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MISSION CREW FATIGUE DURING RIVET JOINT BLOCK II DEMONSTRATION/--ETC(U)
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MISSION CREW FATIGUE DURING RIVET JOINT BLOCK II DEMONSTRATION/EVALUATION

William F. Storm, Ph.D.

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November 1980

Final Report for Period January 1977 - February 1980

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USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
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NOTICES

This final report was submitted by personnel of the Crew Performance Branch, Crew Technology Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks AFB, Texas, under job order 7930-10-28.

When U.S. Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The operational personnel who participated in this study were fully briefed on all procedures prior to participation in the study.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: SAM-TR-80-37

2. GOVT ACCESSION NO.: AD-A094 822

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): MISSION CREW FATIGUE DURING RIVET JOINT BLOCK II DEMONSTRATION/EVALUATION.

5. TYPE OF REPORT & PERIOD COVERED: Final Report, Jan 1977 - Feb 1980

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): William F. Storm, Ph.D.

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
USAF School of Aerospace Medicine (VNE)
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
62202F
7930-10-28

11. CONTROLLING OFFICE NAME AND ADDRESS:
USAF School of Aerospace Medicine (VNE)
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

12. REPORT DATE: November 1980

13. NUMBER OF PAGES: 17

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report):
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):

18. SUPPLEMENTARY NOTES:

19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
Fatigue
Stress
Psychobiology
Urinalysis
Sleep
Mood

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

RIVET JOINT is a USAF Electronic Systems Command (ESC) airborne (RC-135) reconnaissance system. The objectives of an ongoing modernization program are to improve mission capability and manpower utilization through use of state-of-the-art computer technology and surveillance equipment. A prototype modernized system recently underwent testing and evaluation in the real-world operational environment. ESC/SD requested that the USAF School of Aerospace Medicine (USAFSAM/VN) evaluate the impact of the system on operator stress and fatigue. Psychobiological data were systematically collected from 13 operators over 6

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

consecutive days, including two 8-hour airborne test missions. The subjective fatigue and physiological cost associated with the test missions were moderate and did not suggest compromises in performance and safety. The operators were fully recovered from each of the test missions after an extended postmission night of sleep.

PREFACE

The author recognizes the outstanding professional support contributed by several dedicated people. At RAF Mildenhall, United Kingdom, MSgt Joe A. Gutierrez and the staff of the USAF Dispensary provided onsite administrative and biomedical support. SSgt Leonard J. Henry and the 513 TAW Packing and Preservation Section worked diligently to ensure proper protective packing and shipping of physiological specimens.

At the USAF School of Aerospace Medicine, Sgt Robin G. Chavez, USAFSAM/VNE, processed and reduced the data; Dr. Robert Reyes, USAFSAM/VNB, and his staff conducted the biochemical analyses; and Mr. Richard C. McNee, USAFSAM/BRA, directed the statistical analyses.

The participating crewmen of the 6949 Security Squadron, Offutt AFB, Nebraska, willingly supported the biomedical evaluation in the midst of their many other test responsibilities. Their professionalism contributed significantly to the operational validity of the findings. A special thank you is extended to MSgt Thomas E. Adams, MSgt Terry S. Garrett, and TSgt Albert L. Macklin for their assistance in data collection.

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MISSION CREW FATIGUE DURING RIVET JOINT BLOCK II DEMONSTRATION/EVALUATION

INTRODUCTION

RIVET JOINT is a USAF Electronic Systems Command (ESC) airborne (RC-135) reconnaissance system. The primary mission of RIVET JOINT operations is to provide timely intelligence support to tactical command and control authorities. During peacetime, aerial reconnaissance is an important secondary mission. The objectives of an ongoing modernization program are to improve mission capability and manpower utilization by using state-of-the-art computer technology and surveillance equipment. The modernized system permits operational data to be reported in real time and reduces the time required to forward intelligence information. In previous systems, operators spent too much airborne time performing search and acquisition functions. In this system they can devote more time and energy to data analysis and intelligence production.

Designated as RIVET JOINT Block II, a prototype modernized system recently underwent testing and evaluation in the real-world operational environment. As part of the tests on equipment and personnel, ESC/SD requested that the USAF School of Aerospace Medicine (USAFSAM/VN) evaluate the impact of the entire Block II operational milieu on operator fatigue and stress. The results and operational implications of psychobiological data collected in association with operational missions are presented in this report.

METHOD

USAFSAM/VN has used a battery of psychobiological measures to evaluate crew fatigue and stress in a wide variety of USAF airborne and ground operations (1,2,4-6,12). The measures were selected and developed to minimize interference with operational duties, daily schedules, and personal activities. The battery consists of self-ratings of subjective fatigue, a sleep survey, and endocrine/metabolic indices derived from urine samples. The SAM Subjective Fatigue Checkcard (Fig. 1) results in a score ranging from 0-20 (arbitrary units), with lower scores indicating greater fatigue (10). The SAM Sleep Survey (Fig. 2) documents the total hours slept during each 24-hour period.

The urinary measures typically consist of norepinephrine (NE), an index of sympathetic nervous system activity; epinephrine (E), adrenomedullary activity; 17-hydroxycorticosteroids (17-OHCS), adrenocortical activity; urea, protein catabolism; and sodium (Na) and potassium (K), mineral metabolism. Each urinary measure is adjusted to a quantity per 100 mg urinary creatinine. The ratio of sodium to potassium (Na/K) is then calculated as an index of metabolic balance (homeostasis). Changes in the urinary levels of these selected biochemical measures can occur as a result of psychological and biological demands made on the individual (4). The use of a creatinine-based ratio corrects for variations in the timing of urine collections as well as

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NAME AND GRADE	TIME/DATE

INSTRUCTIONS: Make one and only one (✓) for each of the ten items. Think carefully about how you feel RIGHT NOW.

STATEMENT	BETTER THAN	SAME AS	WORSE THAN
1. VERY LIVELY			
2. EXTREMELY TIRED			
3. QUITE FRESH			
4. SLIGHTLY POOPED			
5. EXTREMELY PEPPY			
6. SOMEWHAT FRESH			
7. PETERED OUT			
8. VERY REFRESHED			
9. FAIRLY WELL POOPED			
10. READY TO DROP			

PREVIOUS EDITION WILL BE USED

SAM FORM 136 SEP 78 SUBJECTIVE FATIGUE CHECKCARD

Figure 1. SAM Form 136. A subjective fatigue survey was completed at approximately 0800, 1300, 1700, and 2100 each day of the study.

variations in subject age and body size. Urine samples are mixed immediately upon collection with a dilute hydrochloric acid, frozen within a few hours, and shipped by air freight to USAFSAM/VN for analyses.

In addition to the standard SAM battery of measures, the copyrighted Profile of Mood States (POMS) was used to assess each operator's affective state on six independent dimensions: tension-anxiety, depression-dejection, anger-hostility, vigor, fatigue, and confusion-bewilderment (9). POMS scores are standardized T-scores based on normative data from 856 college students; the mean standard score for each scale is 50 with a standard deviation of 10. For each of the six POMS scales, the larger the T-score the more prevalent the affective state. Feelings of fatigue are indicated by low scores on the SAM subjective fatigue checkcard and by high scores on the POMS fatigue scale.

The fatigue and stress evaluation was conducted in association with two missions flown out of RAF Mildenhall, United Kingdom, in September 1978. The 13 ESC operators (3 of whom were maintenance technicians) participating in the test missions were in a 3-week TDY status from their home base, Offutt AFB, Nebraska. Data were collected from the operators on each of 6 consecutive days. On the first and fourth days, missions of 8+ hours were flown. The

SLEEP SURVEY

NAME (Last, First, MI)	GRADE	DATE/TIME

1. On the chart below, mark an X in each half hour interval you slept yesterday and today.

YESTERDAY

MID-NIGHT	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	MID-NIGHT

TODAY

MID-NIGHT	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	MID-NIGHT

2. HOW MUCH TROUBLE DID YOU HAVE GOING TO SLEEP LAST NIGHT?

☐ NONE ☐ SLIGHT ☐ MODERATE ☐ CONSIDERABLE

3. HOW RESTED DO YOU FEEL?

☐ WELL RESTED ☐ MODERATELY RESTED ☐ SLIGHTLY RESTED ☐ NOT AT ALL

4. DO YOU FEEL LIKE YOU COULD HAVE USED SOME MORE SLEEP?

☐ YES ☐ NO

SAM FORM SEP 76 154 PREVIOUS EDITION WILL BE USED REMARKS ON REVERSE

Figure 2. SAM Form 154. A sleep survey was completed at 0800 (or upon awakening) each day of the study.

operators arrived at RAF Mildenhall about 48 hours before the first mission. Takeoff was at approximately 0900 for both missions.

Each operator completed a subjective fatigue checkcard every day at approximately 0800, 1300, 1700, and 2100; on mission days, the operators were airborne during the 1300 data collection. They completed a sleep survey every morning to document the hours slept during the previous 24-hour period. Urine samples were collected at 0800, 1700, and 2100. Each operator completed a POMS survey before (0800) and after (1700) each mission; for this test, the operators were instructed to respond to each item as to "how you feel right now."

RESULTS

Subjective Fatigue

The within-day patterns of subjective fatigue checkcard scores are presented in Figure 3A for each of the 6 study days. But for a couple of aberrant values, the 4 nonmission days tended to group together in one pattern over time, and the 2 mission days grouped together in a different pattern. An obvious exception occurred between the 2 mission days at 1300, where the mean fatigue score was 8.1 on the first mission and 12.5 on the second ($p < .001$). The distinct temporal patterns are emphasized in Figure 3B, where fatigue scores have been averaged across the 2 mission days versus the 4 nonmission days. The mean data in Figure 3B show no statistically significant difference between subjective fatigue scores collected at 0800 on mission and nonmission days. However, the mean fatigue scores reported during (1300) and after (1700 and 2100) missions were significantly lower (indicating greater fatigue) than the mean nonmission day scores ($p < .001$ in all cases).

Hours Slept

The average amount of sleep acquired on postmission nights (8.6 hours) was significantly greater than the average amount acquired on premission nights (7.1 hours; $p<.01$) and nights following the mission by 1 day (7.4 hours; $p<.05$).

Mood States

Mean premission and postmission POMS scores are presented in Figure 4 for each of the six affective dimensions. Statistically significant postmission increases occurred for depression ($p=.017$), anger ($p=.006$), and fatigue, ($p=.001$); and a decrease for vigor ($p=.01$). The mean increases in tension and confusion approached statistical significance ($p<.10$). A significant ($p=.031$) day x premission-vs-postmission interaction occurred for the POMS fatigue dimension, as the increase in POMS fatigue was greater for the first mission (pre=40.9; post=57.44) than for the second (pre=42.8; post=52.4).

SUBJECTIVE FATIGUE

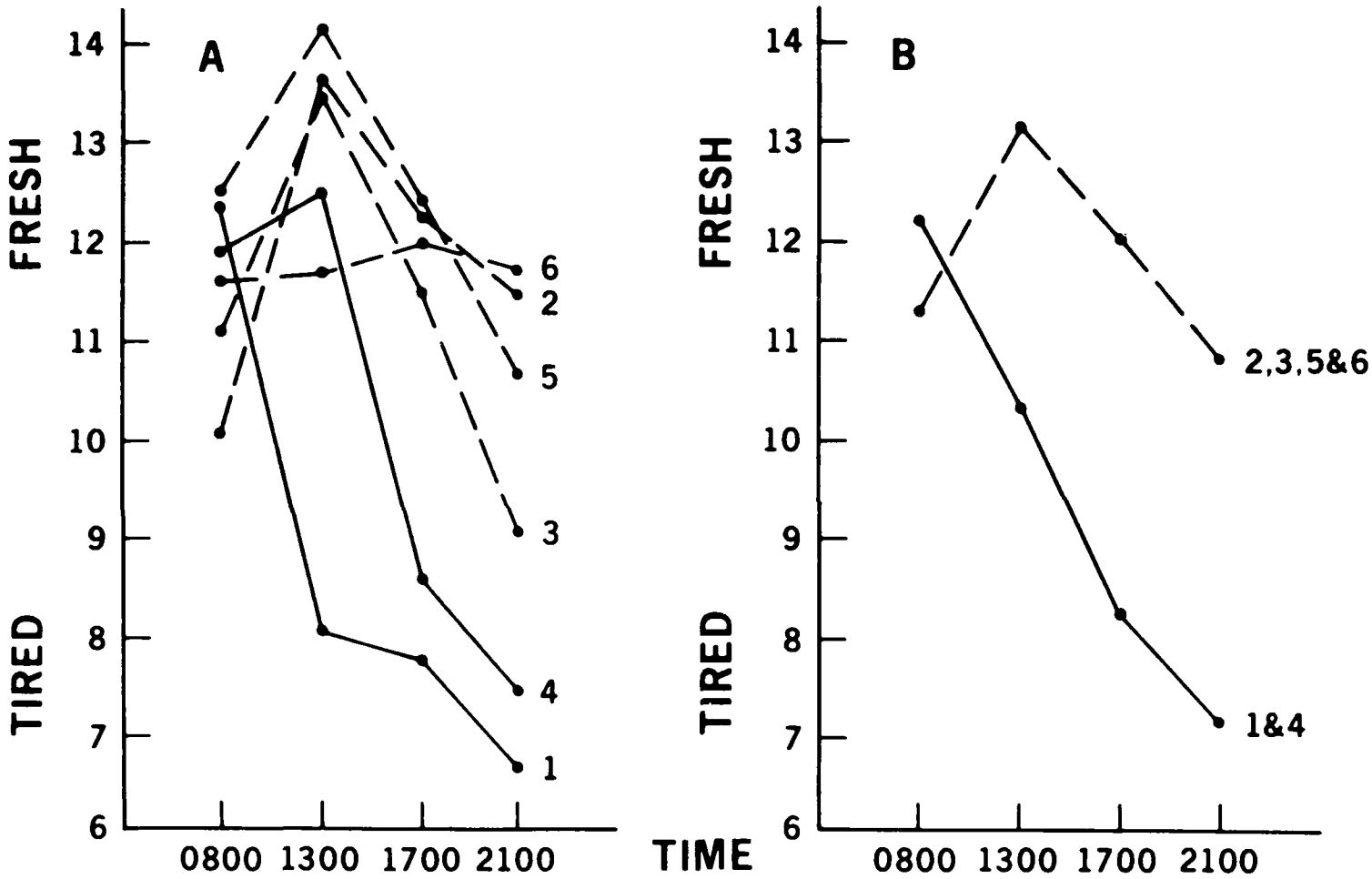

Figure 3. A. Mean SAM subjective fatigue scores for each day of evaluation. Airborne missions: days 1 & 4; ground duties: days 2, 3, 5, & 6.

B. Same data averaged: 2 mission versus 4 nonmission days.

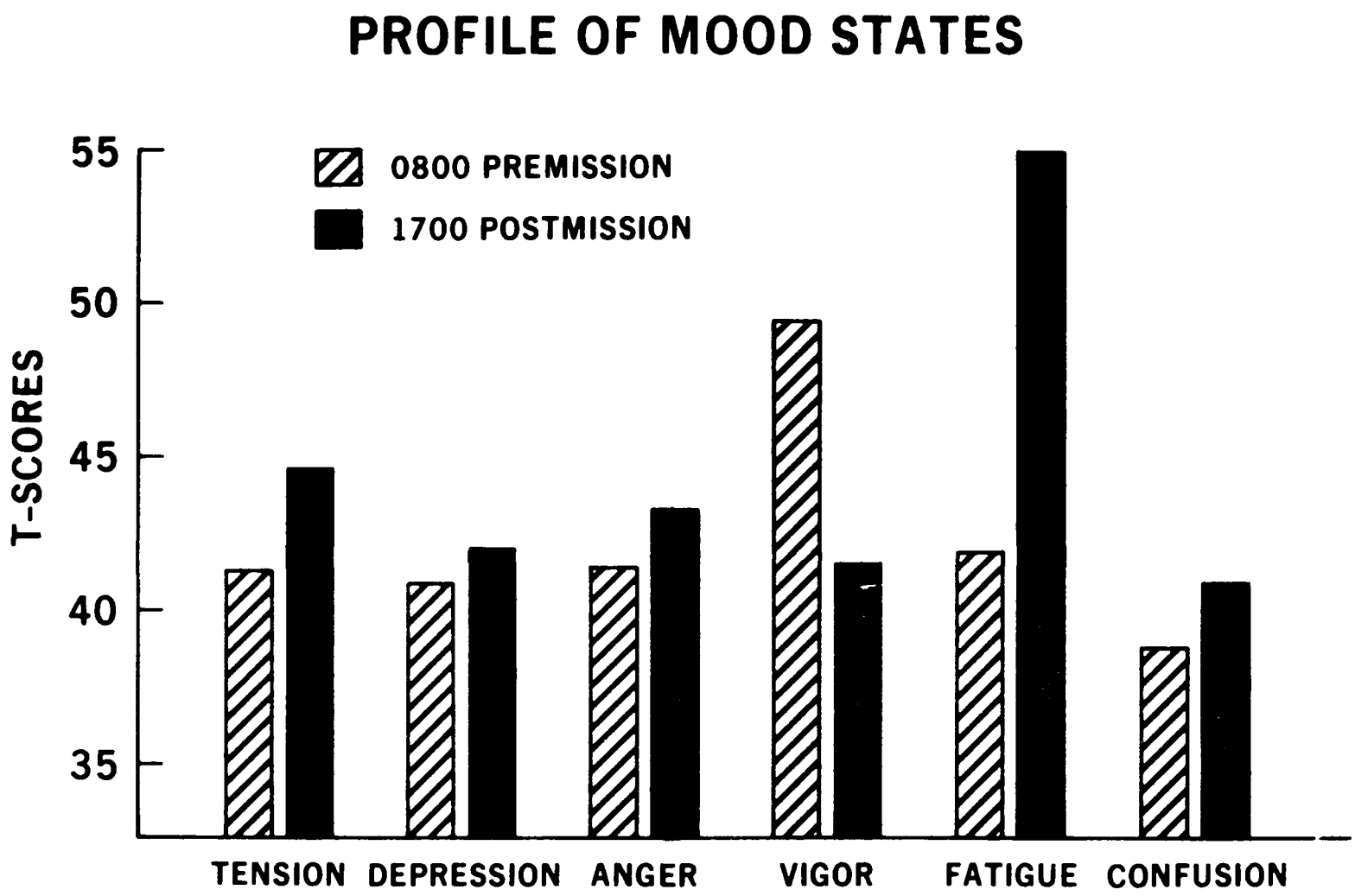

Figure 4. Mean Profile of Mood States (POMS) scores before (0800) and after (1700) two airborne missions.

Biochemical Measures

The urine measures were statistically analyzed in log units and then reconverted to standard units for reporting purposes. The 17-OHCS data were deleted due to procedural problems that made the reliability of these data suspect. Typical within-day changes occurred in the mean urinary levels of epinephrine and norepinephrine on both mission and nonmission days (Fig. 5). However, because of large day-to-day variability, neither displayed statistically significant changes related to the RIVET JOINT Block II missions.

Statistically significant findings related to differences between the 2 mission days or between mission and nonmission days did occur for sodium, potassium, Na/K, and urea. Mean values for these measures are presented in panels A and C of Figures 6-9 in the same format as that for the fatigue data (Fig. 3). Comparing the 2 mission days (Fig. 6A), mean sodium levels for the first mission were statistically greater than for the second mission at both 0800 ($p=.040$) and 1700 ($p=.016$). Comparing mission-versus-nonmission days, potassium levels were higher at 0800 ($p=.049$) and 1700 ($p=.035$) on nonmission days than on mission days (Fig. 7C). The mean Na/K was greater ($p=.010$) at 0800 on the first mission than on the second (Fig. 8A), Na/K ($p=.001$) and urea ($p=.008$) levels were greater at 1700 after a mission than at 1700 on nonmission days (Figs. 8C and 9C respectively).

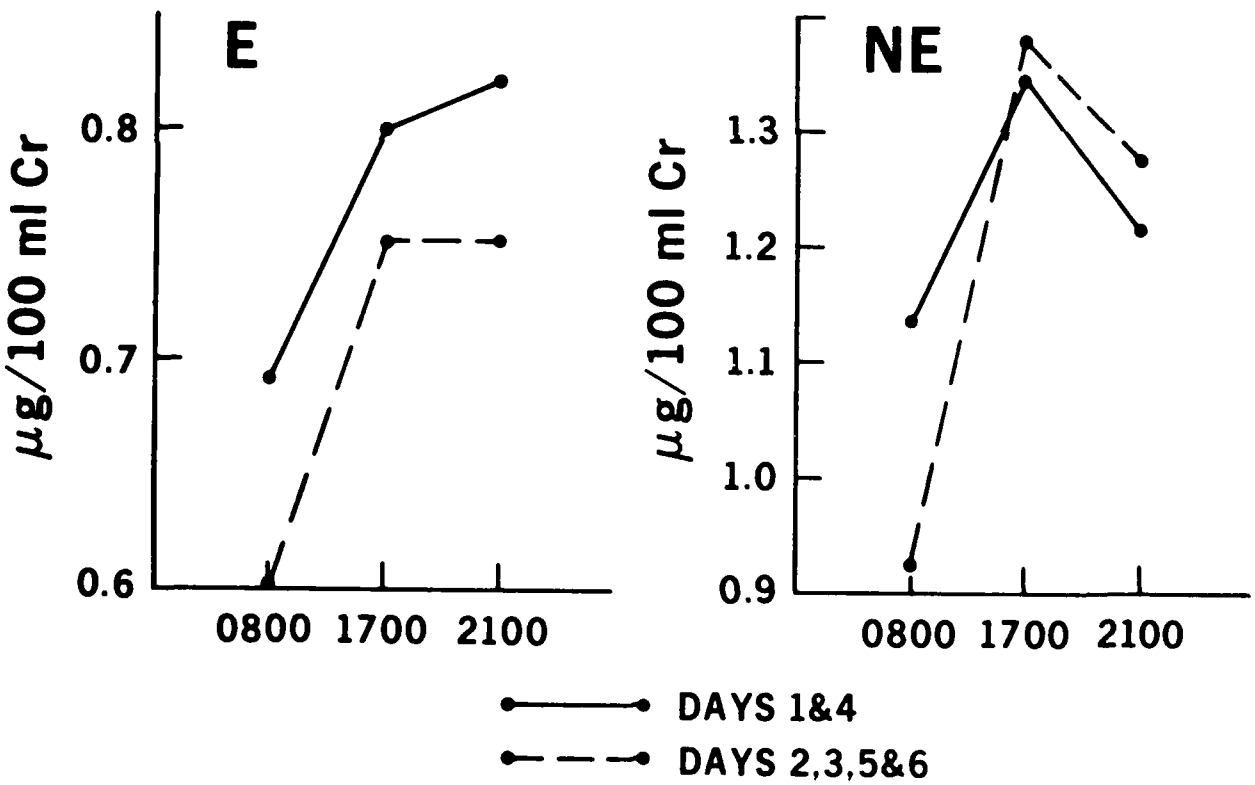

Figure 5. Mean within-day changes in epinephrine (E) and norepinephrine (NE) for mission (solid line) versus nonmission (broken line) days.

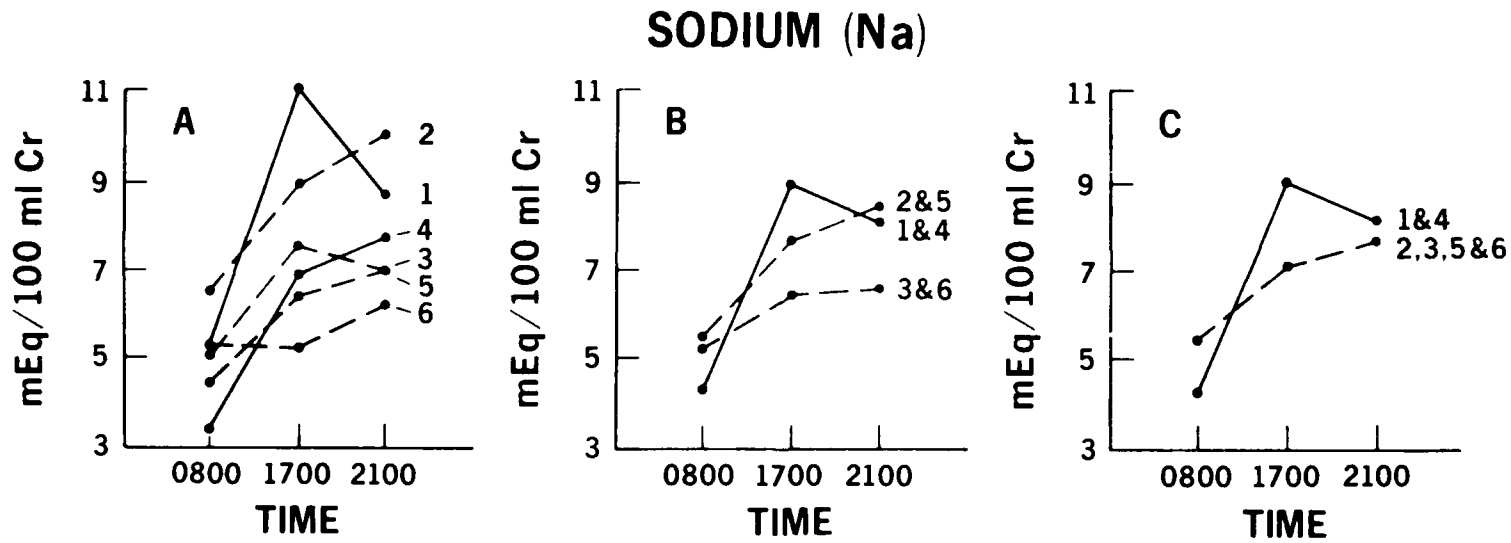

Figure 6. Mean within-day changes in sodium for each study day (A); mission days, 1 day postmission, and 2 days postmission (B); and mission versus nonmission days (C). Mission days--1 & 4; nonmission days--2, 3, 5, 6.

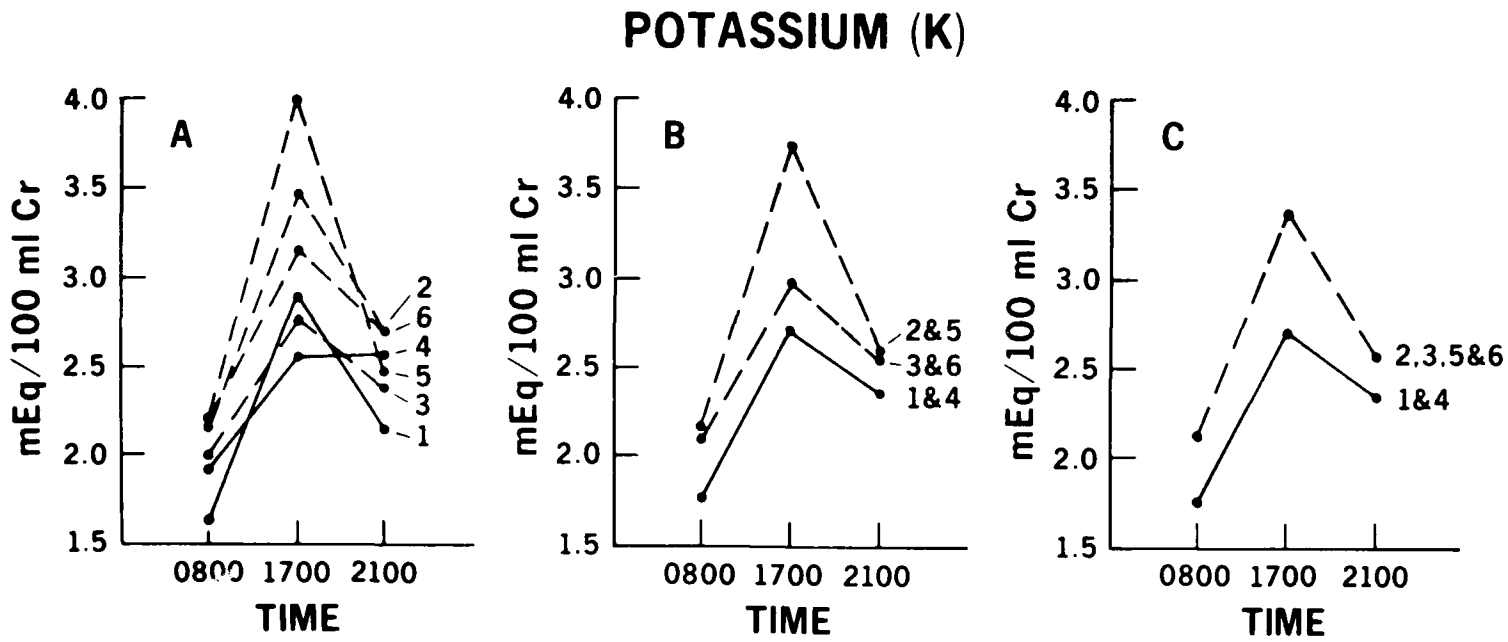

Figure 7. Mean within-day changes in potassium for each study day (A); mission days, 1 day postmission, and 2 days postmission (B); and mission versus nonmission days (C). Mission days--1 & 4; nonmission days--2, 3, 5, 6.

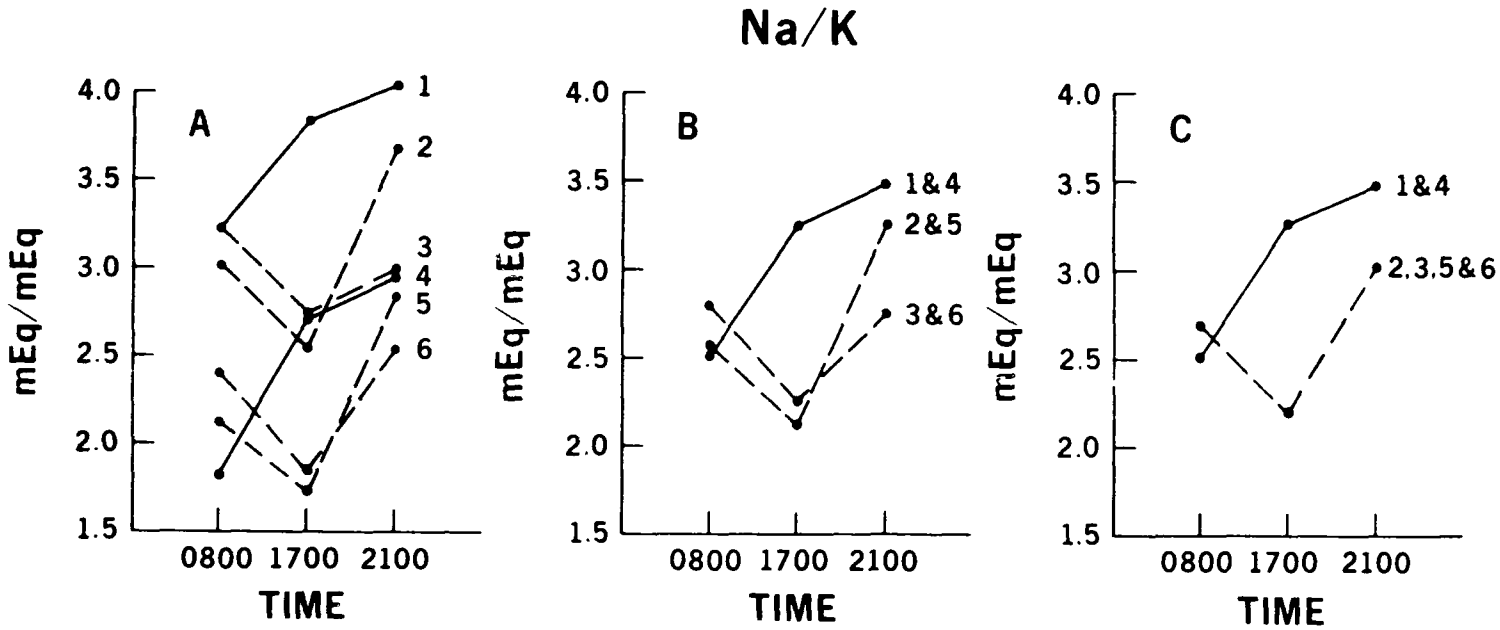

Figure 8. Mean within-day changes in Na/K for each study day (A); mission days, 1 day postmission, and 2 days postmission (B); and mission versus nonmission days (C). Mission days--1 & 4; nonmission days--2, 3, 5, 6.

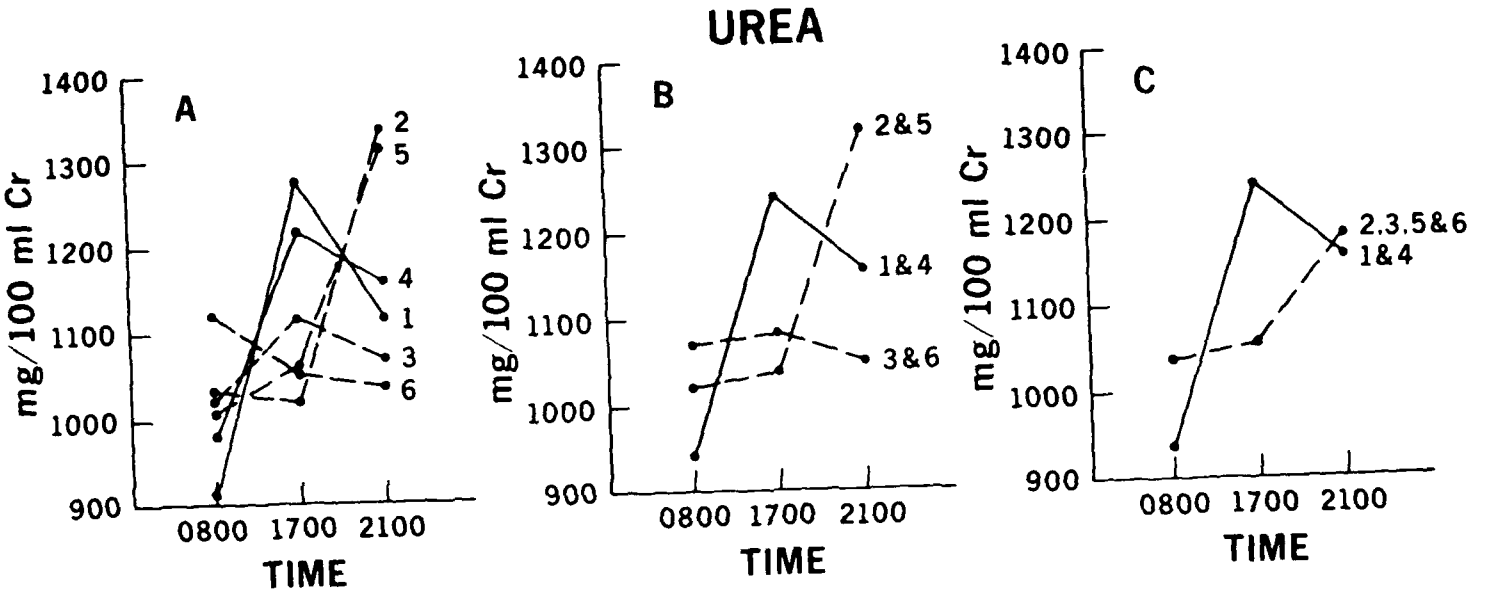

Figure 9. Mean within-day changes in urea for each study day (A); mission days, 1 day postmission, and 2 days postmission (B); and mission versus nonmission days (C). Mission days--1 & 4; nonmission days--2, 3, 5, 6.

The daily mean values presented for sodium, potassium, Na/K, and urea in panel A of Figures 6-9 suggested that the dichotomous comparison of mission days versus nonmission days, as presented in panel C of the same figures, masked some systematic, progressive changes for the 2 days following each mission. These day-to-day sequential changes became more apparent when the data were plotted in an intermediate fashion (panel B) for the average of days 1 and 4 (mission days), days 2 and 5 (1 day postmission), and days 3 and 6 (2 days postmission). The day-to-day changes in sodium and potassium were primarily modifications in amplitude, while notable within-day variations in pattern occurred for Na/K and urea.

The results of paired t-tests comparing mission days versus postmission days and 1 day postmission versus 2 days postmission are summarized in Table 1. Most of the significant effects for urinary biochemical levels occurred between mission days and postmission days at 1700. But for urea at 2100, no significant differences occurred between 1 day postmission and 2 days postmission. The elevated levels of urea at 2100 on 1 day postmission are very likely artifacts. The absence of similar elevated levels at 0800 and 1700 on the same days suggests that this effect is unrelated to mission events, but possibly a result of social activities on these evenings.

TABLE 1. SIGNIFICANT DIFFERENCES IN MEAN URINARY LEVELS OF SODIUM, POTASSIUM, NA/K, AND UREA--PAIRED T-TEST COMPARISONS

Time-of-Day	Mission day vs One day post	Mission day vs Two days post	One day post vs Two days post
0800	potassium*		
1700	potassium** Na/K** urea**	sodium* Na/K** urea*	
2100	urea*		urea**

* $p<.05$
** $p<.01$

DISCUSSION

Interpretation of SAM subjective fatigue scores is based on both relative values and absolute scores. In general, mean subjective fatigue scores of 12 and above suggest feelings of alertness; 11 through 8, moderate fatigue; and 7 and lower, severe fatigue. For the typical day worker, feelings of alertness and freshness prevail during morning and afternoon (represented by higher and/or increasing scores), while feelings of mild to moderate fatigue (represented by lower and/or decreasing scores) become more prevalent in the late afternoon and evenings. Such a typical daytime subjective fatigue pattern occurred for the average of nonmission days in the present study. These nonmission days were not days-off for the operators but were devoted to administrative support activities, debriefings, mission planning, and some personal activities. Thus, the subjective fatigue data collected on the nonmission days provided a ground-duty baseline for comparison with airborne-mission data.

The RIVET JOINT Block II operators were refreshed and alert at 0800 on both mission and nonmission days. Neuroendocrine and metabolic activity were also generally comparable at 0800 on mission and nonmission days. After 0800, however, different patterns emerged for mission and nonmission days in both the fatigue and the biochemical measures. On mission days, mean feelings of subjective fatigue increased (represented by progressively lower scores) through mission termination at 1700 and into postmission crew rest at 2100. The mean subjective fatigue level reported at mission termination was moderate but not severe, and not of a magnitude associated with compromises in performance and safety.

The psychophysiologic cost of the missions was also reflected by a moderate increase in metabolic activities at 1700, just after mission termination. Compared to nonmission days, urea and sodium were elevated, potassium was reduced, and as a result, Na/K was noticeably elevated. Unlike the subjective fatigue scores on mission days, by 2100 no reliable differences were seen in biochemical urinary levels between mission and nonmission days, indicating physiological cost to have been mild and/or recovery to be well underway.

Statistically significant or near-significant premission-to-postmission changes occurred for each POMS dimension. The largest percentage changes in T-scores were for fatigue and vigor, the dimensions of primary operational significance in this evaluation. In accord with the SAM Subjective Fatigue Checkcard scores, POMS fatigue increased and POMS vigor decreased from 0800 to 1700 on mission days. In evaluating postmission increases in the other POMS dimensions, it is important to note that both before and after the missions, the mean scores for tension, depression, anger, and confusion were less than the mean normative T-score (50) established for healthy young adults. Thus, while the direction and magnitude of changes in the mood scores provided information on operator status, at no time did the absolute scores indicate even mild emotional disturbance.

Several results indicate that the demands of the first mission were greater than those for the second. Although moderate subjective fatigue was reported at the end of both missions (1700), the mean fatigue scores reported

midway (1300) into the second mission indicated that the operators still felt fresh and alert, although the scores reported midway through the first mission had fallen to levels indicating considerable fatigue. The premission-to-postmission increase in POMS fatigue scores was greater on the first mission than the second. Premission and postmission levels of sodium and premission values of Na/K were greater for the first mission than the second. Several factors probably contributed to the differences between missions. All of the operators were intimately familiar with the airborne operation of the Block II system, but the initial mission of this deployment was the first in the real-world operational environment in several months. In the 48 hours since arriving in the United Kingdom, the operators' day-night cycles had probably not completely adapted or synchronized to the 6-hour change in time zones. After rapid transmeridian travel over several time zones, at least 2-3 days are required for general behavioral adaptation and some physiological adaptation may continue for a week or more (8,11). Finally, the first mission may have been inherently more demanding and stressful than the second mission.

On the nights following the missions, the operators acquired 1.0-1.5 hours of sleep more than the typical 7-8 hours reported for the other nights of the evaluation. The extra sleep contributed significantly to the operators reporting for duty in a recovered and refreshed state on the days following the missions. As found repeatedly in operational studies, a postmission night of extended, uninterrupted sleep is a potent counteraction against cumulative fatigue (3,5,7,13,14). The absence of significant differences between the first and second postmission days in the biochemical measures suggests that physiological activity was also stabilized after the first postmission night of recovery.

The subjective fatigue and physiological cost associated with RIVET JOINT Block II test missions of about 8-hour duration were moderate, short-lived, and not of a magnitude indicative of compromises in performance and safety. After airborne missions of 8-10 hours, a postmission crew rest of at least 12 hours should be firmly scheduled, permitting ad lib acquisition of extended, uninterrupted sleep. Missions of similar duration flown at night can be expected to result in greater and/or more rapid buildup of fatigue due to the operators being more tired at the beginning of a night mission and then having to work during a normal sleep period. While a 12-hour postmission crew rest will probably provide adequate recovery, daytime sleep and rest is seldom as restorative as that acquired at night (7,14). The fatigue and stress associated with RIVET JOINT Block II missions of 12 or more hours should be empirically evaluated, particularly in contingency situations where missions may be launched as frequently as every other day for 1-2 weeks. As missions become longer, interference with normal sleep periods may result in severe operator fatigue and increased potential of performance degradation. Turnaround time will also be negatively affected.

Although not specifically evaluated during this study, fatigue during RIVET JOINT Block II missions could be <u>significantly</u> reduced by allowing use of the back and seat cushions in the crew-station chairs. Currently, because of the severely limited onboard storage space, the operators (to be in accord with regulations) must stow survival packs in the chair seats, and parachutes in the seat backs. A concerted effort to modify requirements and/or make other storage arrangements would yield high returns in operator health and morale.

CONCLUSION

The subjective fatigue and physiologic cost associated with RIVET JOINT Block II missions of 8-10 hours were moderate and not indicative of compromises in performance and safety. A minimum of 12 hours for postmission crew rest and sleep should be allotted after each mission.

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