NASA Technical Memorandum 108838

Crew Factors in Flight Operations VI: Psychophysiological Responses to Helicopter Operations

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July 1994

National Aeronautics and
Space Administration

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TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF TABLES

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Philippa H. Gander[1], Rory M. Barnes[2], Kevin B. Gregory[3], Linda J. Connell[4],
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SUMMARY

Thirty-two helicopter pilots were studied before, during, and after 4- to 5-day trips providing support services from Aberdeen, Scotland, to rigs in the North Sea oil fields. Early on-duty times obliged subjects to wake up 1.5 hr. earlier on trip days than on pretrip days. Consequently, they slept nearly an hour less per night on trips. They reported more fatigue on posttrip days than on pretrip days, suggesting a cumulative effect of duty-related activities and sleep loss. Fatigue and negative affect were higher, and activation lower, by the end of trip days than by the end of pretrip days. The earlier a subject went on duty, the lower his activation by the end of the day. Caffeine consumption increased 42% on trip days. The incidence of headache increased twofold, of back pain twelvefold, and of burning eyes fourfold. In the aircraft studied, thermal discomfort and high vibration levels were common. The longer the time the pilots were on duty, the more negative their mood became. The most important environmental factor affecting subjective workload during preflight, taxi, climb, and cruise was the quality of the aircraft systems (as rated by the pilots on a 5-point scale from ‘perfect’ to ‘useless’). During descent and approach, landing weather had the greatest effect. During landing, workload was most influenced by the quality of the landing site and air traffic control.

1.0 OPERATIONAL OVERVIEW

This report is the sixth in a series on the physiological and psychological effects of flight operations on flight crews, and on the operational significance of these effects. This section presents an overview of the major findings and their significance. The rest of the volume contains the complete scientific description of the work.

Thirty-two helicopter pilots (average age 34 yr.) were studied before, during, and after 4- to 5-day trips providing support services from Aberdeen, Scotland, to rigs in the North Sea oil fields. Duty days began and ended in Aberdeen. Half the trips studied took place in winter/spring, and the other half in summer/autumn. Heart rate, rectal temperature, and activity of the non-dominant wrist were monitored continuously by means of portable biomedical monitors. Subjects kept daily logs of sleep timing and quality, food and fluid intake, medications taken, and medical symptoms. They also rated their fatigue and mood every 2 hr. while awake. For every segment flown, they rated their workload (on a modified Bedford Scale) for each phase of flight, and the following five environmental factors assumed to influence workload: 1) functioning of the aircraft systems (rated

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on a 5-point scale from 'perfect' to 'useless'); 2) weather conditions for landing; 3) the landing site; 4) letdown aids; and 5) air traffic control (2-5 each rated on a 5-point scale from 'very favorable' to 'very unfavorable').

On trip mornings, subjects were required to wake up about 1.5 hr. earlier than on pretrip mornings (average on-duty time 0725 local time). Although they came off duty relatively early (average 1437 local time), they averaged only 6.4 hr. of sleep during layovers at home that averaged almost 17 hr. The inability to fall asleep earlier than the habitual bedtime is due to properties of the physiological mechanisms controlling sleep. Subjects were thus unable to compensate for the early wake-ups, and therefore averaged about 50 minutes less sleep per night on trips than pretrip. In the laboratory, 1 hr. per night of sleep restriction has been shown to accumulate and to progressively increase daytime sleepiness. Sleep was rated as better overall posttrip than on trip nights and deeper posttrip than pretrip, as is typical during recovery from sleep loss. Delaying the start of on-duty times (by 1.5-2 hr. on average) would be expected to produce a significant improvement in the amount of sleep pilots are able to obtain, and should be given serious consideration.

Pilots reported more fatigue on posttrip days than on pretrip days, suggesting a cumulative effect of duty-related activities and sleep loss. Fatigue and negative affect were higher, and activation lower, by the end of trip days than by the end of pretrip days. The inability to maintain subjective activation by the end of trip days was exacerbated by early on-duty times.

Pilots drank 42% more caffeine on trip days than on pretrip and posttrip days. More caffeine was consumed in the early morning, in association with the early wake-ups, and also around the time of the mid-afternoon peak in physiological sleepiness. The urge to fall asleep at this time would increase as the sleep debt accumulated across trip days.

There were twice as many complaints of headaches on trips as at home. Reports of back pain increased twelvefold, and reports of burning eyes increased fourfold. Helicopter pilots were three times more likely to report headaches, and five times more likely to report back pain than were pilots of fixed-wing aircraft on short-haul commercial flights. The physical environment on the helicopter flight deck was probably an important factor. Studies of the same operations, conducted in parallel, demonstrated that pilots often had skin temperatures outside the range of thermal comfort, and that vibration levels in all of the helicopters studied exceeded the 'reduced comfort' boundary defined by the International Standards Organization (I.S.O. 263). The longer pilots remained on duty, the more negative their mood became. This situation could be improved with better seat design, including better isolation of the seat from floor vibration, and better flight-deck ventilation.

The predominant environmental factors affecting subjective workload assessments were different for different phases of flight. The quality of the aircraft systems had a significant effect during preflight, taxi, climb, and cruise. Paying particular attention to aircraft maintenance, thereby minimizing failures, might be one way of reducing workload during these phases of flight. Landing weather was the major factor influencing workload ratings during descent and approach. However, the effect of adverse weather on workload was reduced with better landing sites and better letdown aids. The quality of the landing site and air traffic control had a significant effect on workload ratings during landing. These findings confirm that improvements in landing sites, letdown aids, and air traffic control can reduce subjective workload during descent, approach, and landing.

2.0 INTRODUCTION

2.1 Field Studies of Fatigue in Flight Operations

It is now widely recognized that fatigue, sleep, and circadian rhythms can have critical effects on safety margins in aviation. About 21% of all incidents reported to the NASA Aviation Safety Reporting System can be interpreted as fatigue-related. Such incidents tend to occur more frequently in the early hours of the morning, and are often potentially serious (refs. 1, 2). The National Transportation Safety Board, which is responsible for the investigation of transportation accidents in the United States, in 1989 reviewed a number of major accidents which they concluded "raise serious concerns about the far-reaching effects of fatigue, sleepiness, sleep disorders, and circadian factors in transportation system safety" (ref. 3).

Beginning in the early 1980s, the Flight Human Factors Branch at NASA Ames Research Center undertook an extensive program of field and simulator research into the effects of fatigue, sleepiness, and circadian rhythms on flight crew performance (refs. 4-13). In the field studies, the approach was to use a core set of physiological and subjective measures, together with detailed recordings of operational events, to document the psychophysiological effects of different types of flight operations (commercial and military short-haul and long-haul operations, commercial overnight cargo operations). The present study, conducted jointly with the United Kingdom Civil Aviation Authority (CAA), extends these observations to helicopter operations.

2.2 North Sea Helicopter Operations

The discovery of oil in the North Sea and subsequent development of the oil fields called for major support services by sea and air. The first oil-support helicopter flight from Aberdeen, Scotland, took place on August 1, 1967. At the time of this study, Aberdeen Airport had handled more than half a million helicopter flights, and there were four support companies operating about 50 helicopters, making it one of the largest helicopter operations ever undertaken. The operations covered all normal activities such as lifting, shuttling, and the carriage of goods and personnel between Aberdeen and the various rigs. A particular feature of these operations was the extended duration of some flights, for example, to the North Shetland Basin, which was a round trip of about 560 miles or 5 hr. flying time.

2.3 Helicopter Versus Fixed-Wing Flight Operations

There are some similarities between these helicopter operations and the commercial short-haul fixed-wing operations studied in the NASA Fatigue Countermeasures Program (ref. 9). Both involved two-person crews flying primarily during daylight. The maximum daily time zone change was 1 hr. in the short-haul fixed-wing operations; there were no time zone changes in the helicopter operations. In both operations, people and goods were transported. However, there are also important differences. Helicopter cockpits are characterized by high levels of vibration (ref. 14). In North Sea helicopter operations, low water temperatures and severe weather often require that the flight crews wear immersion suits; also, the large transparent areas surrounding the flight deck expose the crews to solar heating. As a result, complaints of being too hot are common (ref. 15). In comparison with fixed-wing aircraft, flying helicopters involves much more manual control. Automation may be single channel, rather than multiplex, and the required response time in emergencies is generally very short. The helicopter crews also returned to their domicile between duty days, whereas the short-haul fixed-wing crews stayed in hotels at different enroute locations.

To investigate in more detail the particular problems involved in North Sea helicopter operations, the CAA sponsored two other studies in parallel with the joint NASA/CAA study presented here. The first addressed vibration levels in the cockpit, and was undertaken by the Institute of Sound and Vibration Research at the University of Southampton (ref. 14). The second examined the thermal environment and its effects on body temperature, and was carried out by the Royal Air Force Institute of Aviation Medicine at Farnborough (ref. 15). Data collection for all three studies was carried out in parallel, although never simultaneously with the same flight crew. Thus, the findings of these two studies are directly applicable to the present work; their summaries have therefore been included here in the appendix. In addition to the standard NASA field study measures, the present study also included measures of flight crew workload. A preliminary analysis of the workload data indicated that the paperwork required of crews before, during, and after off-shore support flights was extensive. The CAA therefore commissioned a follow-up study aimed at finding ways of reducing the workload associated with paperwork (ref. 16). The summary of that study is also included in the appendix.

The data presented in this report thus have the dual advantage of being part of an exceptionally rich series of CAA studies on North Sea helicopter operations, as well as providing a comparison with the NASA field studies of fatigue, sleep, and circadian rhythms in fixed-wing operations.

This work was made possible by the enthusiasm and dedication of the pilot volunteers and the generous cooperation of the following companies: British Airways Helicopters (now British International Helicopters); British Caledonian Helicopters; Bristows Helicopters; and Bond Helicopters. We would also like to acknowledge the invaluable assistance of Hazel Courtney and Keith Biggin of Westland Helicopters, who served as cockpit observers, and the Statistics Department of the RAF Institute of Aviation Medicine at Farnborough for analyzing the workload data. Malachi Boyle provided excellent support for the production of the figures. Drs. Charles Billings and Mark Rosekind offered valuable comments on the original manuscript.

3.0 METHODS

3.1 Subject Recruitment

Thirty-two male pilots from four companies took part in the study. Each company distributed a CAA/NASA letter explaining the study and calling for volunteers. The response of pilots to this letter was extremely positive, and the research team was therefore able to select the longest trips being flown during the times when the cockpit observers were available to accompany crews (see sec. 3.2). An additional preference was to have trips for which both pilots had volunteered to participate. The confidentiality of data was assured, as in the other NASA field studies (ref. 9).

3.2 Data Collected

All flights took place in the Shetland Basin, off the east coast of Scotland (fig. 1). Each duty day began and ended in Aberdeen, Scotland (local time = Greenwich mean time [GMT] in winter, GMT + 1 in summer), with the following exception: on the first day of trip 3, a hydraulic failure forced the crew to remain overnight on a rig. The following day they returned to Aberdeen, where they remained on standby for the rest of the day. Half of the trips took place during the winter/spring (February to May) of 1986, and the other half in the summer/autumn (July to September) of the same year. The crews studied flew one of the following types of helicopter: the Aerospatiale Super Puma; the Aerospatiale Tiger; the Bell 214 ST; or the Boeing Vertol BV234.

Subjects were monitored for a maximum of 4 days before the trip, throughout the trip (4-5 days), and for up to 4 days after the trip. In most instances, subjects were accompanied during the trip by a cockpit observer. The observers were applied psychologists working in the helicopter sector of the aviation industry, but were not qualified pilots. They instructed subjects in the use of test equipment and kept a log of operationally significant events for each trip segment flown. At the end of the trip, they also offered each subject the opportunity to examine his own physiological data.

Throughout his participation in the study, each subject wore a Vitalog PMS-8 biomedical monitor which recorded rectal temperature, average heart rate, and average activity of the non-dominant wrist every 15 sec. These data were subsequently converted to 2 min. averages (temperature and heart rate) or summed in 2 min. bins (activity). Subjects also kept a daily log of sleep timing and quality, naps, showers or baths, exercise, duty times, food, caffeine, and alcohol consumption, bowel movements, urinations, cigarettes, medications and medical symptoms. Every 2 hr. during the waking day, they completed a 26-adjective mood checklist, and estimated their fatigue by placing a mark on a 10 cm line signifying a continuum from alert to drowsy. Subjects also completed a Background Questionnaire compiled to obtain information on demographic and lifestyle variables, sleep and nutritional habits, and personality profiles. These measures are described in detail in another publication (ref. 9).

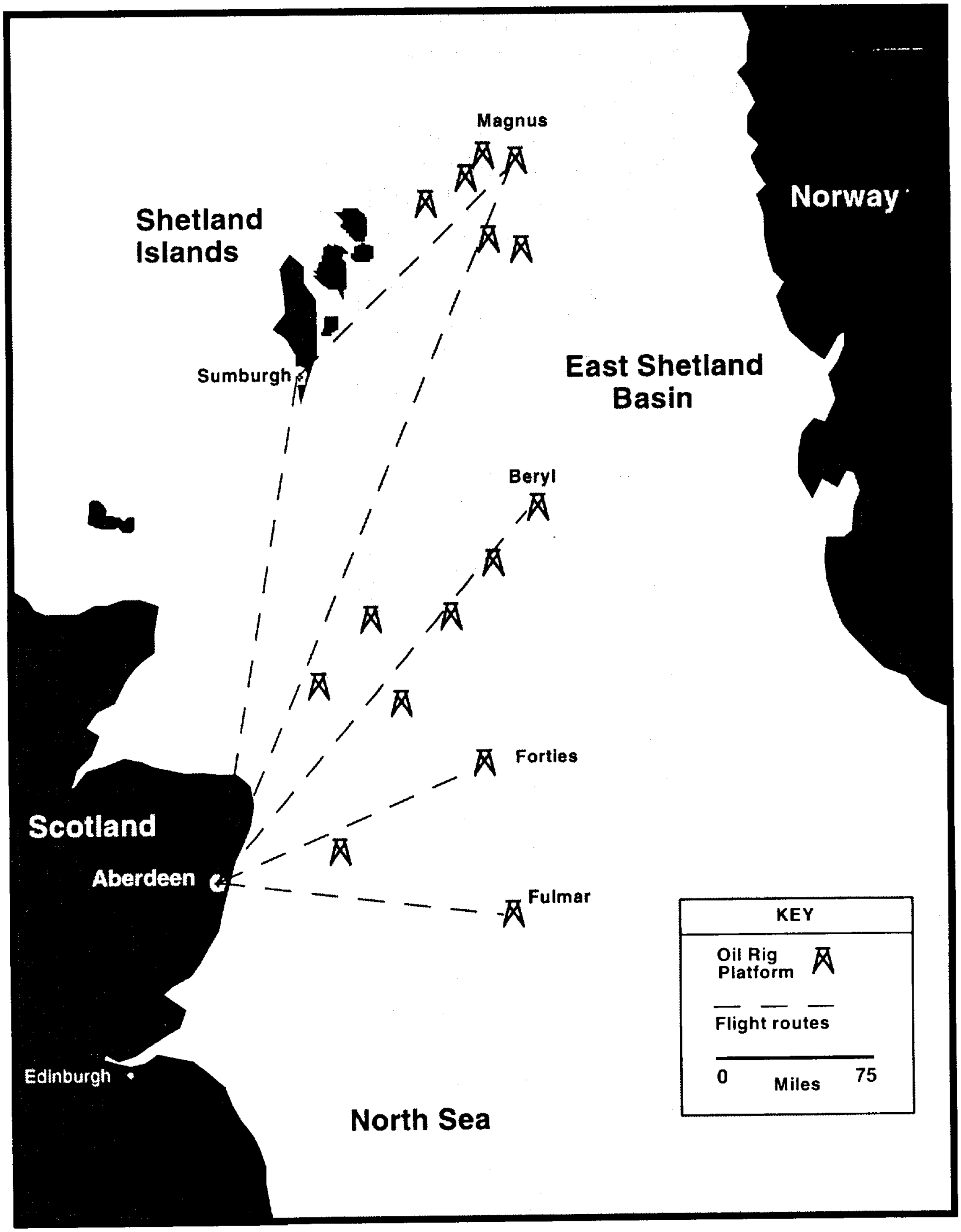
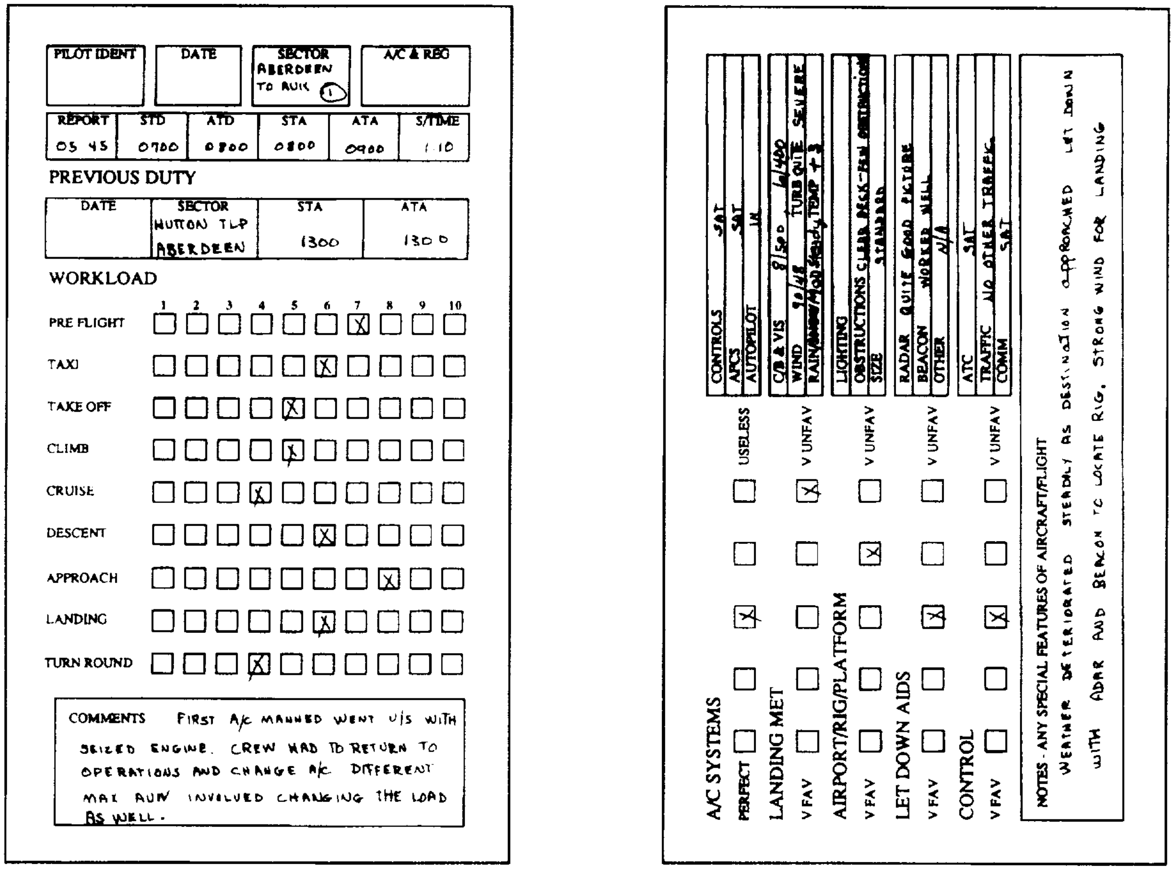


Figure 1. Shetland Basin, where the operations studied took place.

The subjective measure of workload used in this study was a modified Bedford Scale (ref. 17), which provides an assessment of the overall workload (on a scale from 1-10) without attempting to differentiate between mental, physical, and temporal loads. In general, a score of 1-3 is acceptable, and a score of 4-5 is acceptable for limited periods, for example, during landing. For a score of 6-7, a reduction in workload is desirable, and a score greater than 7 indicates an increasing potential for overload. Before each trip, subjects were briefed on the use of the Bedford Scale and provided with a copy of the briefing materials for later reference. Pilots were asked to rate their workload during each phase of the flight, as soon as possible after the completion of that phase. They also rated, on a scale from 1 ('very favorable') to 5 ('very unfavorable'), the following aspects of each flight segment: the weather conditions for landing; the particular airport, platform, or rig where the landing took place; and (where applicable) the letdown aids and air traffic control. The functioning of the aircraft systems was rated for every segment on a scale from 1 ('perfect') to 5 ('useless'). Figure 2 shows an example of the rating cards used.



PILOT IDENT	DATE	SECTOR	A/C & REG
		SECTOR ABERDEEN TO AUK ①	

REPORT	STD	ATD	STA	ATA	S/TIME
05 45	0700	0800	0800	0900	1.10

PREVIOUS DUTY

DATE	SECTOR	STA	ATA
	HUTTON TLP ABERDEEN	1300	1300

WORKLOAD

	1	2	3	4	5	6	7	8	9	10
PRE FLIGHT	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
TAXI	☐	☐	☐	☐	☐	☒	☐	☐	☐	☐
TAKE OFF	☐	☐	☐	☐	☒	☐	☐	☐	☐	☐
CLIMB	☐	☐	☐	☐	☒	☐	☐	☐	☐	☐
CRUISE	☐	☐	☐	☒	☐	☐	☐	☐	☐	☐
DESCENT	☐	☐	☐	☐	☐	☒	☐	☐	☐	☐
APPROACH	☐	☐	☐	☐	☐	☐	☐	☒	☐	☐
LANDING	☐	☐	☐	☐	☐	☒	☐	☐	☐	☐
TURN ROUND	☐	☐	☐	☒	☐	☐	☐	☐	☐	☐

COMMENTS FIRST A/C MANNED WENT U/S WITH SEIZED ENGINE. CREW HAD TO RETURN TO OPERATIONS AND CHANGE A/C. DIFFERENT MAX AUW INVOLVED CHANGING THE LOAD AS WELL.

Side A

A/C SYSTEMS
PERFECT ☐ ☐ ☒ ☐ ☐ USELESS

CONTROLS	SAT
APCS	SAT
AUTOPILOT	IN

LANDING MET
V FAV ☐ ☐ ☐ ☐ ☒ V UNFAV

C/B & VIS	8/500, 6/400
WIND	90/48 TURB QUITE SEVERE
RAIN/~~[illegible]~~/	Mod Steady TEMP +3

AIRPORT/RIG/PLATFORM
V FAV ☐ ☐ ☐ ☒ ☐ V UNFAV

LIGHTING	
OBSTRUCTIONS	CLEAR DECK-FEW OBSTRUCTIONS
SIZE	STANDARD

LET DOWN AIDS
V FAV ☐ ☐ ☒ ☐ ☐ V UNFAV

RADAR	QUITE GOOD PICTURE
BEACON	WORKED WELL
OTHER	N/A

CONTROL
V FAV ☐ ☐ ☒ ☐ ☐ V UNFAV

ATC	SAT
TRAFFIC	NO OTHER TRAFFIC
COMM	SAT

NOTES - ANY SPECIAL FEATURES OF AIRCRAFT/FLIGHT
WEATHER DETERIORATED STEADILY AS DESTINATION APPROACHED LET DOWN WITH ADAR AND BEACON TO LOCATE RIG. STRONG WIND FOR LANDING

Side B

Figure 2. Workload rating card: side A, modified Bedford Scale; side B, ratings of environmental factors. One card was completed by each subject for each segment flown.

4.0 RESULTS

4.1 Trip Statistics

The trips studied are illustrated in figure 3. Not all subjects on these trips provided complete data. The first criterion for inclusion in the analyses was that subjects provide complete data on sleep for at least 1 day pretrip and 2 days posttrip. This precluded 10 subjects (subjects 161, 201, 251, 261, 271, 281, 291, 301, 311, 321). Of the remaining 22 subjects, 17 flew 4-day trips and 5 flew 5-day trips. Three other subjects were excluded from the duty statistics summarized in table 1 because they gave no data for duty times on at least one day of the trip. Data on flight times were unavailable for subjects 91 and 101 on first and third days of their trips, and for subjects 151 and

161 on the first and fourth days. The two trip patterns undertaken by these four subjects are therefore not included in the summary statistics on flight times in table 1.

Table 1. Trip Statistics

Variable	n	Mean (SD)	Range
On-duty time, GMT	19 subjects	7.42 (2.02)	4.33 - 12.50
Off-duty time, GMT	19 subjects	14.62 (2.55)	7.75 - 22.00
Duty duration, hr.	19 subjects	7.13 (1.67)	3.00 - 11.83
Layover duration*, hr.	19 subjects	16.97 (3.08)	10.00 - 23.00
Segments/day	10 trips	2.90 (1.37)	1.00 - 7.00
Segment duration, hr.	10 trips	1.31 (0.55)	0.03 - 2.55
Daily flight hours	10 trips	3.40 (1.19)	1.13 - 5.61
Segments/trip	10 trips	11.60 (3.03)	7.00 - 17.00

*Nighttime layover, i.e., between duty days.

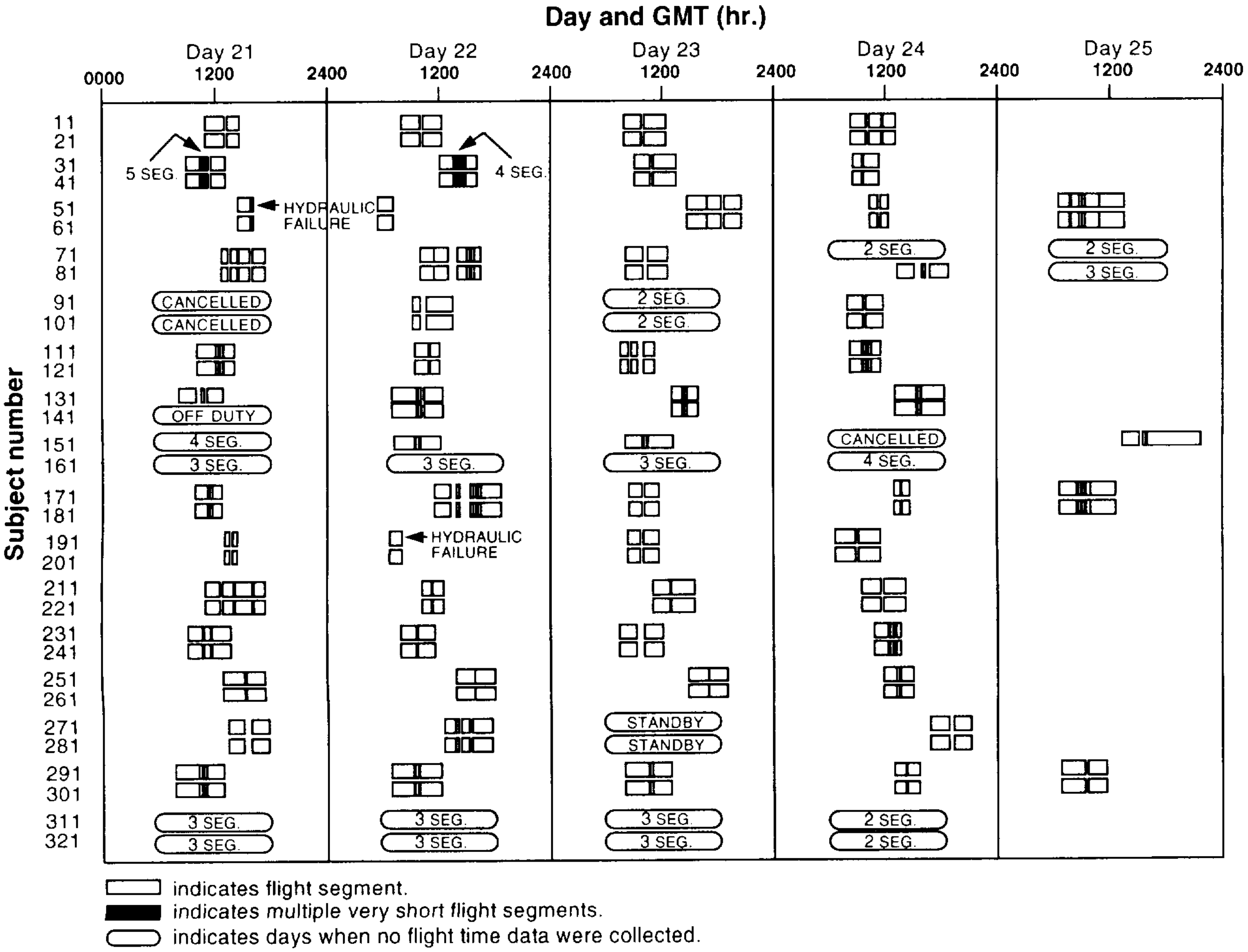


Figure 3. Time lines of the trips studied.

4.2 Pilot Statistics

The distributions of the age, experience, weight, and height of the 22 pilots included in the analyses are shown in figures 4 and 5. These distributions are based on responses to the Background Questionnaires. The number of years of experience was taken as the largest value from among the following categories: years with the present airline; years of military experience; years of airline experience; years of general aviation experience; and other. This value may well have underestimated the total years of helicopter flying experience, since half the pilots had some years of military experience before going into commercial aviation. If experience had been calculated as the sum of the highest "other" category plus the years of military experience, the average number of years of experience would have been 10.68.

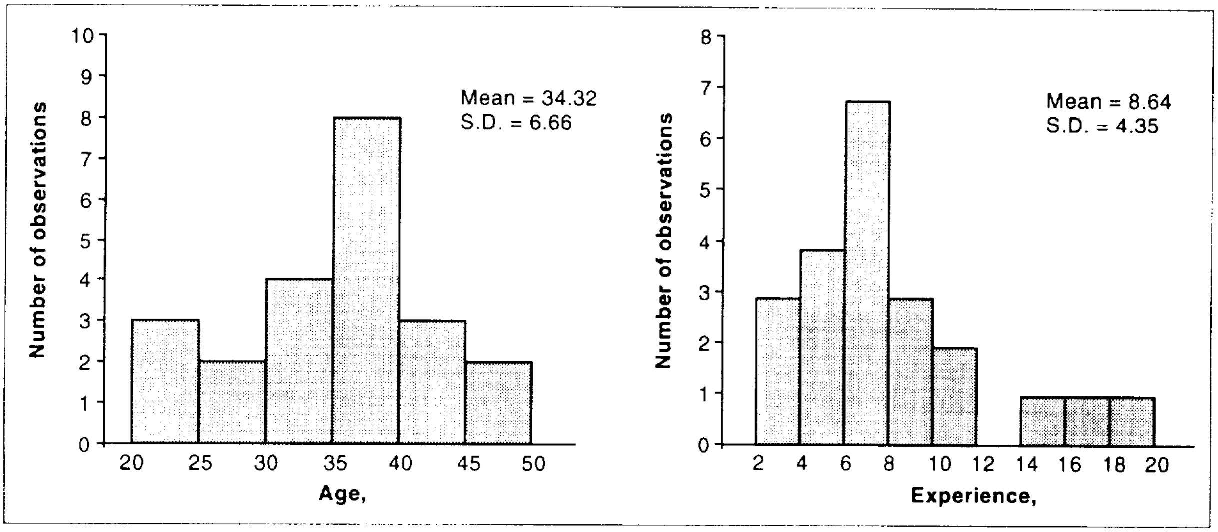


Figure 4. Age and experience distributions of 22 subjects included in analyses.

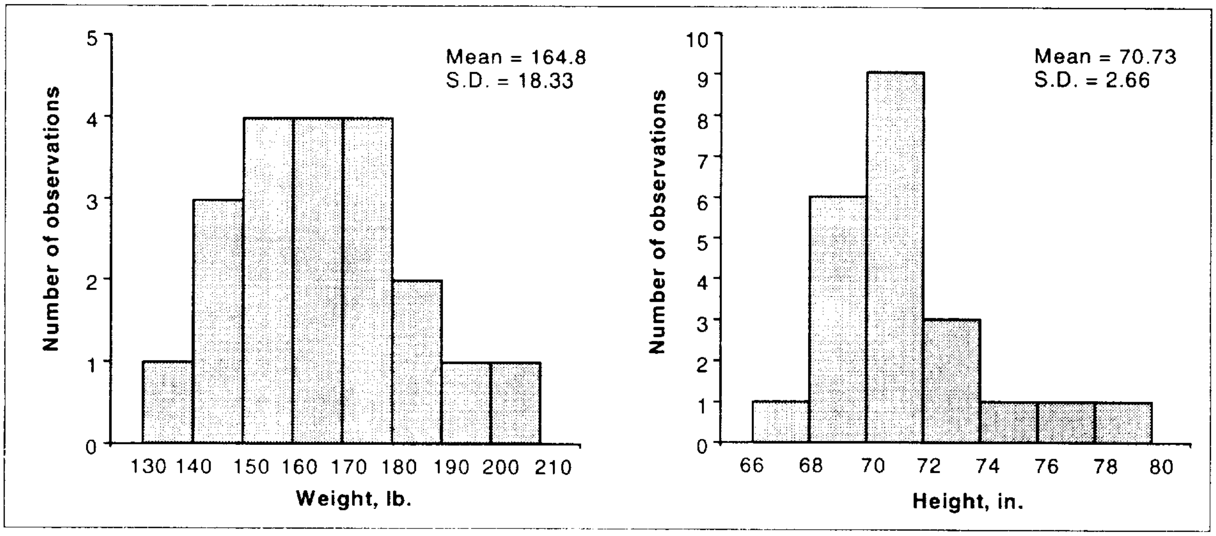


Figure 5. Distributions of the Weight and height distributions of 22 subjects included in analyses.

The distributions for the personality inventories in the Background Questionnaire are shown in figures 6-9. On the Personality Attributes Questionnaire (fig. 6), the group tended to score higher on Instrumentality (I) than on Expressiveness (E), and therefore averaged in the third quartile of the combined (I + E) scale. For American flight crews, high scores on both instrumentality and expressiveness have been found to be associated with higher check-airman ratings of crew performance (ref. 18). On the Work and Family Orientation Questionnaire, the average scores were high for Mastery and for Work and were relatively low for Competitiveness (fig. 7), conforming to the pattern found for high achievers in other occupations (ref. 19). On the Eysenck Personality Inventory (ref. 20), subjects tended to score high on Extraversion and low on the Neuroticism index (fig. 8). There is some evidence to suggest that extraverts, particularly neurotic extraverts, adapt more rapidly to shift work and time-zone shifts (refs. 8,21,22).

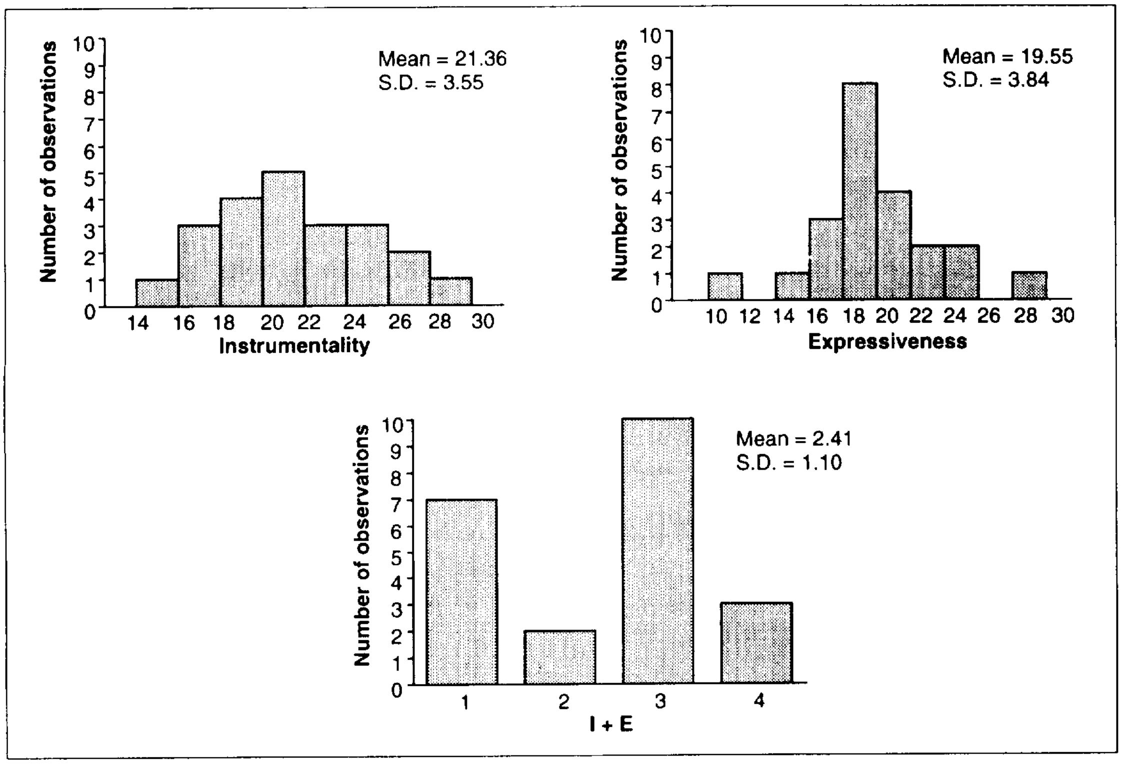


Figure 6. Distributions of subjects' scores on scales of Personality Attributes Questionnaire (n = 22).

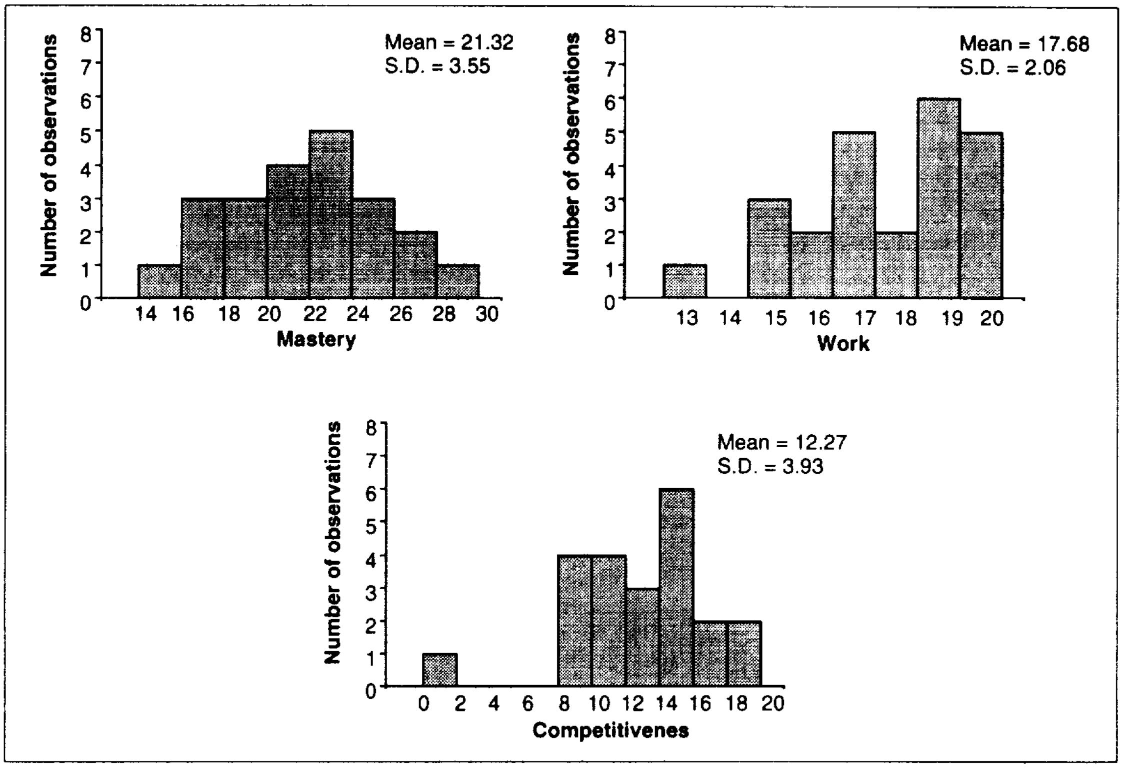


Figure 7. Distributions of subjects' scores on scales of Work and Family Orientation Questionnaire (n = 22).

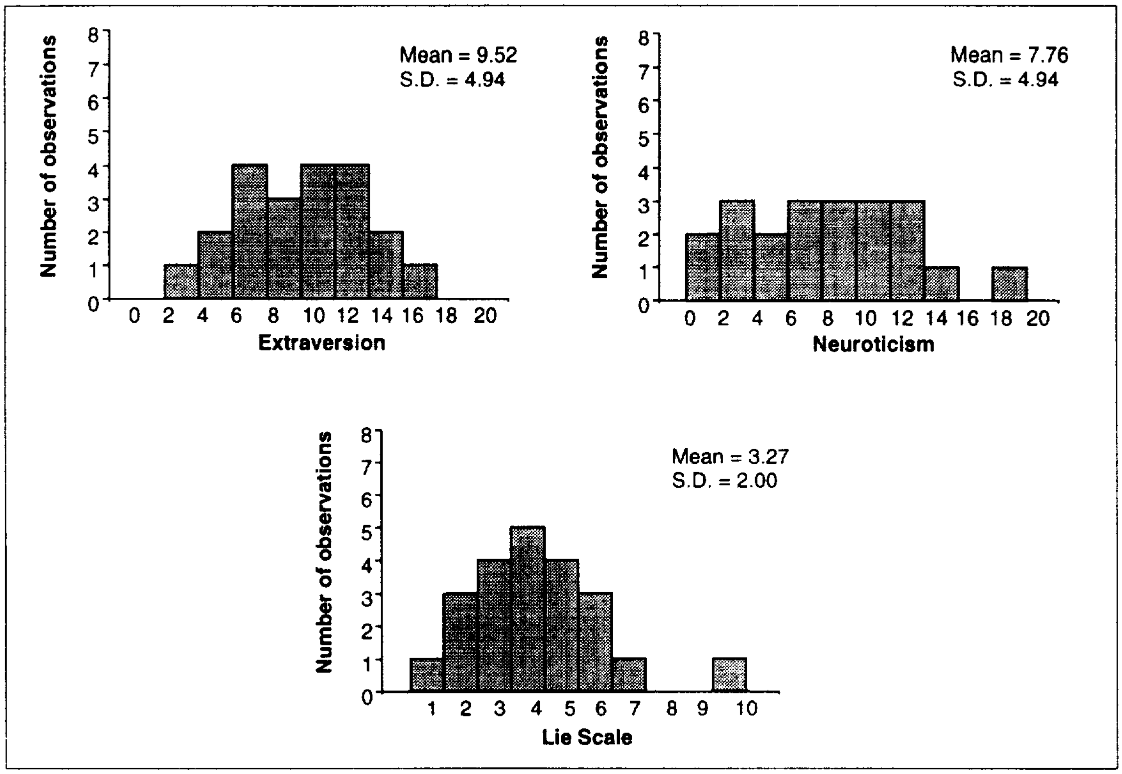
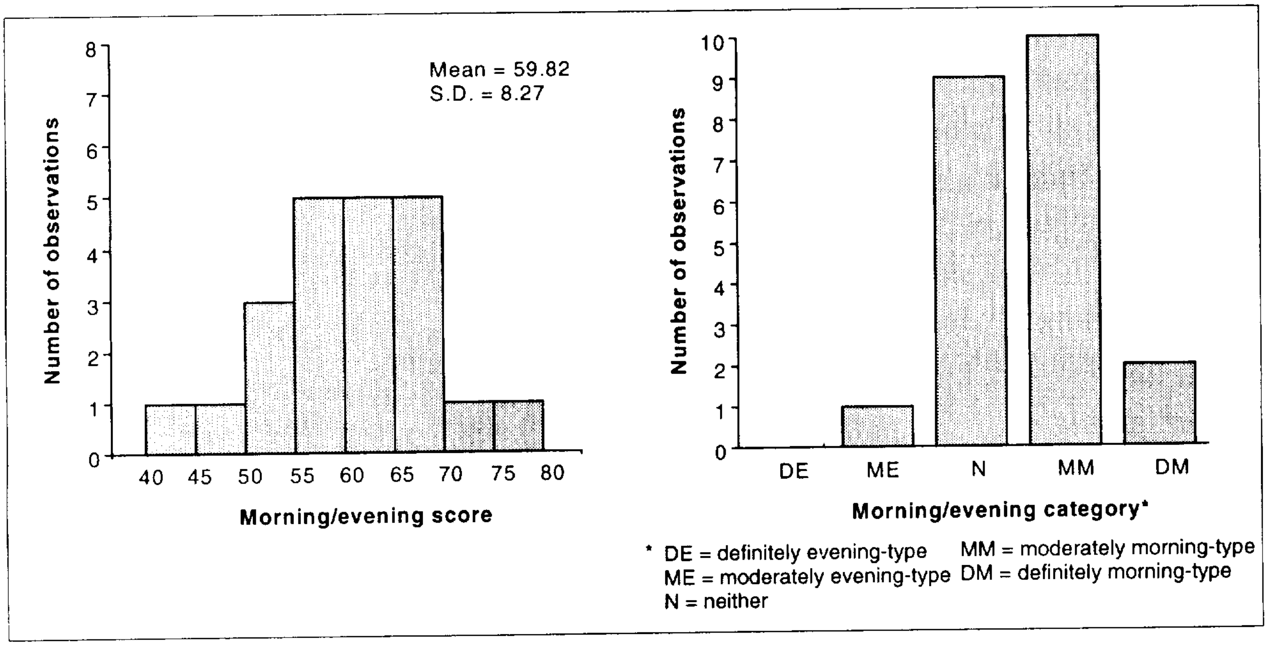


Figure 8. Distributions of subjects scores on scales of Eysenck Personality Inventory (n = 22).

On the circadian type questionnaire of Horne and Ostberg (ref. 23), the present population tended to be more morning-type (fig. 9). Generally, evening-types have been reported to adapt more rapidly to shiftwork (refs. 24-28). Comparative studies of morning/eveningness in students, soldiers, and shiftworkers showed different frequency distributions of the raw scores for the three groups, that is, this type of questionnaire may need to be adapted for different subject groups (refs. 27, 28).



* DE = definitely evening-type MM = moderately morning-type
ME = moderately evening-type DM = definitely morning-type
N = neither

Figure 9. Distributions of subjects' scores on Morning/Eveningness Questionnaire (n = 22) and of morning/eveningness categories as defined in reference 23.

4.3 Effects of Trips on Physiological and Psychological Variables

4.3.1 Sleep

For the measures of subjective sleep quality, 22 subjects (69%) provided data for at least one pretrip sleep episode, all trip sleep episodes, and at least two posttrip sleep episodes. Twenty subjects (63%) provided complete physiological data during those sleep episodes. For each subject, mean heart rate, temperature, and activity levels during each sleep episode were calculated from 20 min. after the reported sleep onset time until 10 min. before the reported wake-up time. This trimming minimized contamination of the estimates of mean heart rate, temperature, and activity levels during sleep by eliminating the comparatively high values that occur immediately before and after sleep (ref. 9). Variability in heart rate and activity during sleep was estimated as the standard deviation of the raw scores for each sleep episode for each subject.

Mean values for each of the sleep-related variables on pretrip, trip, and posttrip days are given in table 2. Sleep ratings have been converted so that higher values indicate better sleep.

Table 2. Sleep Measures Before, During, and After Trips

	Pretrip	Trip	Posttrip	p(F)†
Time of sleep onset, GMT	23.63	22.75	23.42	6.88**
Time of wake-up, GMT	7.17	5.58	7.27	36.68***
Sleep latency, min.	11.30	29.52	34.63	11.17***
Getting-up latency, min.	39.35	14.44	40.53	5.39**
Duration primary sleep episode, hr.	7.30	6.43	7.39	8.06**
Total sleep per 24 hr., hr.	7.55	6.71	7.49	5.50**
Sleep efficiency, %	87.70	84.89	82.91	3.97*
Difficulty falling asleep? (1-5)	4.17	3.93	4.33	2.75
How deep was your sleep? (1-5)	3.25	3.42	3.67	3.30*
Difficulty rising? (1-5)	3.40	3.32	3.57	0.73
How rested do you feel? (1-5)	2.97	2.93	3.04	0.37
Sleep rating (4-20)	13.71	13.64	14.61	3.52*
Number of awakenings	1.16	1.22	1.14	0.12
Mean heart rate during sleep, beats/min.	60.39	58.20	59.03	0.93
Standard deviation of heart rate during sleep, beats per min.	4.52	4.39	4.92	1.30
Mean activity during sleep, counts/min.	2.34	1.32	1.35	1.85
Standard deviation of activity during sleep, counts/min.	5.79	5.38	4.14	0.66
Mean temperature during sleep, °C	36.01	36.08	36.16	0.77
Standard deviation of temperature during sleep, °C	0.14	0.12	0.15	1.63

† p(F) from 1-way ANOVA (subjects treated as a random variable).
* $0.05 > p > 0.01$; **$0.01 > p > 0.001$; ***$p < 0.001$.

To test if sleep differed significantly over pretrip, trip, and posttrip days, 1-way ANOVAs were performed (pre/trip/post), with subjects treated as a random variable. These analyses are summarized in table 3, and are the source of the significance levels indicated in table 2. Where the ANOVA revealed significant pretrip/trip/posttrip differences, the values for pretrip, trip, and posttrip sleeps were intercompared by post hoc t-tests.

Table 3. Intersubject Differences and Sleep Before, During, and After Trips

	F Subjects	F Pre/trip/post
Time of sleep onset, GMT	28,132.28***	6.88**
Time of wake-up, GMT	1783.40***	36.68***
Sleep latency, min.	80.54***	11.17***
Getting-up latency, min.	74.91***	5.39**
Duration primary sleep episode, hr.	2223.52***	8.06**
Total sleep per 24 hr., hr.	2180.52***	5.50**
Sleep efficiency, %	7635.97***	3.97*
Difficulty falling asleep? (1-5)	1089.58***	2.75
How deep was your sleep? (1-5)	929.07***	3.30*
Difficulty rising? (1-5)	779.39***	0.73
How rested do you feel? (1-5)	958.74***	0.37
Sleep rating (4-20)	1918.70***	3.52*
Number of awakenings	135.84***	0.12
Mean heart rate during sleep, beats/min.	1366.38***	0.93
Standard deviation of heart rate during sleep, beats per min.	555.63***	1.30
Mean activity during sleep, counts/min.	25.62***	1.85
Standard deviation of activity during sleep, counts/min.	68.93***	0.66
Mean temperature during sleep, °C	222,477.47***	0.77
Standard deviation of temperature during sleep, °C	187.29***	1.63

*0.05 > p(F) > 0.01; **0.01 > p(F) > 0.001; *** p(F) < 0.001.

Subjects fell asleep significantly earlier on trip days than either pretrip (t = 3.09, 0.01 > p > 0.001) or posttrip (t = -3.49, 0.001 > p > 0.0001) days. They also woke up significantly earlier on trip days than on either pretrip (t = 6.73, p < 0.0001) or posttrip (t = -7.25, p < 0.0001) days. The primary nighttime sleep episode was significantly shorter on trip days than on either pretrip (t = 4.06, p < 0.0001) or posttrip (t = -3.93, p < 0.0001) days. Total sleep per 24 hr. (i.e., including naps) was also significantly less on trip days relative to pretrip (t = 3.42, 0.001 > p > 0.0001) or posttrip (t = -3.12, 0.01 > p > 0.001) days. For each sleep episode, sleep latency was calculated as the difference between the reported time of going to bed and falling asleep. Sleep latencies were significantly shorter on pretrip days than on trip (t = -3.43, 0.01 > p > 0.001) or posttrip (t = -4.38, p < 0.0001) days. The getting-up latency was calculated as the difference between the reported time of awakening and getting up. On days containing duty periods, subjects spent significantly less time in bed before getting up than on either pretrip (t = 3.10, 0.01 > p >

0.001) or posttrip (t = -2.88, 0.05 > p > 0.01) days. The sleep efficiency was calculated as the percentage of time that subjects reported being asleep between the times of going to bed and getting up. Sleep efficiency was significantly higher pretrip than posttrip (t = 2.29, 0.05 > p > 0.01). Sleep quality was rated as better overall on posttrip nights than on trip nights (t = -2.25, 0.05 > p > 0.01), and deeper posttrip than pretrip (t = -1.99, p = 0.05).

The frequency of napping or of multiple sleep episodes per 24 hr. was very low in this study (fig. 10). One reason for this is that CAA regulations prohibit napping in two-person cockpits. Since the total sleep per 24 hr. on trip days averaged 0.81 hr. less than during baseline, pilots accumulated a sleep debt across the trip days (fig. 11). The sleep loss for each trip day was calculated for each subject as the difference between his total sleep (including naps) that day and his average total daily sleep (including naps) during baseline. For each subject, these differences were expressed as a percentage of his baseline sleep (including nap) duration and averaged across all trip days, to give his average daily percentage sleep loss on trips. The average daily percentage sleep loss on 4-day trips was not significantly different from that on 5-day trips (two-group t-test on the z-scores, t = 0.455, p = 0.657). This suggests that the cumulative sleep loss would be greater by the end of a 5-day trip. A two-group t-test on the z-scores comparing the cumulative sleep loss after 4-day trips with that after 5-day trips did not show a significant difference (t = -1.65, p = 0.12), probably because of the large individual variability and the small number of subjects (14 for 4-day trips and 5 for 5-day trips). The hours of sleep lost during the trips were not regained after two nights of posttrip sleep. However, this is not unexpected since sleep loss is normally compensated by deeper rather than proportionally longer sleep.

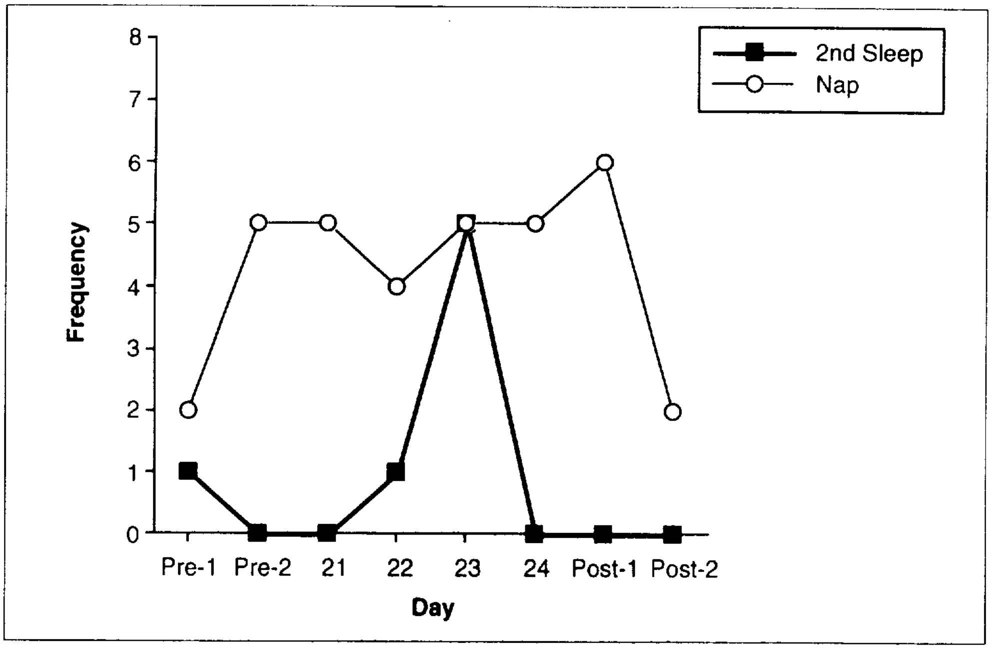


Figure 10. Number of subjects (/22) reporting naps or secondary sleep episodes for pretrip, trip, and posttrip days. Day numbers indicate the day of wake-up; first trip day is day 21.

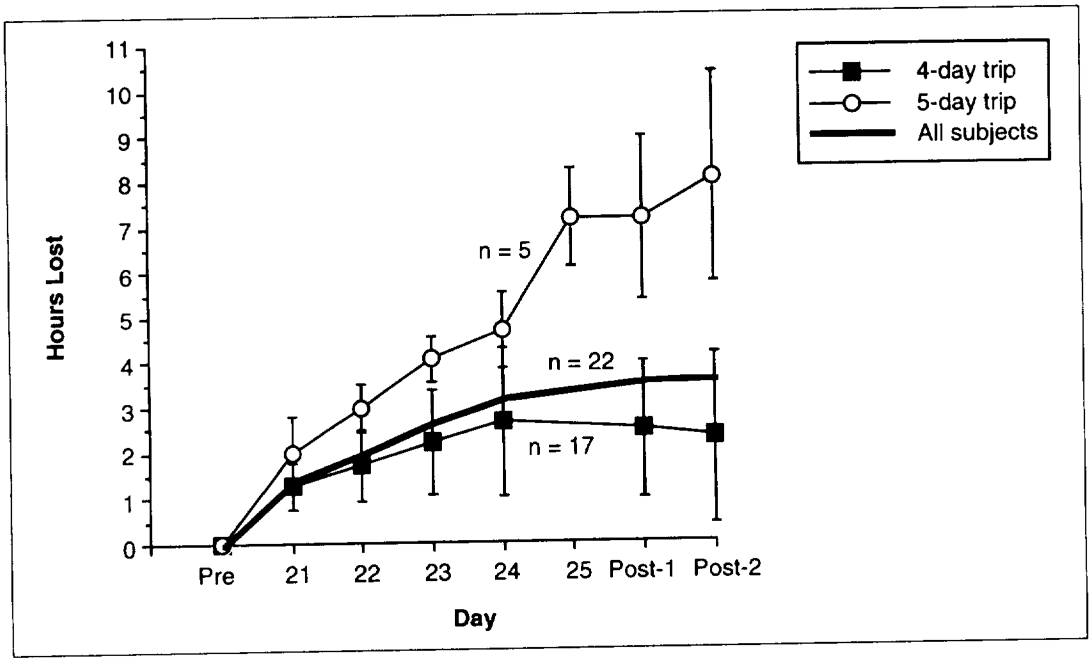


Figure 11. Average day-by-day cumulative sleep loss with respect to baseline sleep; first trip day is day 21.

4.3.2 Fatigue Ratings

Every 2 hr. while they were awake, subjects rated their fatigue level along a 10 cm line representing levels from 'drowsy' to 'alert.' The results of this measure of subjective fatigue have previously been shown to differ significantly between subjects, and to exhibit a marked time-of-day variation (ref. 9). A 2-way ANOVA, with subjects treated as a random variable, was therefore performed to compare fatigue levels between subjects at different times of day, for pretrip, trip, and posttrip days (table 4). Complete data were available for 16 subjects when the data were grouped in 4 hr. time bins.

Table 4. Fatigue Ratings, 2-Way ANOVA (Time-of-day-by pretrip/trip/posttrip)

	F
Time-of-day	26.33**
Pre/trip/post	4.16*
Time-of-day by pre/trip/post	5.93**

* 0.05 > p(F) > 0.01; ** p(F) < 0.001.

These analyses confirm the previous findings of significant intersubject and time-of-day variability in this measure. Fatigue ratings were significantly higher posttrip (mean = 48.79) than pretrip (mean = 44.49, t = -1.93, p = 0.05). The significant interaction (time-of-day by pre/trip/post) suggests that the time-of-day variation in fatigue ratings was different across pretrip, trip, and posttrip days (fig. 12). Fatigue ratings increased linearly across the day on trips, whereas pretrip and posttrip they declined to a minimum around 1300 and then increased to a maximum in the last rating of the day. This was examined further in 1-way ANOVAs, with subjects treated as a random variable, which compared pretrip, trip, and posttrip values in each 4 hr. time bin (table 5).

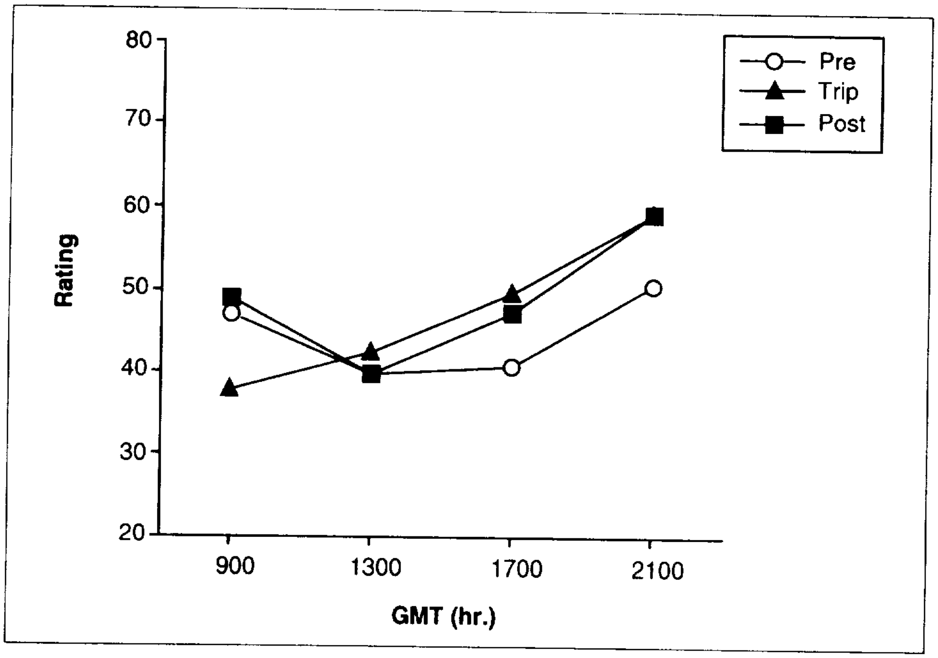


Figure 12. Average fatigue ratings at different times of day for pretrip, trip, and posttrip days. Ratings were indicated on a 100-mm line ranging from alert (0) to drowsy (100).

Paired t-tests were used to compare pretrip, trip, and posttrip fatigue ratings for each 4 hr. time bin. Fatigue in the first rating of the day (0900) was significantly lower on trips than either pretrip ($t = 2.32$, $p < 0.05$) or posttrip ($t = 2.38$, $p < 0.05$). At 1300 there were no significant differences between fatigue ratings pretrip, trip, and posttrip. At 1700, fatigue was significantly lower pretrip than on trips ($t = 2.33$, $p < 0.05$). At 2100, fatigue was rated as significantly lower pretrip than either trip ($t = 2.66$, $p < 0.05$) or posttrip ($t = 2.27$, $p < 0.05$).

Table 5. Fatigue Ratings Pretrip, Trip, and Posttrip: Comparisons at Different Times of Day

Time	Pretrip mean	Trip mean	Posttrip mean	F (pre/trip/post)
0900	46.98	37.91	48.94	7.43**
1300	39.66	42.39	39.66	0.69
1700	40.78	49.74	47.29	4.03*
2100	50.55	59.33	59.27	13.06***

* 0.05 > p(F) > 0.01;** 0.01 > p(F) > 0.001;*** p(F) < 0.001.

4.3.3 Mood Ratings

Every 2 hr. while they were awake, subjects rated their current mood from 1 ('not at all') to 4 ('extremely') on 26 adjectives. These 26 adjectives have been shown to load on three orthogonal factors, designated positive affect, negative affect, and activation (ref. 9). A 2-way ANOVA, with subjects treated as a random variable, was performed to compare ratings on each of these factors at different times of day, for pretrip, trip, and posttrip days (table 6). The data were grouped in 4 hr. time bins.

Table 6. Mood Ratings, 2-Way ANOVA
(Time-of-day by pretrip/trip/posttrip, n = 21)

	F Positive affect	F Negative affect	F Activation
Time-of-day	1.31	9.49*	39.87*
Pre/trip/post	1.11	1.42	0.45
Time-of-day by pre/trip/post	1.07	4.79*	8.97*

* p(F) < 0.001.

These analyses confirm the previous findings of significant intersubject differences in these ratings, and of time-of-day variability in negative affect and activation (ref. 9). None of the mood ratings changed significantly on trip days, by comparison with pretrip or posttrip days. However, negative affect and activation both showed significant interactions, suggesting that the time-of-day variation was different across pretrip, trip, and posttrip days (figs. 13, 14).

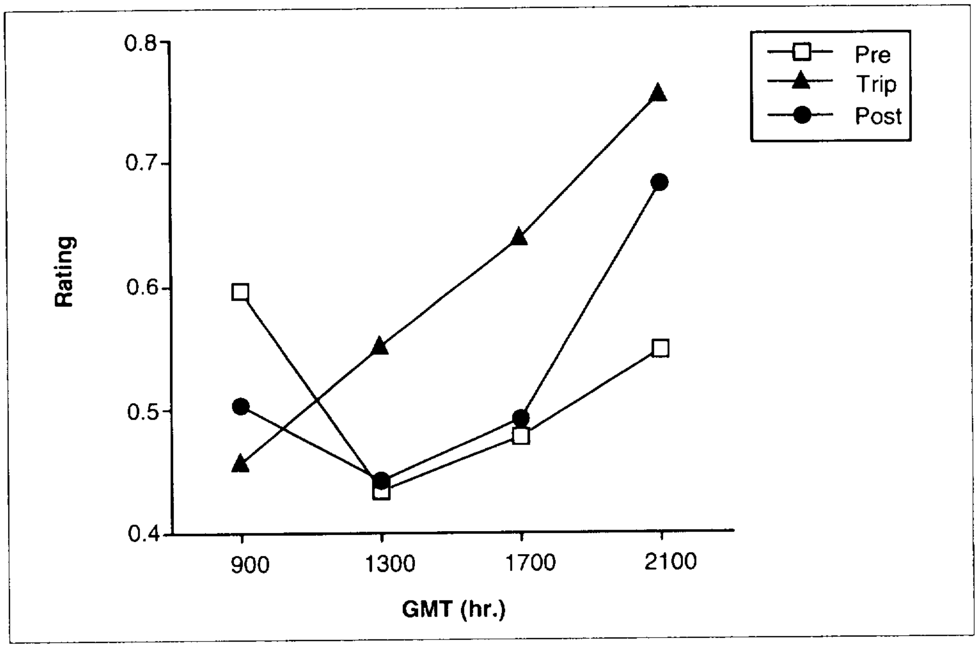


Figure 13. Average negative affect ratings at different times of day for pretrip, trip, and posttrip days.

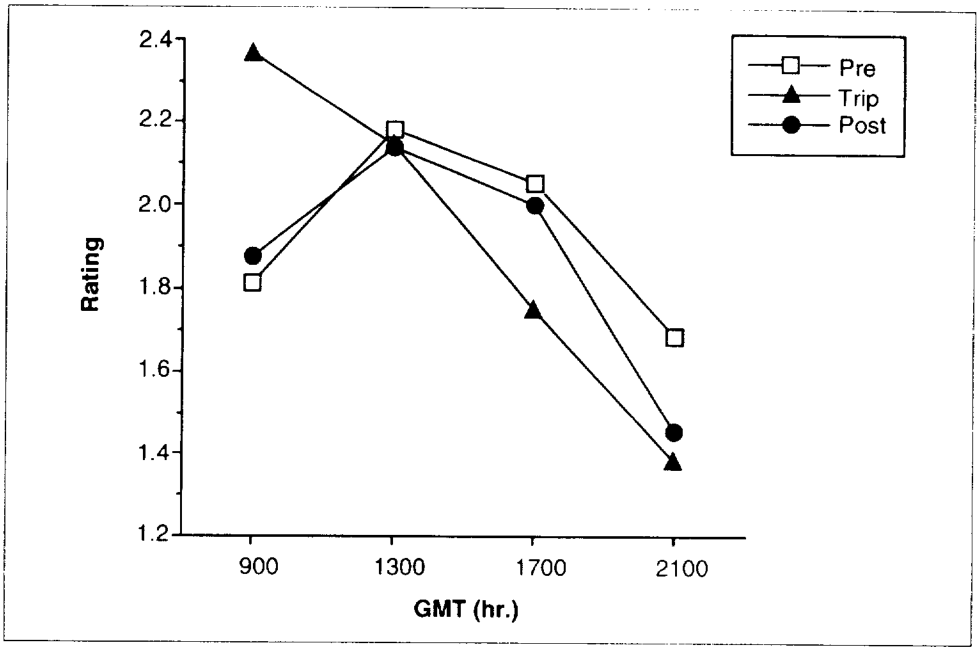


Figure 14. Average activation ratings at different times of day for pretrip, trip, and posttrip days.

This was examined further in 1-way ANOVAs, with subjects treated as a random variable, comparing pretrip, trip, and posttrip values in each 4 hr. time bin (table 7).

Table 7. Mood Ratings Pretrip, Trip, and Posttrip: Comparisons at Different Times of Day.

Time	Pretrip mean	Trip mean	Posttrip mean	F (pre/trip/post)
Negative affect				
0900	0.60	0.46	0.50	1.65
1300	0.43	0.55	0.44	2.03
1700	0.48	0.64	0.49	3.68*
2100	0.55	0.75	0.68	4.05*
Activation				
0900	1.81	2.37	1.87	10.66***
1300	2.19	2.14	2.14	0.16
1700	2.05	1.75	2.00	2.86
2100	1.69	1.38	1.46	6.05**

* 0.05 > p(F) > 0.01; ** 0.01 > p(F) > 0.001; *** p(F) < 0.001.

Where the ANOVAs indicated significant differences, post hoc t-tests were used to compare pretrip, trip, and posttrip ratings for the respective 4 hr. time bins. At 1700, negative affect was significantly higher on trips than either pretrip (t = -2.72, 0.01 > p > 0.001) or posttrip (t = -2.51, 0.05 > p > 0.01). At 2100, negative affect was significantly higher on trips than pretrip (t = -3.36, 0.001 > p > 0.0001). At 0900, activation was significantly higher on trip days than on either pretrip ($t = -4.79$, $p < 0.0001$) or posttrip ($t = 4.33$, $p < 0.0001$) days. At 2100, activation was significantly lower on trip days than pretrip ($t = 3.41$, $0.001 > p > 0.0001$) days.

4.3.4 Caffeine Consumption

Coffee was available in Aberdeen, but not in flight on most of the aircraft. Pilots could also request coffee on the rigs. The number of cups of caffeinated beverages, and the time of day at which caffeine consumption occurred, were recorded in the daily logbook. All 22 of the subjects included in the sleep analyses consumed caffeine at some time during the study. To test whether caffeine consumption was different on trip days than on pretrip and posttrip days, a 1-way ANOVA was performed in which subjects were treated as a random variable. Consumption was found to significantly vary ($F = 10.55$, $p < 0.001$) over the pretrip/trip/posttrip study period.

Caffeine consumption was higher on trip days (mean 4.7 cups/day) than on either pretrip days (mean 3.1 cups/day, $t = -3.74$, $0.001 > p > 0.0001$) or posttrip days (mean 3.5 cups/day, $t = 2.38$, $0.05 > p > 0.01$). Figure 15 suggests that this extra caffeine consumption on trips occurred shortly after wake-up (which was significantly earlier on trips; see table 2), and in the early afternoon.

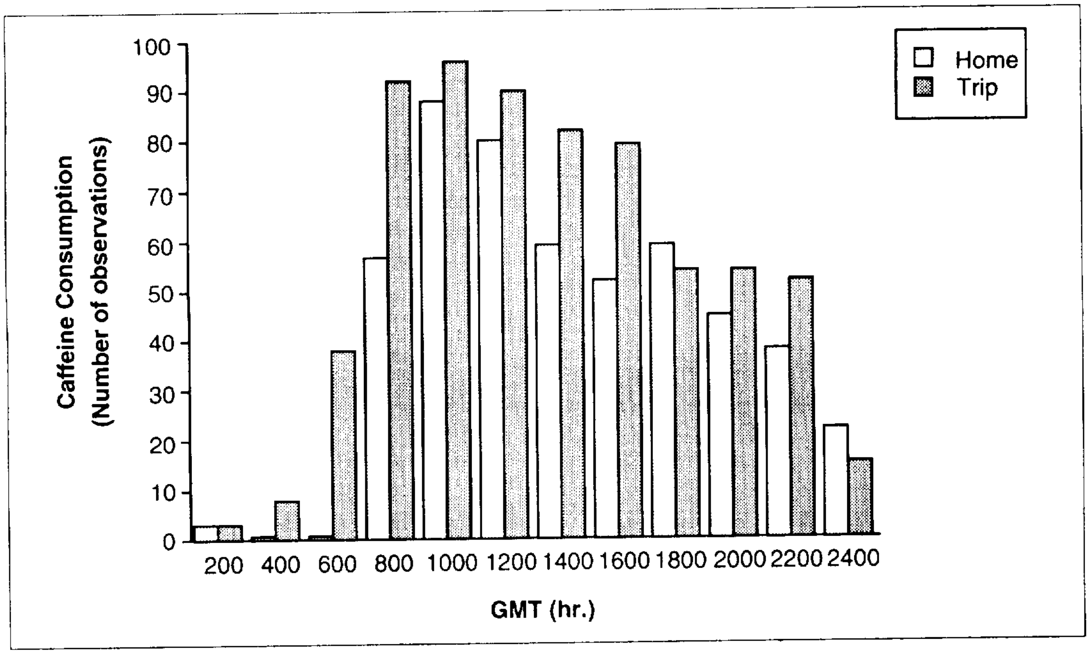


Figure 15. Caffeine consumption at different times of day for trip and home days (pretrip and posttrip days combined).

4.3.5 Meals and Snacks

Food was available in Aberdeen. At the beginning of the study, pilots were experiencing some difficulty obtaining food in early morning hours; however, this situation was rectified later in the study. Food was not available in flight, but pilots could request meals on the rigs. The time of eating and the general content of meals (breakfast, lunch, dinner) and snacks were recorded in the daily logbook. One-way ANOVAs (pretrip/trip/posttrip), with subjects treated as a random variable, were performed to test whether the number of meals or snacks eaten per day varied between pretrip, trip, and posttrip days (table 8).

Table 8. Meals and Snacks: Pretrip, Trip, and Posttrip

	F
Meals	2.53
Snacks	5.71*

* 0.01 > p > 0.001.

Subjects reported significantly fewer snacks per day posttrip (mean = 0.83) than on either pretrip (mean = 1.20, t = 2.01, 0.05 > p > 0.01), or on trip days (mean = 1.27, t = 2.49, 0.05 > p > 0.01).

4.3.6 Medical Symptoms

Subjects also noted when they experienced medical symptoms which were classified into 20 categories (ref. 9). Eighteen of the 22 subjects included in the analyses (82%) reported symptoms at some time during the study. The three most common symptoms were headaches (34% of all reports, reported by 73% of subjects at some time during the study), back pain (18% of all reports, reported by 32% of subjects at some time during the study), and burning eyes (10% of all reports, reported by 18% of subjects at some time during the study). The percentage of these reports that occurred on pretrip, trip, and posttrip days is shown in table 9.

*Table 9. Reports of Common Medical Symptoms**

Symptom	Pretrip, %	Trip, %	Posttrip, %
Headache	33	52	15
Back pain	7	86	7
Burning eyes	17	66	17

*Percent of 18 subjects reporting.

Complaints of headache were twice as common on trip days as on pretrip and posttrip days, complaints of back pain increased twelvefold on trip days over pretrip and posttrip days, and complaints of burning eyes increased fourfold. Only eight subjects (36%) reported using medications at some time during the study. Cold remedies were used by two subjects pretrip and one subject posttrip. Analgesics were used by four subjects pretrip, four subjects on trip days, and two subjects posttrip.

4.3.7 Summary

On trips, subjects fell asleep earlier, slept for a shorter duration, awoke earlier, and then spent less time in bed before getting up. Sleep latencies were significantly shorter on pretrip days than on either trip or posttrip days. Sleep efficiency was significantly higher pretrip than posttrip. Sleep was rated as significantly better posttrip than during trips. The effect of duty requirements was also evident in the subjective fatigue ratings, which were significantly higher posttrip than pretrip. By the end of duty days, fatigue was rated as significantly higher than by the end of pretrip days. Overall, there were no significant differences between trip days and either pretrip or posttrip days in ratings of positive affect, negative affect, or activation. However, by the end of duty days, negative affect was significantly higher, and activation significantly lower, than at the end of pretrip days. More caffeine was consumed daily on trips than either pretrip or posttrip. Fewer snacks were consumed daily posttrip than either pretrip or during trips. On trip days, headache complaints doubled, back pain complaints increased twelvefold, and complaints of burning eyes increased fourfold.

4.4 Relationships Between Duty Factors and the Changes Measured on Trips

All-possible-subsets regression analyses were carried out to examine which aspects of duty schedules contributed most to the changes observed on trips. Only data for duty days for each of the 22 subjects with complete pretrip, trip, and posttrip data were included in these analyses. It should be noted that differences between individuals are not taken into account in these analyses, and that the relationships between dependent and independent variables are assumed to be linear.

4.4.1 Sleep

The dependent variables that were examined for their contributions to the variance in the sleep-related variables are shown in table 10. These analyses are based on 48 nights of trip sleep. The best possible subsets for each of the independent variables are shown in table 11.

Table 10. Dependent Variables Used in All-Possible-Subsets Regressions for Trip Sleep

Dependent variables	Independent variables
Asleep time Sleep latency	Preceding duty duration, preceding flight hours, preceding number of flight segments, preceding off-duty time, layover duration
Wake-up time Sleep duration Sleep rating	Preceding duty duration, preceding flight hours, preceding number of flight segments, layover duration, following on-duty time
Get-up latency	Preceding duty duration, preceding flight hours, preceding number of flight segments, off-duty time, following on-duty time

About 20% of the variability in wake-up time was accounted for by the next on-duty time, with earlier wake-ups being associated with earlier duty report times. Similarly, the earlier subjects had to be on duty, the less time they spent in bed after waking up, with on-duty time accounting for 29% of the variability in get-up latency. On-duty time also accounted for 41% of the variability in sleep duration, with small but significant contributions coming from the duration of the previous duty day, and the number of flight legs flown during that day. These analyses support the hypothesis that early on-duty times were an important cause of the sleep loss on trips.

Table 11. Multiple Regression Analyses of The Duty Factors Affecting Sleep on Trips

Variable	Unstandardized reg. coeff.	Standardized reg. coeff.	p	Contribution to r^2 (*)
Asleep time				
Flight legs	-0.840	-0.227	0.120	0.052
For best subset: $r^2 = 0.052$; F = 2.50; p = 0.121				
Sleep Latency				
Flight legs	-0.056	-0.232	0.1113	0.054
For best subset: $r^2 = 0.054$; F = 2.61; p = 0.113				
Wake-up Time				
On-duty time	0.548	0.444	0.002	0.197
For best subset: $r^2 = 0.197$; F = 11.27; p = 0.002				
Get-up Latency				
On-duty time	4.415	0.539	0.000	0.291
For best subset: $r^2 = 0.291$; F = 18.85; p = 0.0001				
Sleep Duration				
On-duty time	0.470	0.654	0.000	0.410
Duty duration	0.223	0.312	0.026	0.055
Flight hours	-0.301	-0.276	0.043	0.045
For best subset: $r^2 = 0.544$; F = 17.49; p = 0.000				
Sleep Rating				
On-duty time	0.182	0.135	0.361	0.018
For best subset: $r^2 = 0.018$; F = 0.85; p = 0.361				

* The contribution to r^2 indicates the amount by which r^2 would be reduced if the variable were removed from the regression equation.

4.4.2 Final Fatigue and Mood Ratings

By the end of trip days, fatigue and negative affect were significantly higher than on pretrip days, and activation was significantly lower. All-possible-subsets regressions were therefore performed (table 12) to see which duty demands contributed most to the variance in these final ratings. The dependent variables included in these analyses were: prior sleep duration, on-duty time, off-duty time, duty duration, flight hours, and the number of segments flown that day.

The time of getting off duty accounted for 13% of the variation in fatigue ratings in the final 4 hr. time-bin on duty days, such that the later a subject came off duty, the higher he rated his fatigue. The longer a subject remained on duty, the more negative his affect became, and this relationship accounted for 11% of the variability in negative affect in the final 4 hr. time-bin. The earlier a subject went on duty, the lower his activation rating by the end of the duty day, and this relationship accounted for 16% of the variance in activation in the final 4 hr. time-bin.

Table 12. Multiple Regression Analyses of Duty Factors Affecting Final Fatigue and Mood Ratings on Trip Days

Variable	Unstandardized reg. coeff.	Standardized reg. coeff.	p	Contribution to r^2 (*)
Fatigue				
Off-duty time	4.050	0.362	0.011	0.131
For best subset: $r^2 = 0.131$; F = 6.94; p = 0.011				
Negative Affect				
Duty duration	0.084	0.335	0.020	0.112
For best subset: $r^2 = 0.112$; F = 5.80; p = 0.020				
Activation				
On-duty time	0.148	0.409	0.005	0.163
Off-duty time	-0.052	-0.2 01	0.148	0.039
For best subset: $r^2 = 0.181$; F = 4.97; p = 0.011				

* The contribution to r^2 indicated the amount by which r^2 would be reduced if the variable were moved from the regression equation.

4.4.3 Caffeine Consumption

More caffeine was consumed on trip days than on either pretrip or posttrip days. To test whether this increased consumption was correlated with specific duty factors, an all-possible-subsets regression was performed (table 13). The dependent variables included were on-duty time, duty duration, the number of flight hours, and the number of segments flown that day. None of these duty factors contributed significantly to the variance in caffeine consumption on trip days.

Table 13. Multiple Regression Analyses of Duty Factors Affecting Caffeine Consumption on Trip Days

Variable	Unstandardized reg. coeff.	Standardized reg. coeff.	p	Contribution to r^2
On-duty	0.182	0.153	0.299	0.023
For best subset: $r^2 = 0.023$; F = 1.10; p = 0.299				

4.5 Comparison with Commercial Short-Haul Fixed-Wing Operations

As discussed in section 2.3, these helicopter operations have the following characteristics in common with the commercial fixed-wing operations documented in the NASA short-haul field study (ref. 9): two-person flight crews; predominantly daytime flying; minimal time zone changes; and the transport of passengers and goods. On the other hand, the physical environment in the helicopter cockpit is less comfortable, and more manual control is required in flying helicopters than in flying fixed-wing aircraft. It is of interest, therefore, to compare the responses of pilots in the two operating environments.

4.5.1 Comparison of Responses to Trips

To compare the effect of helicopter and short-haul fixed-wing operations on sleep, changes from pretrip to trip nights were compared by two-group t-tests (table 14). The short-haul fixed-wing data include the 33 subjects who gave pretrip baseline data (ref. 9).

Table 14. Sleep Changes on Helicopter Trips and Short-Haul Fixed-Wing Operations

Change	Helicopter, (trip - pretrip)	Short-haul, (trip - pretrip)	t
In sleep onset time, hr.	-0.88	-0.31	1.32
In sleep latency, min.	18.22	25.55	1.35
In wake-up time, hr.	-1.59	-1.53	0.16
In sleep duration, hr.	0.87	1.37	-1.53

The changes in sleep timing and duration were not significantly different between the helicopter and short-haul fixed-wing operations studied.

Although the fatigue and mood data were analyzed somewhat differently in the two studies, both groups showed higher fatigue and lower activation ratings by the end of trip days than by the end of pretrip days.

Both groups also consumed significantly more caffeine on trips. Helicopter pilots increased their daily consumption by 42% on trips, and the short-haul fixed-wing pilots increased their consumption by 48%. In both cases, more caffeine was consumed early on trip days, in association with the earlier wake-up times dictated by early on-duty times. There was also some indication of increased caffeine consumption in the mid-afternoon on trips, around the time of the mid-afternoon peak in physiological sleepiness.

Headaches were the most commonly reported medical symptom in both studies. They were reported by 73% of helicopter pilots at some time during the study, and by 25% of short-haul fixed-wing pilots. Back pain was the second most common symptom reported by helicopter pilots (32%), and was the third most common symptom reported by short-haul fixed-wing pilots (7%). The second most common symptom reported by short-haul fixed-wing pilots was congested nose (16%). The third most common symptom reported by helicopter pilots was burning eyes (18%).

4.5.2 Comparison of the Duty Demands

To interpret these similarities in the psychophysiological changes observed in response to the helicopter operations and commercial short-haul fixed-wing operations, it is necessary to compare in detail the duty demands of each type of operation (table 14), and the characteristics of the pilot populations studied (table 15). These comparisons include data for 22 helicopter pilots and 44 short-haul fixed-wing pilots. It should also be noted that in the operations studied, helicopter crews returned home each night whereas the short-haul fixed-wing crews slept in layover hotels throughout their 3-4 day trips.

The information for table 15 came from the daily logbooks kept by the pilots. The subject helicopter pilots began work about an hour earlier, but had duty days more than 3 hr. shorter and finished work more than 4 hr. earlier than the short-haul fixed-wing pilots studied. The helicopter pilots also averaged about an hour less flight time and two flight segments fewer per day, and had nighttime layovers more than 4 hr. longer than those of the short-haul fixed-wing pilots.

Table 15. Duty Characteristics of Helicopter and Short-Haul Fixed-Wing Operations

	Helicopter, mean (S.D.)	Short-haul, mean (S.D.)	t
Local time on-duty, hr.	7.47 (2.20)	8.71 (3.14)	3.62*
Local time off-duty, hr.	14.77 (2.53)	19.06 (3.54)	11.05*
Duty duration, hr.	7.30 (2.53)	10.66 (2.41)	12.81*
Layover duration, hr.	16.77 (3.05)	12.52 (2.52)	10.14*
Flight hours/day	3.58 (1.11)	4.50 (1.39)	5.08*
Flight segments/day	3.02 (1.46)	5.12 (1.34)	8.82*
Flight hours/month	61.48 (18.69)	70.21 (9.92)	1.95

* $p < 0.001$; t from 2-group t-tests.

4.5.3 Comparison of the Subject Populations

Demographic and personality measures for the pilots included in the helicopter and short-haul fixed-wing analyses are compared in table 16. This information came from the Background Questionnaire. The number of years of experience was taken as the largest value from among the following categories: years with the present airline; years of military experience; years of airline experience; years of general aviation experience; and other. As noted above, in the case of the helicopter pilots, this is probably an underestimate. If experience had been calculated as the sum of the highest "other" category plus the years of military experience, the average experience of the helicopter pilots would have increased to 10.68 years, which was still significantly less than that of the short-haul fixed-wing pilots (2-group $t = -3.84$, $0.001 > p > 0.0001$).

The study helicopter pilots were, on average, 9 years younger and less experienced than the short-haul fixed-wing pilots. They also weighed less, perhaps because of the age difference. The comparison of scores on the personality inventories is complicated by the fact that the helicopter pilots were British, whereas the short-haul fixed-wing pilots were American. The only significant difference between the groups was that the helicopter pilots scored somewhat lower on the expressivity scale of the Personal Attributes Questionnaire.

Table 16. Pilot Characteristics of Helicopter and Short-Haul Fixed-Wing Operations

	Helicopter, mean (S.D.)	Short-haul, mean (S.D.)	t
Age, yr.	34.32 (6.66)	43.02 (7.65)	4.54**
Experience, yr.	8.64 (4.35)	17.07 (6.56)	6.22**
Height, in	70.73 (2.66)	70.59 (1.86)	0.24
Weight, lb.	164.80 (4.10)	174.84 (2.15)	2.15*
Eysenck Personality Inventory			
Neuroticism	7.76 (4.94)	6.58 (4.51)	0.95
Extraversion	9.52 (3.72)	10.91 (3.46)	1.46
Lie	3.27 (2.00)	3.41 (1.92)	0.27
Morning/Eveningness Questionnaire			
	59.82 (8.27)	63.41 (9.47)	1.51
Personal Attributes Questionnaire			
Instrumentality	21.36 (3.71)	23.27 (3.94)	1.89
Expressivity	19.55 (3.84)	22.34 (4.40)	2.53*
I+E	2.41 (1.10)	2.84 (1.01)	1.59
Work and Family Orientation Questionnaire			
Mastery	21.32 (3.55)	19.95 (4.10)	1.33
Competitiveness	12.27 (3.93)	12.57 (3.49)	0.31
Work	17.68 (2.06)	17.66 (2.09)	0.04

* $0.05 > p > 0.01$; ** $p < 0.001$; t from 2-group t-tests.

4.6 Analysis of Workload

The mean workload ratings for each phase of flight are summarized in table 17.

Table 17. Mean Workload Ratings During Different Phases of Flight

	Mean	S.D.	% Acceptable (1-3)	% Acceptable for limited time (4-6)	% Unacceptable* (7-10)
Preflight	3.56	1.50	59	35	5
Taxi	3.62	1.64	54	40	7
Takeoff	4.53	1.58	29	59	11
Climb	4.02	1.42	41	54	5
Cruise	3.38	1.24	60	38	2
Descent	3.61	1.16	51	47	2
Approach	4.21	1.35	32	61	6
Landing	4.60	1.52	28	62	10
Turnaround	3.40	1.51	59	34	6

* Scores 6-7 indicate that a reduction in workload is desirable; scores 8-10 indicate an increasing potential for overload.

As expected, highest workload ratings were associated with takeoff and landing. In both cases, about 10% of the ratings were sufficiently high to indicate that a reduction in workload would be desirable.

Subjects also rated, on a scale from 1 to 5, the following environmental factors for each segment: functioning of the aircraft systems; the weather conditions for landing; the particular airport, platform, or rig where the landing took place; and (where applicable) the letdown aids and air traffic control. Scores for each of these factors are summarized in table 18.

Table 18. Summary of Scores for the Five Environmental Factors

	Mean	S.D.	% Favorable (1-2)	% Neither (3)	% Unfavorable (4-5)
Aircraft systems	1.79	0.91	83	11	6
Landing weather	1.93	1.00	74	16	9
Airport	1.94	0.88	75	21	4
Letdown aids	1.98	1.05	69	24	7
Air traffic control	1.88	0.87	77	19	4

Segments were also categorized by their position in the daily flight schedule (first, second, third, etc. segment flown) and by season (winter/spring versus summer/autumn). This gave a total of seven factors to be tested for their effects on workload ratings, as well as the effects of intersubject differences. Analyses of variance using these seven factors, with subjects treated as a random variable, were performed for workload ratings during the following phases of flight: preflight, taxi, takeoff, climb, cruise, descent, approach, land, and turnaround. These analyses are summarized in table 19.

At every phase of flight, there were significant intersubject differences in workload ratings. These analyses suggest that aircraft systems had an important effect on workload ratings from preflight through cruise, with the exception of during takeoff. Weather at the landing site had a major effect during descent and approach, and the landing site itself had an important effect on the workload during landing. There were seasonal differences in the workload associated with turnarounds.

Table 19. Effects of Environmental Factors on Workload Ratings During Different Phases of Flight (F, P(F))

Flight Phase	Source of Variation						
	Season	Segment number	Aircraft systems	Landing weather	Airport	Letdown aids	Air traffic control
Preflight	0.63	1.73	4.75**	4.43**	3.85*	0.86	0.61
Taxi	3.06	3.02*	3.02*	2.03	0.23	1.31	2.00
Takeoff	4.72	1.95	1.43	0.56	0.60	1.25	0.60
Climb	1.44	2.15	4.27**	0.47	0.10	0.57	1.67
Cruise	1.60	1.51	2.79*	1.22	0.93	0.28	0.38
Descent	2.20	0.46	2.48	5.65**	1.93	0.34	0.67
Approach	2.18	1.30	1.21	7.90***	0.56	0.37	0.82
Landing	3.45	0.65	2.57	0.53	6.33**	0.78	0.32
Turnaround	5.88*	0.64	0.68	0.65	0.31	0.28	1.16

* $0.05 > p > 0.01$; ** $0.01 > p > 0.001$; *** $0.001 > p > 0.0001$.

To test whether ratings on the five environmental factors were independent, ANOVAs were performed in which each factor in turn was taken as the independent variable, with subjects treated as a random variable. The dependent variables were the remaining four rated environmental factors, together with season and segment number. The results of these analyses are summarized in table 20.

Table 20. Relationships Among the Environmental Factors Affecting Workload (F, P(F))

Environmental Factor	Source of Variation							
	Subject	Season	Segment No.	Aircraft systems	Landing weather	Airport	Letdown aids	Air Traffic control
Aircraft systems	5.58***	0.67	0.32	...	1.10	1.10	1.60	0.60
Landing weather	3.59***	0.69	2.32	1.47	...	5.89**	3.07*	1.79
Airport	1.36	0.40	3.48*	2.42	6.68***	...	1.53	1.52
Letdown aids	2.94***	0.75	0.97	1.58	4.25**	3.67*	...	10.29***
Air-traffic control	1.69*	0.29	0.66	2.16	0.62	0.75	8.17***	...

* 0.05 > p > 0.01; ** 0.01 > p > 0.001; *** 0.001 > p > 0.0001.

There were significant differences between subjects in their ratings of the five environmental factors except the landing sites ("Airport" in table 20). Ratings of the landing weather varied according to the landing site and the letdown aids available. Ratings of the landing site varied according to the segment number and the landing weather. Ratings of the letdown aids varied with the landing weather, the airport, and the air traffic control. Ratings of the air traffic control varied with the ratings of the letdown aids.

In summary, the analyses in table 20 indicated that ratings on the five environmental factors were not always independent. This could have obscured significant relationships in the analyses in table 19, where all factors were included in the ANOVA model. Therefore, for each phase of flight, smaller ANOVAs were performed with different subsets of factors, and with subjects treated as a random variable (table 21).

Table 21. Subsets of Environmental Factors Tested for Effects on Workload During Different Phases of Flight

Source of variation	Subset 1	Subset 2	Subset 3	Subset 4	Subset 5	Subset 6
Subjects	X	X	X	X	X	X
Season	X	X	X	X	X	X
Segment number	X	X	X	X	X	X
Aircraft systems		X				
Landing weather			X			
Airport				X		
Letdown aids					X	
Air traffic control						X

In some instances, these smaller ANOVA models suggested effects of environmental factors in addition to those identified in the ANOVAs with all seven factors (table 19). For preflight, each of the ANOVAs shown in table 20 indicated that the segment number also had a significant effect on workload ratings. For workload ratings during taxi, season or segment number also showed significant effects, depending on which subset of variables was included in the model. For workload during landing, there was a significant interaction between the quality of the landing site and the quality of the air traffic control.

5.0 DISCUSSION

The operations flown by the pilots in this study had a number of measurable psychophysiological effects, all of which have the potential to reduce safety margins. Differences between individuals, between flight schedules, and between operating conditions on the same schedule (weather, status of the aircraft, etc.) make it impossible to define precisely when the increased risk associated with these changes becomes sufficiently important to require remedial action. Careful analyses of the observed changes can, however, identify areas for improvement.

5.1 Effects of Trips on Sleep

Subjects tried to go to bed earlier on trip nights, in anticipation of early wake-ups. This strategy was only partially successful. Although they succeeded in falling asleep on average 48 min. earlier, they took 18 min. longer to fall asleep on trip nights, than on pretrip nights. The advance in sleep onset time was insufficient to compensate for the average advance in wake-up time (95 min.) on trip nights. Consequently, subjects averaged about 50 min. of sleep loss per trip night. In the laboratory, 1 hr./night of sleep restriction has been shown to accumulate to progressively increase daytime sleepiness (ref. 29). Multiple regression analyses confirmed that the major cause of the sleep loss on trips was the early on-duty times. The on-duty time that followed accounted for 41% of the variance in sleep durations and 20% of the variance in wake-up times during trips. On mornings when they had duty, subjects also spent significantly less time in bed after awakening and before getting up.

Generally, the accumulating sleep debt would have been expected to lead to shorter sleep latencies (ref. 30), rather than to the longer latencies observed here. This difficulty falling asleep earlier than the habitual bedtime can be attributed to three aspects of the physiological mechanisms controlling sleep. First, the period of the "biological day" generated by the circadian system tends to be longer than 24 hr., and it is therefore easier to delay sleep than to advance it. Second, sleep onset is less likely at certain phases of the circadian cycle (the so-called "wake maintenance zones"), one of which occurs shortly before the habitual bedtime (refs. 31, 32). Third, the "pressure to sleep" increases with increasing duration of wakefulness (refs. 33, 34). Both the early awakenings (refs. 35, 36) and the accumulating sleep debt (ref. 30) observed in the present study would be expected to reduce disproportionately the amount of rapid-eye-movement (REM) sleep obtained by pilots on trips.

Sleep efficiency (the percentage of time in bed that the subjects reported sleeping) was higher on pretrip than posttrip nights, whereas the intermediate values on trip nights were not significantly different from either those of pretrip or posttrip nights. However, sleep efficiency may not be a useful measure of sleep quality when, as in the present study, the amount of time spent in bed is not subject to similar constraints in all phases of the study. Short sleep latencies pretrip, when subjects were able to go to bed at their usual bedtime, led to high sleep efficiencies pretrip. Sleep latencies were longer on trips, when subjects went to bed earlier but were unable to advance their sleep onset accordingly. However, they were unable to spend as much time in bed after waking up on trip mornings. This caused a misleading improvement in the calculated sleep efficiency on trips. Sleep latencies posttrip remained significantly longer than pretrip, suggesting a continuing effect of trips on sleep. Subjects also remained in bed longer after waking up on posttrip mornings than on trip mornings. Thus the calculated sleep efficiency posttrip was low. In contrast, sleep was rated as better overall on posttrip nights than on trip nights, and deeper on posttrip nights than on pretrip nights. This finding is in agreement with data from controlled studies in which sleep has been recorded polygraphically, which indicate that recovery sleep after sleep loss is deeper than normal (ref. 33).

It should be noted that all of the changes in sleep on trips are based on subjective reports. A previous study using the same measures showed a high level of internal consistency among subjective reports of sleep timing, duration, and quality (ref. 9). Nevertheless, subjective reports are clearly not as reliable as polysomnographic recordings of sleep. However, the changes in sleep timing and duration in the present study are sufficiently great that it seems reasonable to assume that the inaccuracies inherent in subjective reporting would not alter the major trends. The strong relationships between the subjective sleep variables and duty timing, and the consistency of the findings with physiological sleep data from laboratory studies, further support the meaningfulness of the measures used.

5.2 Effects of Trips on Fatigue and Mood Ratings

Fatigue was rated as significantly higher posttrip than pretrip, which could be interpreted as an accumulated effect of duty requirements and sleep loss. In the first rating on trip mornings, fatigue was lower and activation higher than on either pretrip or posttrip mornings. This finding is somewhat surprising since subjects were required to wake up 1.5 hr. earlier and averaged almost an hour less sleep per night on trips than on either pretrip or posttrip nights. It may be a result of increased motivation associated with going on duty. By the end of trip days, fatigue and negative affect were higher, and activation was lower, than by the end of pretrip days, suggesting an effect of duty-related activities on these measures. Multiple regression analyses indicated that the later a subject came off duty, the higher his fatigue ratings at the end of the duty day. This relationship may be due, at least in part, to the linear increase in fatigue ratings across duty days (fig. 12). Longer duty periods were associated with higher negative affect ratings. This suggests a cumulative effect of duty-related activities on negative affect. The earlier a subject went on duty, the lower his activation rating by the end of the duty day. Earlier on-duty times would be associated with greater sleep loss, which might be expected to impair the ability of subjects to maintain their levels of activation by the end of the day.

5.3 Effects of Trips on Caffeine Consumption

Caffeine consumption was 42% higher on trip days than on pretrip and posttrip days. More caffeine was consumed early on trip days, in association with the earlier wake-up times dictated by early on-duty times. There was also some indication of increased caffeine consumption in the mid-afternoon on trips, around the time of the mid-afternoon peak in physiological sleepiness. The urge to fall asleep at this peak would increase progressively with the accumulating sleep debt across trip days (ref. 28). Multiple regression analyses did not reveal any duty factors that contributed significantly to the variability in caffeine consumption on trips.

5.4 Effects of Trips on Reports of Medical Symptoms

Headache was the most commonly reported medical symptom, affecting 73% of subjects at some time during the study, and was about twice as common on trips as at home. Back pain was the second most commonly reported symptom, affecting 32% of subjects at some time during the study; it was 12 times more common on trips than at home. Burning eyes was the third most commonly reported symptom, affecting 18% of subjects at some time during the study; it was 4 times more common on trips than at home.

5.5 Comparison with Commercial Short-Haul Fixed-Wing Operations

In the helicopter operations studied, duty began about 1 hr. earlier and ended about 4 hr. earlier, on average, than in the short-haul fixed-wing operations studied. Total daily flight times averaged about 2 hr. less, there were two flight segments fewer per day, and nighttime layovers averaged about 4 hr. longer in the helicopter operations. The helicopter pilots, on average, were about 9 yr. younger and had less total flight experience.

The changes in sleep timing and duration in response to these two types of flight operations were not significantly different. This, despite the fact that the helicopter crews returned to their domicile each night, whereas the short-haul fixed-wing crews stayed in layover hotels at different enroute locations. Both groups showed a sleep loss of about 1 hr. per night on trips, by comparison with pretrip nights, primarily a result of the early wake-up times dictated by early duty report times. Although helicopter pilots finished duty about 4 hr. earlier, they were unable to take advantage of the additional time available for sleep because of physiological constraints (sec. 5.1). Both helicopter and short-haul fixed-wing pilots rated their fatigue higher and their activation lower at the end of trip days, than at the end of pretrip days. Both groups also consumed significantly more caffeine on trips: helicopter pilots increased their daily consumption by 42% and short-haul fixed-wing pilots by 48%.

There were some interesting differences between the two groups in the medical symptoms reported. Complaints of headaches were three times more common among the helicopter pilots than among the short-haul fixed-wing pilots. Complaints of back pain were almost five times as frequent among helicopter pilots.

The physical environment of the helicopter cockpit is commonly thought to be more stressful than that of commercial short-haul fixed-wing aircraft. The CAA-sponsored study on the cockpit thermal environment (ref. 15), which was conducted in parallel with the present study, indicated that core temperatures of pilots remained below the level where any performance decrement owing to heat stress might be expected. However, 40-50% (depending on the season) of the skin temperature readings fell outside the range of thermal comfort (33°C-34.5°C). The authors concluded that this might contribute, along with other factors, to fatigue. Poor ventilation and airflow on many flight decks also probably accentuated sensations of physical discomfort (Barnes, unpublished observations). The CAA-sponsored study on vibration exposures (ref. 14), also conducted in parallel with the present study, indicated that all the aircraft studied exceeded the "reduced comfort" boundary defined by I.S.O. 263, and several approached or exceeded the "fatigue decreased proficiency" boundary. This is the limit beyond which exposure to vibration can be regarded as carrying a significant risk of impaired working efficiency. Improved seat design, and improved isolation of the seat from floor vibration were recommended as countermeasures. The twelvefold increase in reports of back pain on trips in the present study highlights the importance of this recommendation. In some aircraft, the vibration of the instrument panels was sufficient to induce legibility problems when reading instruments. It was therefore recommended that the presentation of information on the cockpit instruments take into account the worst vibration conditions in which they could be used, and that it would be desirable to reduce the instrument panel vibration in some aircraft.

5.6 Analysis of Workload

Overall, the workload ratings in this study tended to be higher than those during the flight test evaluation of workload in a short-haul fixed-wing aircraft (Barnes, unpublished observations). Very high workload ratings were usually associated with exceptional events. For example, in one instance, an engine seizure on start-up caused a last minute change of aircraft. This necessitated a rapid recalculation of the weight and balance, resulting in an exceptionally high preflight workload score. The highest workload rating during landing was given by a co-pilot who was attempting a difficult landing in high winds, in a situation he felt was beyond his capabilities.

The analyses of variance indicated that workload ratings during different stages of flight were influenced differently by the environmental factors examined. For preflight ratings, the segment number, the landing weather, the landing site, and the aircraft systems had significant effects. These findings are not unexpected, given that the aircraft were often operating near the upper limit of their range and in poor weather with limited alternative landing sites. The pilots also indicated that the amount of paperwork that had to be completed before flight, often in a limited amount of time following last minute changes, had an important influence on their perceived workload. This prompted a follow-up study on the paperwork requirements (ref. 16).

For workload ratings during taxi, it was shown that the aircraft systems, the flight segment number, and the season had significant effects, when different combinations of dependent variables were included in the ANOVA. In response to direct questioning, pilots indicated that weather and traffic conditions at peak times also contributed to their perceived workload during taxi.

None of the environmental factors tested had a significant effect on workload ratings during takeoff. During climb, the only significant factor was the functionality of the aircraft systems. The cockpit observers noted that the high workload associated with this phase of flight can be exacerbated by heavy air traffic control demands in the presence of other traffic.

The workload ratings during cruise were related only to the functionality of the aircraft systems. The cockpit observers noted that in poor weather, the non-flying pilot could spend a considerable amount of time obtaining weather information from the individual rigs. The present analyses did not find a significant effect of landing weather on workload ratings during cruise.

During descent and approach, the landing weather had a major effect on the subjective workload ratings. This is consistent with the weather conditions in the North Sea oil fields which often present a hostile environment for helicopter operations, including high winds, reduced visibility owing to fog banks and low clouds, icing at low levels, turbulence over the rigs, and, at low levels, salt spray.

Subjective ratings of workload during landing were associated with the quality of the landing site and the air traffic control. Traffic control, at sites other than airfields, is usually procedural in the terminal areas, requiring a high level of alertness. Turbulence over the rig, obstructions, and the size of the landing area may also increase workload. Landings on platforms on tankers at fixed moorings often require fine judgment because of the additional problems of heave and sway.

6.0 CONCLUSIONS

Helicopter servicing of the North Sea oil fields is a large and very challenging operation. Multiple factors contribute to the stresses that this environment imposes on pilots. Some are impossible to modify directly, for example, extreme weather conditions. Others cannot be modified, at least in the short term, because of technological or financial constraints, for example, limited automation of aircraft systems, operating aircraft near the limit of their range and performance capabilities, and difficult landing sites. Given these constraints, it is particularly important to identify those aspects of the operations that can be modified to improve efficiency and safety margins.

The pilots studied lost, on average, nearly an hour of sleep per night because of early on-duty times. The effects of sleep loss on subsequent alertness and performance are well-documented and often cumulative (refs. 29, 30, 37). Sleep loss also appears to exacerbate the decline in activation by the end of duty days. These findings underscore the importance of the timing of nighttime layovers, as opposed to their duration. In layovers averaging about 17 hr., pilots averaged only 6.4 hr. of sleep. Physiological constraints limited their ability to advance sleep sufficiently to compensate for the imposed early wake-ups. Delaying on-duty times (by 1.5-2.0 hr. on average) would be expected to produce a significant improvement in the amount of sleep pilots are able to obtain, and should be given serious consideration.

The helicopter flight deck is often hot, with high levels of vibration, and the average workload while flying helicopters appears to be higher than that in short-haul fixed-wing aircraft. These factors might be expected to contribute to the high incidence of headaches and back pain reported. The longer pilots remained on duty, the more negative their mood became. These findings suggest that improvements in seat design, in the isolation of the seat from floor vibration (ref. 14), and in ventilation on the flight deck, would be beneficial.

The quality of the aircraft systems had a significant effect on subjective workload assessments during preflight, taxi, climb, and cruise. More attention to aircraft maintenance might be one way of reducing workload during these phases of flight. The potential for reducing workload by the systematization or reduction of paperwork requirements was also examined. Landing weather was the major factor influencing subjective ratings of workload during descent and approach. Ratings of landing weather were, in turn, dependent on the quality of the letdown aids and the landing site. This confirms that the effect of adverse weather, at least on subjective workload, can be reduced to some extent by attention to the quality of letdown aids and landing sites. Subjective workload during landing was affected by the quality of the landing site and the air traffic control.

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Appendix

Report Summaries

This appendix presents summaries of the three other studies of North Sea helicopter operations (refs. 14-16), which were sponsored by the Civil Aviation Authority Medical Department and carried out in parallel to the present study.

Reference 14: Assessment of Crew Exposure to Vibration in Helicopters

C.H. Lewis and M.J. Griffin
Human Factors Research Unit, Institute of Sound and Vibration Research
The University, Highfield, Southampton SO9 5NH

Summary

Vibration measurements have been made in 14 helicopters of five types, flown by four different operators, providing support flights to oil rigs in the North Sea. The possible effects of vibration on the comfort, health and instrument reading performance of the aircrew were evaluated by both British Standard 6841 (1987) and International Standard 2631 (1974). The vibration conditions were sufficient to cause a degree of discomfort corresponding to "fairly uncomfortable" or "uncomfortable" according to BS 6841. The vibration dose values determined over complete flights varied between aircraft but sometimes exceeded half that expected to cause severe discomfort and increased risk of injury according to BS 6841. The vibration in several of the aircraft approached or exceeded the appropriate fatigue-decreased proficiency boundary for the period of the flight as defined in ISO 2631. In some aircraft there was sufficient vibration of the instrument panels to expect legibility problems when reading instruments. There was a considerable variation in the vibration attenuation provided by the crew seats and improvements to the seats is suggested as one means of reducing vibration exposures. Improved monitoring of the aircraft vibration and appropriate balancing may also significantly reduce the vibration in some aircraft.

Reference 15: A Study of the Thermal Environment of Helicopter Aircrew in Civil Operations over the North Sea in Spring and Summer

C.T. Kirkpatrick, C. Higenbottam, and N. Bayley
IAM Report No 654, RAF Institute of Aviation Medicine
Farnborough, Hants GU14 6SZ

Summary

Physiological temperatures were measured on 32 flights, together with cockpit environmental temperatures on 40 flights, for civil helicopter pilots flying over the North Sea. There were no excessively high or low temperatures recorded during any of the flights, lasting from 2-6 hr. in conditions ranging from bright sunshine to gale force winds. No pilot had a measured core temperature greater than 38°C, though the distribution of skin temperatures often suggested that the pilots were experiencing mild thermal discomfort. There were no major differences between cockpit conditions in spring and summer, though radiant heating was greater in summer, and paradoxically the cabin air temperature was higher in spring. The measurements of core and skin temperatures were very similar in the two seasons. Only some pilots were required to wear immersion suits in the summer, but there were no significant differences in core or skin temperatures between those who did and those who did not wear immersion suits.

Reference 16: Report on the Study of North Sea Helicopter Paperwork

T. Porteous*
CAA, London, 1989

Summary

The report sets out the review and findings of a study for the Civil Aviation Authority into helicopter pilot workload in North Sea operations. The investigations included discussions with helicopter pilots and managers of all three companies involved in support of offshore facilities in the North Sea. One company also provides offshore support to platforms in the Irish Sea in Morcambe Bay, and because of the similarity of its operation to those on the North Sea, it was also examined. Operations visited were those based at Unst, Aberdeen, Humberside, Strubby, North Denes, Beccles, and Blackpool. Appropriate representatives of pilot organizations were consulted. The following agencies who also have relevant input to the investigation were consulted: CAA Flight Operations Inspectorate, Shell Aircraft, BP Petroleum Development Ltd., HM Customs and Excise, Racal, KLM Helicopters, McAlpine Helicopters, and British Airways Highland Division.

The paperwork which creates workload problems pertains to passenger, baggage and cargo loads on sectors other than the first, to sequencing of multiple-sector routes, and to recording of flying and other times which are of contractual importance. The first part of the problem is mainly that of the long range pilot who is faced with being given load and route information for multi-sectors when he is close to his first destination. Short range crews who specialize in multi-sector or shuttle work tend to have their load and route information before departure, and are able to prepare their paperwork before take-off from their base airfield. The problem of times recording exists in both long and short range work. Engineering and operations departments of helicopter companies require some similar and some different sets of times to be recorded, and oil companies require sets of times which may be different from these. Therefore, crews are constantly aware of clock-watching, particularly at critical times during multi-sector operations. In some instances times must be recorded to the nearest minute. It is felt that such attention to detail could be a contributor to the build up of workload which could be reduced. The following recommendations are set forth.

1. Where possible, the helicopter operators should seek to make use of the oil/gas company's computer system in pre-planning individual sectors and loads. In the absence of a computer generated loadsheet and route, the person on the offshore facility with the responsibility for compiling the return, or onward, load should have available the relevant aircraft data (APS weight, etc transmitted to him along with the departure details) and would be told by the incoming pilot, after consideration of the desired route, what payload is available. The responsible person on the rig should then compile the load sheet, which will be that of the helicopter company, and detail the required route for a multi-sector flight. On landing on the offshore facility the completed load sheet and desired route should be presented to the pilot for his approval. This would obviate the need for unnecessary in-flight clerking by the incoming crew. Safeguards will be required to ensure adequate training for the offshore personnel, and knowledge of deck restrictions, fuel availability, etc will be required.

2. Wider use of radio magnetic recordings should be made. The requirements for the Tech Log to be signed and a copy left on the platform during a refuel could be met by the signature of the pilot who accepts the fuel, and for an acceptable defect by including the unserviceability in the departure message. The departure message would be made immediately before take-off and would be transmitted to the helicopter's base by the platform's radio or telex in addition to being retained for the required period. This system would not remove the need for pilots to note their flying times, and efforts should be made to have rotors running times, at least on offshore platforms, included in the contract price. This would take pressure to reduce time on the deck off the crews. Alternately, an electronic system of recording the required flying and other times could be introduced. RNavl can be

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modified to record logging of taxi, flight, engine and rotor running times. The system is not yet fully operational, and it is not clear if the times recorded are total elapsed times, or if sector times can be identified.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
July 1994

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Crew Factors in Flight Operations VI: Psychophysiological Responses to Helicopter Operations

5. FUNDING NUMBERS
505-64-53

6. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NUMBER
A-94113

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM-108838

11. SUPPLEMENTARY NOTES
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12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified-Unlimited
Subject Category – 52

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Thirty-two helicopter pilots were studied before, during, and after 4–5 day trips providing support services from Aberdeen, Scotland, to rigs in the North Sea oil fields. Early on-duty times obliged subjects to wake up 1.5 hours earlier on trip days than on pretrip days. Consequently, they slept nearly an hour less per night on trips. They reported more fatigue on posttrip days than on pretrip days, suggesting a cumulative effect of duty-related activities and sleep loss. Fatigue and negative affect were higher, and activation lower, by the end of trip days than by the end of pretrip days. The earlier a subject went on duty, the lower his activation by the end of the day. Caffeine consumption increased 42% on trip days. The incidence of headache doubled, of back pain increased twelve fold, and of burning eyes quadrupled. In the aircraft studied, thermal dicomfort and high vibration levels were common. The longer pilots remained on duty, the more negative their mood became.

14. SUBJECT TERMS
Helicopter, Fatigue, Short-haul

15. NUMBER OF PAGES
48

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT