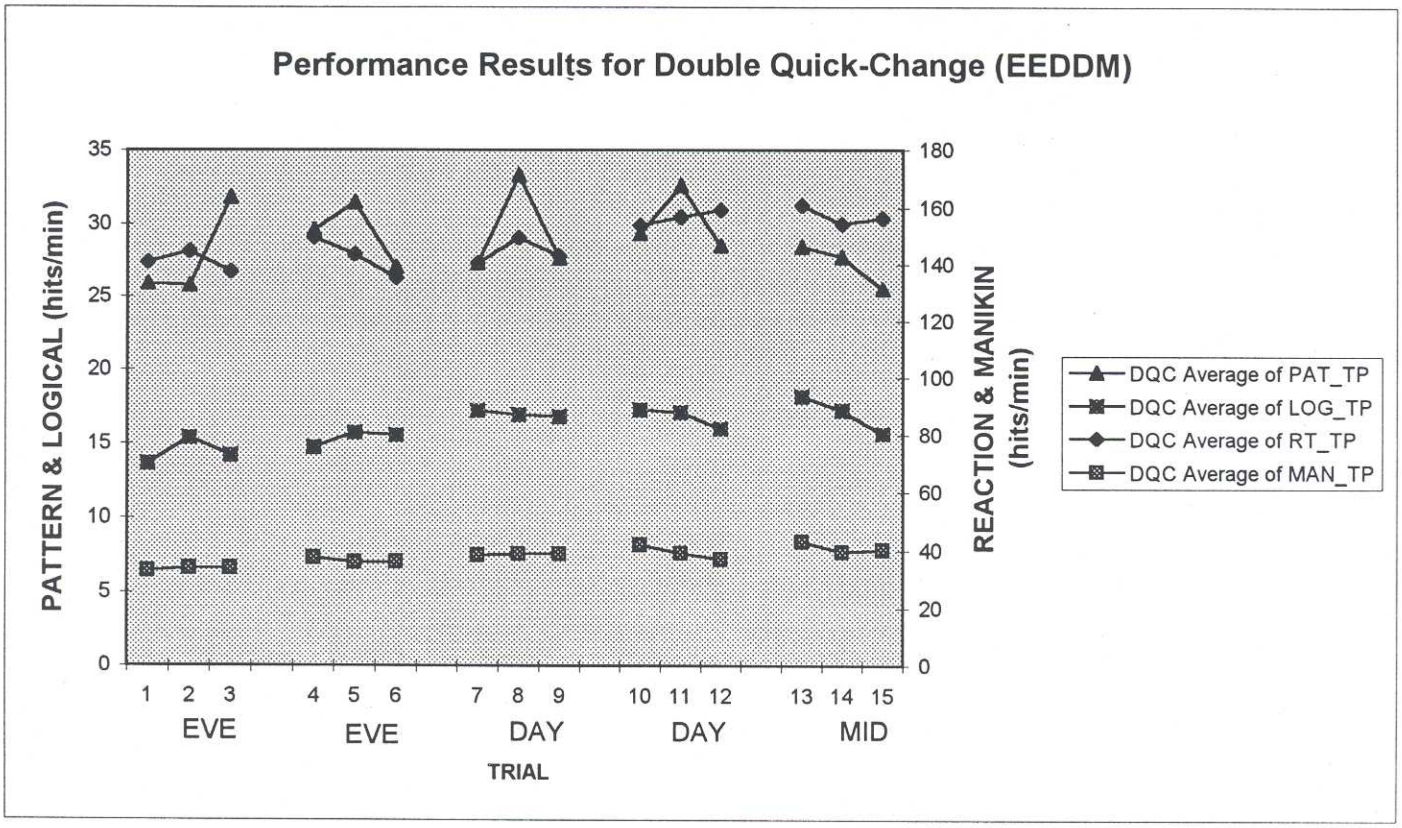


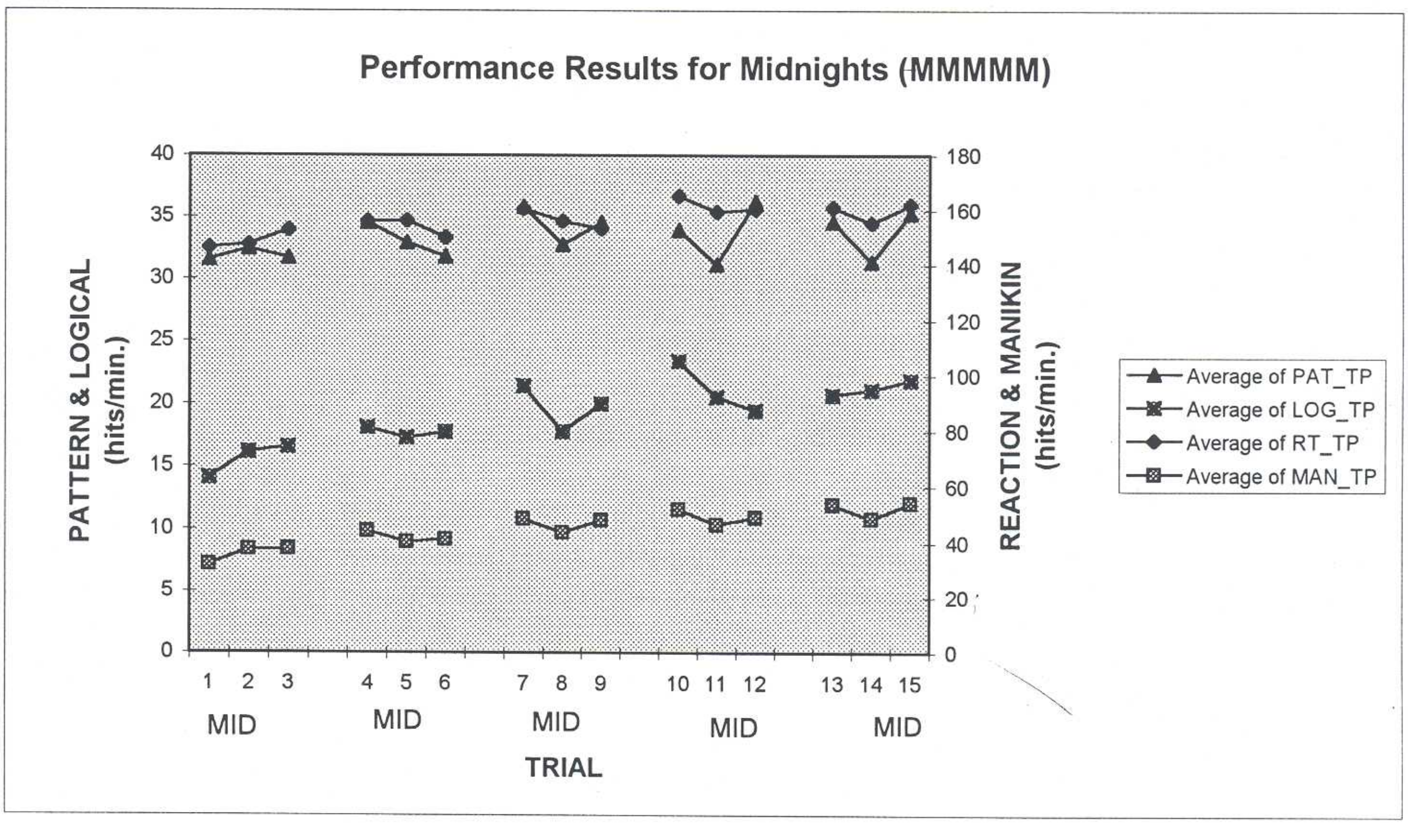
Performance Results for the Gander Shift Cycle (ESDMN)
PATTERN & LOGICAL (hits/min.)
REACTION & MANIKIN (hits/min.)
35
30
25
20
15
10
5
0
180
160
140
120
100
80
60
40
20
0
1 2 3
EVE
4 5 6
SWING
7 8 9
DAY
10 11 12
MID
13 14 15
NIGHT
TRIALS
Average of PAT_TP
Average of LOG_TP
Average of RT_TP
Average of MAN_TP



Performance Results for Days-Evenings (DDDEE)
PATTERN & LOGICAL (hits/min)
REACTION & MANIKIN (hits/min)
45
40
35
30
25
20
15
10
5
0
180
160
140
120
100
80
60
40
20
0
1 2 3
DAY
4 5 6
DAY
7 8 9
DAY
10 11 12
EVE
13 14 15
EVE
TRIALS
Average of PAT_TP
Average of LOG_TP
Average of RT_TP
Average of MAN_TP


Performance Results for Single Quick-Change (EEDDD)
PATTERN & LOGICAL (hits/min.)
REACTION & MANIKIN (hits/min)
40
35
30
25
20
15
10
5
0
180
160
140
120
100
80
60
40
20
0
1 2 3
EVE
4 5 6
EVE
7 8 9
DAY
10 11 12
DAY
13 14 15
DAY
TRIAL
Average of PAT_TP
Average of LOG_TP
Average of RT_TP
Average of MAN_TP


Performance Results for Double Quick-Change (EEDDM)
PATTERN & LOGICAL (hits/min)
REACTION & MANIKIN (hits/min)
35
30
25
20
15
10
5
0
180
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
EVE
EVE
DAY
DAY
MID
TRIAL
DQC Average of PAT_TP
DQC Average of LOG_TP
DQC Average of RT_TP
DQC Average of MAN_TP


Performance Results for Midnights (MMMMM)
PATTERN & LOGICAL (hits/min.)
REACTION & MANIKIN (hits/min.)
40
35
30
25
20
15
10
5
0
180
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
MID
MID
MID
MID
MID
TRIAL
Average of PAT_TP
Average of LOG_TP
Average of RT_TP
Average of MAN_TP

APPENDIX C: Air Traffic Controller Work, Sleep, and Leisure Diary

Rhodes & Associates Inc. #

AIR TRAFFIC CONTROLLER WORK, SLEEP, AND LEISURE DIARY

In Cooperation with
Centre for Sleep & Chronobiology
University of Toronto

Work Activities

[ ] - Bracket regularly scheduled work hours
O - Overtime work at your air traffic control job
J - Work at other jobs
R - Rest periods at work
Z - Travel to and from work

Sleep Activities

↓- mark "down" arrow each time you got into bed
↑- mark "up" arrow each time you got out of bed
| - mark the times you began and ended your sleep; then join lines to indicate sleep periods.
P - Use of toilet during sleep time
N - Noises that disturb your sleep
W - Time of wake-up call or alarm (if any)

Leisure Activites

L - Leisure time ALONE (TV, hobby, etc.)
F - Leisure time with family or friends (golf, playing with children, movie, etc.)
D - Domestic WORK (cleaning, cooking, attending to children, etc.)
R - Other non-ATC Responsibilities (eg. bank, auto repair, dentist appointment, etc.)
E - Physical Exercise

M - Meals
S - Snacks
A - Each alcoholic drink (beer, wine, etc.)
C - Each caffienated drink (coffee, tea, cola)
T - Use of tabacco (eg. cigarette, cigar, etc.)

March ___

noon | midnight

12am 2 4 6 8 10 12pm 2 4 6 8 10 12

Work																							
Sleep																							
Leisure																							

March ___

noon | midnight

12am 2 4 6 8 10 12pm 2 4 6 8 10 12

Work																							
Sleep																							
Leisure																							

APPENDIX D: Healthdyne Alice 3 Computerised Polysomnographic System Research Abstract

Comparison of the Healthdyne® Alice 3™ Computerized Polysomnographic System vs Standard Polysomnography

J. MacFarlane, I. Dumov, I. Bowen, S. Zanon, A.MacLean, T. Kwong, H. Moldofsky
University of Toronto Centre for Sleep & Chronobiology at
the Toronto Hospital (Western Division)

The aim of this study was to determine the accuracy and reliability of the Healthdyne Alice 3 System (DOS Version 1.18), a device marketed for the comprehensive laboratory assessment of patients with a variety of sleep disorders, as compared with standard polysomnographic (PSG) techniques.

Methods: Ten consecutive patients (6M, 4F; mean age 45.9 yrs) completed the study. Each were referred to The Sleep Disorders Clinic, The Toronto Hospital (Western Division) with a variety of presenting diagnoses, ie: sleep apnea (5), periodic limb movements (5), narcolepsy (2), insomnia (1), parasomnia (1). Overnight sleep physiologic data were simultaneously collected using: I) the Healthdyne Alice 3 software recording and analysis system with the Healthdyne Calvin™ system amplifier unit; and ii) the Grass™ Model 78D polysomnograph (PSG). The data included EEG (C3, C4), left & right EOG, EMG from submental and right and left anterior tibialis muscles (RAT/LAT), respiratory effort (Respitrace™), SaO_2 (Healthdyne model 930 pulse oximeter) and airflow by oro-nasal thermocouple. Specialized cables allowed for a split data signal which was recorded simultaneously on both systems. Data were scored blindly using standard criteria.

Parameter	PSG mean (SE)	Alice 3 mean (SE)	t-tests	Pearson Correlation
SOL (mins)	26.7 (60.9)	26.3 (62.7)	p=0.47	r=1.00*
TST (hrs)	5.8 (1.0)	5.9 (0.3)	p=0.05	r=0.98*
ROL (mins)	71.6 (29.5)	71.0 (28.3)	p=0.50	r=0.98*
Stage 1 (mins)	47.9 (23.5)	44.6 (23.0)	p=0.44	r=0.84*
Stage 2 (mins)	210.3 (56.2)	201.2 (46.0)	p=0.30	r=0.89*
Stage 3 (mins)	22.6 (14.5)	21.8 (12.1)	p=0.84	r=0.68*
Stage 4 (mins)	10.2 (19.1)	14.9 (19.7)	p=0.15	r=0.88*
REM (mins)	64.1 (22.4)	63.5 (22.7)	p=0.85	r=0.91*
Wake (mins)	51.4 (30.9)	53.2 (29.3)	p=0.61	r=0.94*
Sleep Efficiency (%)	81.9 (13.3)	80.6 (12.9)	p=0.15	r=0.98*
Movement Arousals/hr	104.8 (58.1)	77.8 (52.1)	p=0.01*	r=0.96*
Apnea total	25.6 (47.2)	17.4 (30.1)	p=0.18	r=0.99*
Hypopnea total	77.7 (113.4)	70.0 (89.4)	p=0.42	r=0.99*
AHI	18.3 (26.6)	15.7 (20.5)	p=0.32	r=0.98*
PLMS (RAT/LAT)	15.5 (21.8)	13.5 (20.9)	p=0.29	r=0.97*

The results of the t-tests indicate that, with the exception of movement arousals, there were no significant mean differences between the designated measures obtained by the Alice 3 system and the Grass paper polysomnograph. In addition, there were extremely high correlations between the two systems for all 16 parameters listed above.

Conclusions: There is significant agreement between the Alice 3 (using automated assisted scoring) and the Grass 78D (using manual paper scoring) in the overnight assessment of patients with a variety of sleep disorders in the standard Sleep Disorders Laboratory.