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Report covers the effects of extended mission lengths on the performance of airborne command and control teams, wherein complex "cognitive" components consisting primarily of information collection, interpretation and communication constitute the bulk of the workload. Survey centers on investigating general categories of performance-related factors, such as overall fatigue, rather than specific task performances such as long-term memory, sensory motor reaction time, or information processing.

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INTRODUCTION

Considerable effort has been extended in attempts to determine the effect of prolonged or repetitive missions on crewmembers performing piloting, navigation, or mechanical duties. Typically, little or no decrement is evident in performance until missions last over about 36 hours, even though subjective feelings of fatigue may occur. Since these studies have involved crewmembers performing duties requiring mostly overlearned psychomotor skills, apparently such skills suffer little from extended missions until some very high threshold has been reached. Whether such results can be extrapolated to tasks where more complex "cognitive" components constitute the bulk of the workload is uncertain. Questions arise as to the effect of extended mission lengths on those performances which, unlike the aircraft crew tasks, consist primarily of information collection, interpretation, and communication. If such performances are placed in a context of high stress imposed by time and emphasis on the criticality of decisions, then the overall mission appears much different from the aircraft control tasks previously studied.

The above context describes the typical command and control situation. A crew, either airborne or ground-based, is assigned the mission of receiving a vast quantity of information, digesting and filtering such information, and presenting it in concise, accurate, and efficient form to a high-ranking command authority, who then must make decisions which might have catastrophic significance. The skills involved in such a mission would appear to call for retention of large amounts of information (short- and long-term memory), integration of the new information with the old (associative function), and comparison and assessment of its significance on the basis of prestablished criteria (evaluative function). Further, the team environment typically requires that each individual constantly remain aware of the information requirements of every other team member, and constantly integrate his information with theirs. To carry out such diverse cognitive tasks, crewmembers must function at peak physical and mental efficiency. It is, therefore, important to assess the overall impact of extended missions on tasks of this nature.

In view of the increasing number of airborne command and control teams which are functioning, we decided to study the effect of one type of extended mission on the performance and status of an airborne crew. At this point, it would be premature to establish firm hypotheses concerning the type of functions that might show decrement under these conditions. A field survey was, therefore, initiated in which interest was centered on investigating general categories of performance-related factors, such as overall fatigue and speed, rather than specific task performances such as long-term memory, sensory-motor reaction time, or information processing. We hoped, thus, to identify areas of difficulty for later study in more detail and with more precision in the laboratory setting.

METHOD

OPERATIONAL ENVIRONMENT

An Air Force airborne command post on continuous alert was used as the experimental environment for the present study. This command post (CP) consisted of three modified EC-135 aircraft manned by three operational teams, each containing 17 team members. Normally, the CP is on ground alert, with one team and one aircraft physically prepared to be airborne within minutes of a signal. The alert crew typically works in an office setting for a normal duty day and then spends the evening in a comfortable alert facility. Thus no excessive stress or fatigue would be expected under routine operations. However, in an emergency situation, this CP might be required to remain operational for long periods of time. An extended mission capability is therefore incorporated into the CP operations, since one team might have to fly for a long period or the three teams might cycle through a continuous operation over a period of several days. This latter mode of operation was employed in the present study.

At a previously unannounced time the klaxon signal initiated the experimental period, and the alert aircraft was airborne within minutes of this "time zero." From that point, at least one aircraft was continuously airborne for a period extending over several days. For the purpose of this study, all flights were timed from the nominal takeoff and landing schedules, since deviations from these were insignificant. The schedule of flights is presented in table 1.

Each operational team consisted of five identical functional sections occupied by similarly ranked individuals from all military services. The functional areas are: (1) The control section, consisting of the Team Chief (T.C., 0-6) and Control Center Operations Chief (CCOC, 0-5), (2) The Intelligence Section, (3) The Emergency Actions and Communications Sections, (4) The Operations and Resources Section, and (5) The Plans Section. Each of these latter sections are manned by 0-5 and 0-4 officers, supported by one or more top-ranking noncommissioned officers. To survey the entire team adequately, representatives from each functional area were chosen for those tests which were impractical to adminster to everyone.

PERFORMANCE MEASUREMENTS

Three types of performance measures were used to survey the general areas of interest The most practical way to obtain an overall impression of the status of performance quality during the missions was through a subjective questionnaire. Thus, any changes noted by the teams could be specified for further study, and a wider range of performance could be tapped than with more objective instruments. Therefore, a questionnaire was designed (see Appendix) which attempted to assess feelings of the crews concerning the following characteristics: (questions A-1, A-7, C-8), accuracy (A-2, A-8, A-10), fatigue

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TABLE 1

SCHEDULE OF COMMAND POST FLIGHTS

FLIGHT NUMBER	TEAM	TIME INTO MISSION	TYPE OF FLIGHT	DURATION
1	3	T zero - 12 hr.	Night	12 hr.
2	1	12 - 20 hr.	Day	8 hr.
3	2	20 - 28 hr.	Evening	8 hr.
4	3	28 - 36 hr.	Night	8 hr.
5	1	36 - 44 hr.	Day	8 hr.
6	2	44 - 56 hr.	Evening	12 hr.
7	3	56 - 64 hr.	Night	8 hr.
8	1	64 - 72 hr.	Day	8 hr.
9	2	72 - 80 hr.	Evening	8 hr.
10	3	80 - 88 hr.	Night	8 hr.
11	1	88 - 96 hr.	Day	8 hr.

(A-6, C-6), certain "psychological" characteristics such as decisiveness, memory, and irritability (A-3, A-4, A-5, A-9, A-11), and the overall quality of performance (C-7, C-9, C-10). In addition, several questions related to evaluations of the coordination and support received from other individuals, from other team functions, and from communication sources outside the aircraft (C-1, C-2, C-3, C-4). An entire section (B) evaluated the status of physical complaints such as visual problems, backache, headache, stomach problems, thirst, noise, and vibration. At the end of each questionnaire, space was provided for subjective comments. This was intended to constitute a "critical incident" survey. Many team members used this section as a vehicle for general comments concerning the test, the mission, and specific problems, and these data were grouped into summary categories.

This questionnaire was filled out twice during each flight, once at mid-flight and once at the end. The subject population consisted of eight selected team members, representing each functional area. Due to scheduling difficulties, data were not obtained on three occasions.

A second evaluation of performance was obtained by systematic observation. During each flight, a practice exercise lasting up to 2 hours was planned. These exercises consisted of actual mission simulations involving data input, preparation, and briefing, as well as decisions by the simulated command authority. To get some indication of the workload on the team members and to observe the team's performance during these exercises as a function of mission duration, five key team members representing major functional sections were selected for study. The experimenter carefully observed these members in a set order, watching each of four key individuals for 15 seconds to determine what major kind of activity he was carrying out. Each functional section was, thus, observed once each minute during the entire exercise scenario. The major categories of activity used for classification were: Communication (refers to telephone, intercom, or other electronic communication), Writing (including preparation of briefing materials), Research (involves processing or looking for data), Talking (face-to-face verbal interaction), Monitoring (monitoring status of exercise, etc.) and Other (any activity not otherwise covered).

Four team members were observed per minute, but the intelligence officer was observed only during the first half of the exercise when his workload was highest, and observation was then shifted to the plans officer during the second half of the exercise when his workload became high. Thus, all five functional sections were covered. These observations were made only for flights carried out by Team 1. Four observation exercises were planned but the exercise scheduled for the fourth flight was not held, and therefore data are available only for the first three flights of this team.

The third type of performance measure used was a general content analysis of the briefings given by two individuals during two of the practice exercises. All briefings given by Team 1 during the exercise scenarios on flights one and three were recorded on magnetic tape. After all flights were completed, selected portions of these tapes were subjected to analysis of the verbal content. Specifically, segments of the briefings which were similar over both missions were identified. These were then played back, and the experimenter classified several parameters of the conversation. These parameters were of two general types. First, the briefer's "style" was quantified by counting such things as hesitations, interjections such as "ah..." and "er...," and the length of sentences used. Secondly, certain characteristics of the exercise were noted, such as the number of times the briefer was interrupted, the length of time taken to answer questions, etc. Although this sample of data is obviously too small for firm conclusions, these analyses were undertaken to reveal any stress- or fatigue-induced trends that could provide clues for future hypotheses.

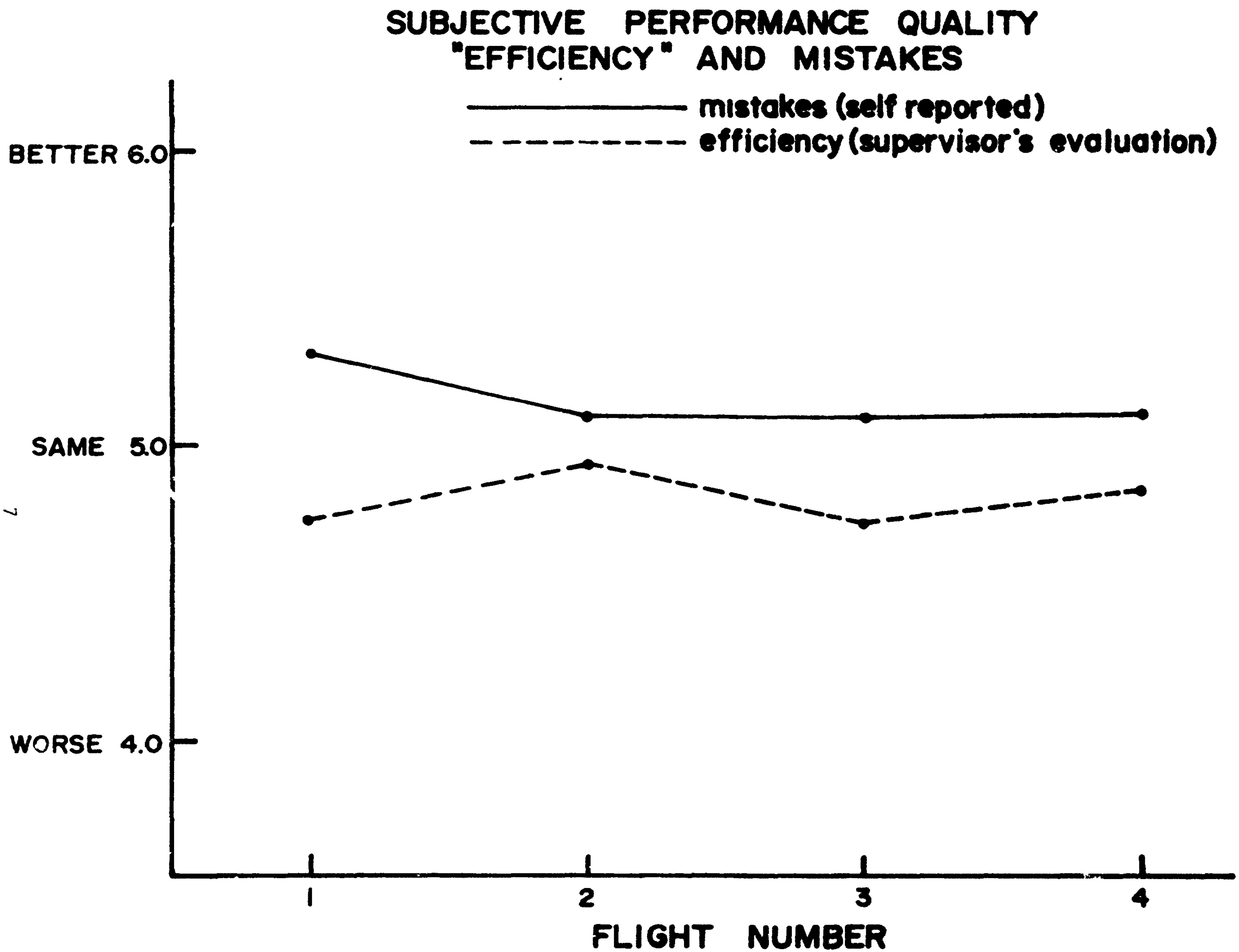
RESULTS

The performance questionnaire resulted in 152 useable forms returned, representing 86 percent of the maximum possible sample. The information gathered on each general performance area of interest is summarized in this section, under the headings of "Subjective Performance Quality," "Physical Complaints," "Psychological Status," and "Subjective Comments." The results of the exercise observation and the briefing content analyses are presented under separate major headings.

SUBJECTIVE PERFORMANCE QUALITY

Overall Performance

A major concern of the present study was the ability of the teams to function effectively over the entire period of the exercise. The most direct question designed to probe this area (C-7) asked the section supervisors to evaluate the overall efficiency of their people. A second direct question (A-8) asked each individual himself whether he felt that the number of mistakes he was making was more or less normal. The averaged results of these two questions are presented in figure 1. No significant changes are seen from one flight to another, with perceived performance near normal throughout the four flights. Differences between halves of each mission were not significant, except that Team 1 supervisors felt there was a drop in efficiency between the first and second half of the first flight ($p < .05$, all tests by non-parametric sign test or Wilcoxon Sign--Rank test). Night flights were not reported to be any different than day or


SUBJECTIVE PERFORMANCE QUALITY
"EFFICIENCY" AND MISTAKES
mistakes (self reported)
efficiency (supervisor's evaluation)
BETTER 6.0
SAME 5.0
WORSE 4.0
1
2
3
4
FLIGHT NUMBER

evening flights, and 12-hour flights were not reported to cause greater changes in efficiency or mistakes than 8-hour flights.

The foregoing indications of little change in the absolute quality of performance are supported by several other questions designed to probe the same area from different viewpoints. Question C-9 asked supervisors whether they felt their people were doing the job in the same way as they usually do. Responses indicated no significant differences in any flight or between flights, with averages indicating teams were functioning close to their normal way. Question C-10 asked supervisors whether their people would react in a satisfactory way if a real emergency were to happen. Again, average ratings on this question were very high, and indicated that there was no progressive change in emergency response capability from flight to flight. A significant drop in the rating was found between the first and second half of the first flight ($p < .01$). This was due primarily to an unusually high rating on the first half of the flight by Team 1 members, combined with slightly low ratings from Team 3 during the second half of their 12-hour night flight. These low ratings were due to ratings of "3" given by the Plans Officer and the Communications NCO. Question A-10 asked team members whether they felt it was more necessary to doublecheck their work. No differences were found within or between any flight.

Coordination

Two questions related to the quality of coordination between individuals (C-1)) and functional areas (C-2). Results on these questions revealed no significant differences between or within any flight. No consistent pattern of coordination change appeared on any flight for any team position, even on the long night and evening flights. Thus, coordination between individuals and positions did not appear to suffer as a result of the extended mission conditions.

Two questions (C-3, C-4) dealt with evaluations of how well the team members were supported, both by other functional areas within the team and by ground-based support facilities. Both of these questions revealed no changes over times in perceived levels of support and no significant differences between day and night flights. One significant difference between the first and second half of the flight on the first mission for Team 1 was found (worst support in last half), but this was not continued throughout other teams or missions.

Speed of Reacting

Several questions attempted to obtain estimates of whether the teams' reaction speed changed over the flights. One question (A-1) dealt with the teams members own evaluation of his "working speed." Another (A-7) asked how fast he felt he was processing information. Finally, question C-8 asked supervisors how well they felt their people were keeping up with the data flow. Results of these three questions are presented in figure 2. None of the differences, either within or between flights, were statistically significant. This indicates that no wide fluctuations were perceived by team members in their response-speed capability. However, inspection of individual ratings on these questions indicated some sporadic low estimates by various team members. These did not seem to follow any consistent pattern of increasing or decreasing speed as a function of flight number, but appeared to be more randomly distributed over all flights. The one exception to this was the Communication Section NCOs, who reported slowing in both working speed and information processing time both between and within flights.

In summary, none of the questions designed to assess subjective performance quality revealed striking changes in performance as a result of the mission duration used here. The first flight appeared to cause some areas of confusion, especially for Teams 1 and 3, but these were all minor and were not reflected in performance on later flights. There did not appear to be an overall tendency for "speed" to decrease from one flight to the next, although specific individuals reported sporadic decreases, and a slowing trend was reported by the communication NCOs. No differences in these performance parameters were found between 12- and 8-hour flights, or between day, evening, or night flights.

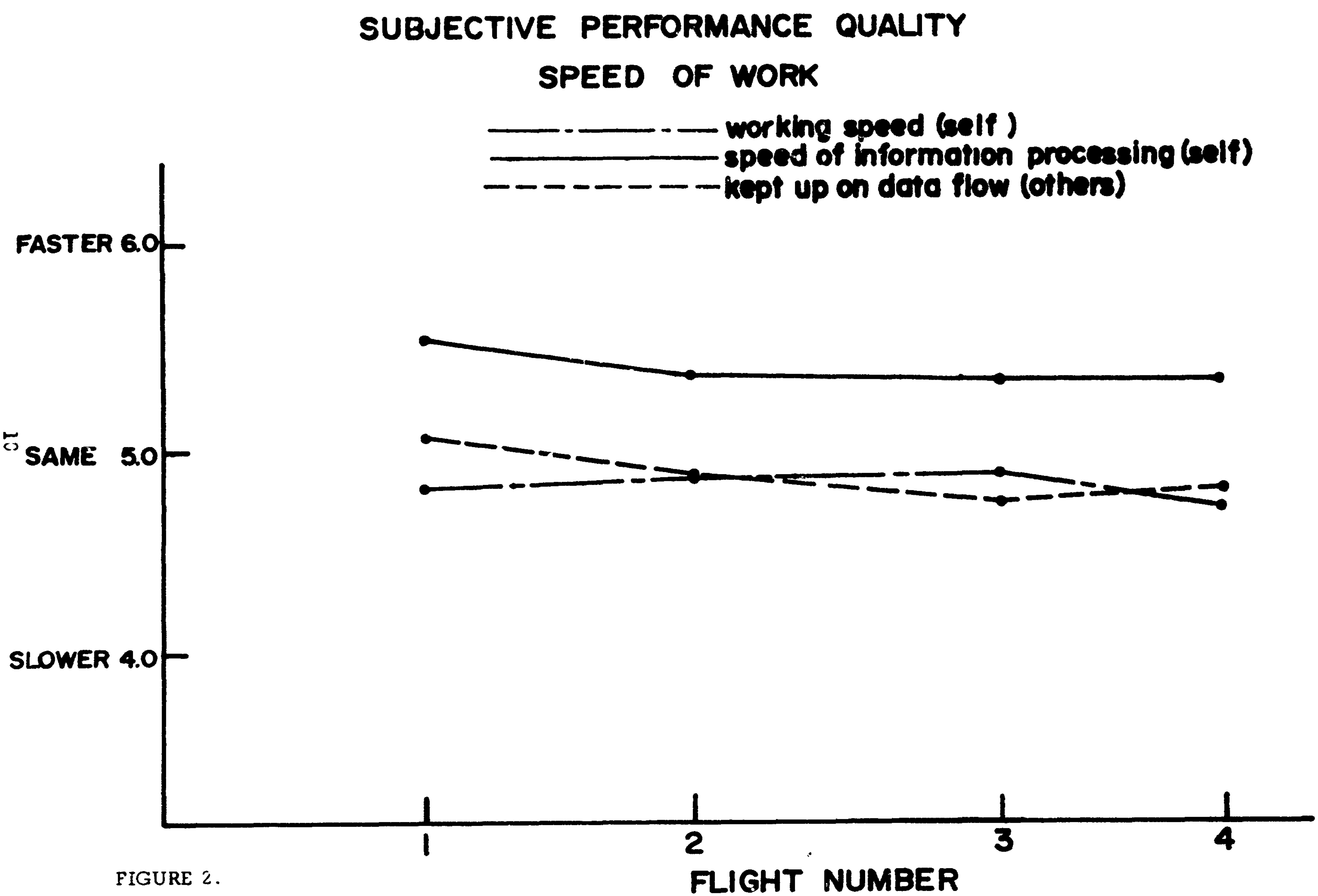
PHYSICAL COMPLAINTS

Stomach, Nerves, and Thirst

Section B of the questionnaire asked each individual the status of certain physical and environmental conditions during each flight. With respect to physical condition, three items failed to show any significant changes from one flight to the next, and no interpretable trends. These consisted of the reported conditions of stomach and nerves, and reported feeling of thirst. None of these questions revealed significant or even remarkable differences as a function of whether the flight was 12 or 8 hours, or whether it was a day or evening flight, although specific individuals appeared slightly affected on the 12-hour night flight for Team 3.

Vision, Backaches, and Headaches

Three other physical complaint questions showed some trends over the course of the four flights. Figure 3 shows that complaints about visual problems arose significantly between the first and second flight ($p < .02$). This large rise was due particularly to complaints from members of Team 2 and their 12-hour evening flight. Visual complaints became slightly lower over the remaining two flights, but showed an increasing trend with respect to the first flight. Overall, complaints about visual problems were worse during the second half of flights than the first half ($p < .02$) indicating that the irritation became worse with continued



SUBJECTIVE PERFORMANCE QUALITY
SPEED OF WORK
working speed (self)
speed of information processing (self)
kept up on data flow (others)
FASTER 6.0
SAME 5.0
SLOWER 4.0
1
2
3
4
FLIGHT NUMBER

FIGURE 2.

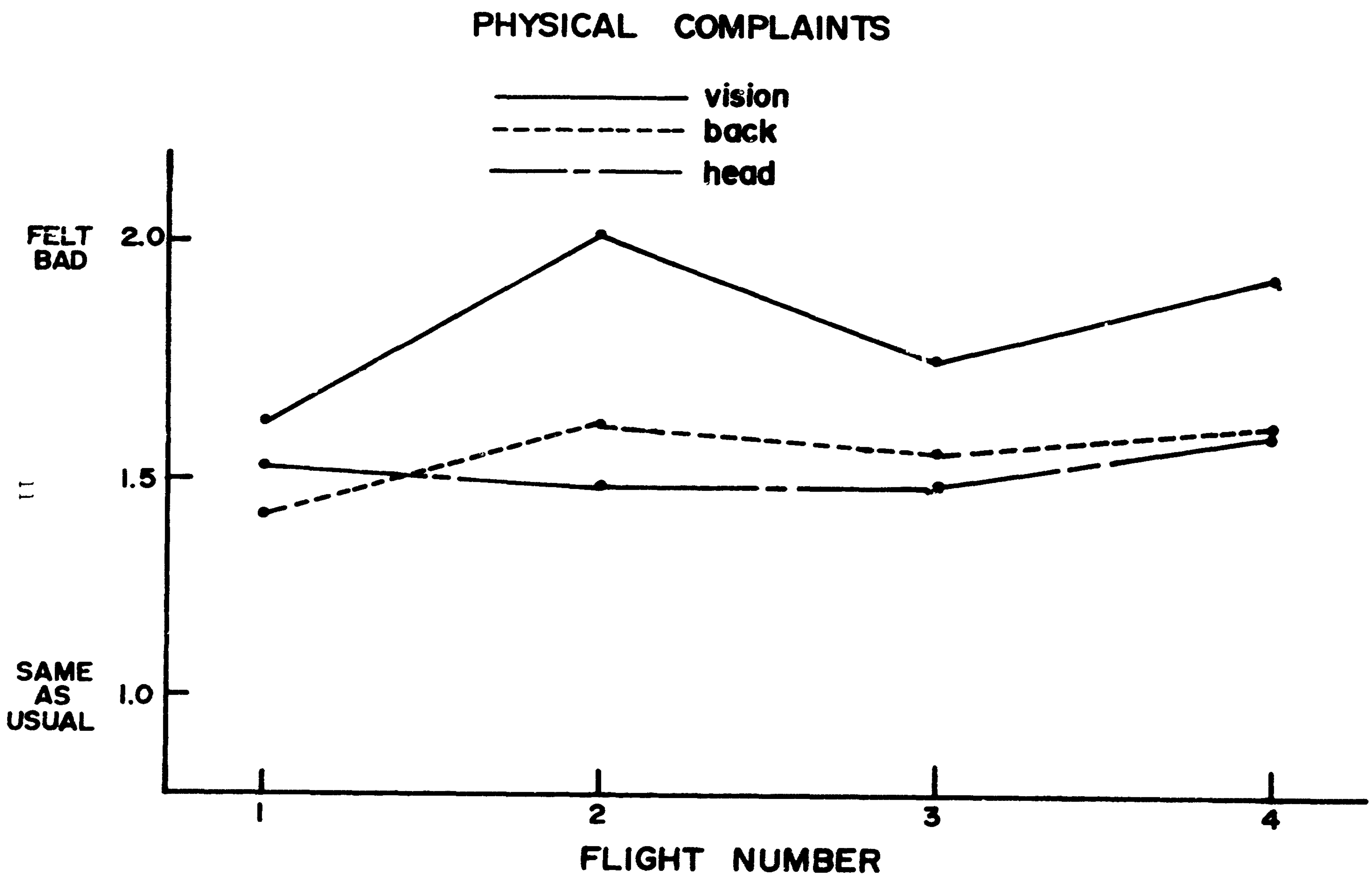

PHYSICAL COMPLAINTS
vision
back
head
FELT BAD
SAME AS USUAL
2.0
1.5
1.0
1
2
3
4
FLIGHT NUMBER

FIGURE 3.

exposure. Complaints about backaches showed a very slight average rise over the four flights, although none of the changes were statistically significant. Looking at reports of specific team members, these complaints appeared to be distributed over several functional areas, with the Communication NCOs, Communications Officer , and Intelligence Officers showing the largest changes. The only complaints about headaches were found on the last flight. Here the rise in the average was due primarily to an increase in the ratings from communications personnel. Both the communication officers and NCOs on both teams, 1 and 3, showed high ratings on this question for all flights, but particularly on the last one. Other team members did not report such consistent patterns.

Complaints about vision, backaches, and headaches were all slightly greater on 12-hour flights than on 8-hour flights but none of these differences were statistically significant. Visual problems on long flights seems especially severe for Team Chief, CCCC, and Communication NCO positions. Backaches and headaches seemed distributed fairly evenly throughout team members during the long flights. Two questions attempted to probe the status of aircraft noise and vibration during the flight. No significant changes in these factors emerged over flights or as a function of flight length or time of day.

PSYCHOLOGICAL STATUS

Irritability and Distractability

One series of questions attempted to determine whether the rigorous schedule tended to make the team members more irritable or short-tempered than normal (A-5, A-9, A-11). Responses to these questions uniformly indicated that team members did not perceive any increase in irritability, either toward the job or toward each other. No increase in distractability was reported over the course of the exercise. These results were consistent over missions of different length and at different times of the day.

Fatigue

Self reports of fatigue (as measured against a criterion of the "normal" amount of fatigue for that point in a mission) indicate some variability over the four flights. Figure 4 indicates that flights 2 and 4 appeared somewhat more fatiguing than normal, both as reported by team members themselves (question A-6), and by their supervisors (question C-6). Statistically, both self- and supervisor-reported fatigue was greater for Team 3 in their 12-hour night flight than for the other teams ($p < .02$). In addition, supervisors generally rated the second and last flights as more fatiguing than the first ($p < .05$ and $p < .02$, respectively). The impression is gained that the night flight lasting 12 hours was the most fatiguing of all single flights. Since this was the first flight, special attention was paid to the subsequent ratings giving by members of this

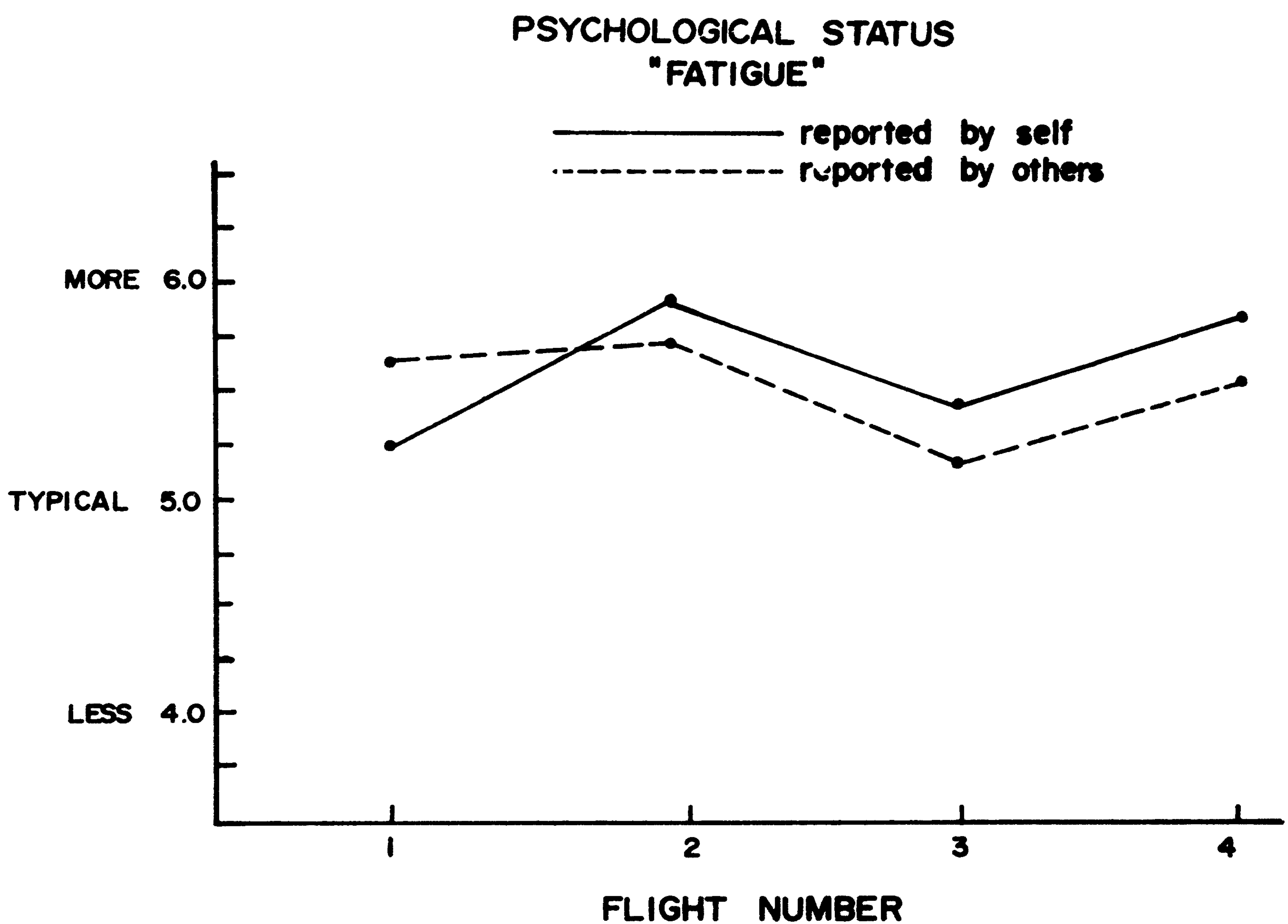

PSYCHOLOGICAL STATUS
"FATIGUE"
reported by self
reported by others
MORE 6.0
TYPICAL 5.0
LESS 4.0
1
2
3
4
FLIGHT NUMBER

FIGURE 4.

team to see if a residual effect could be detected over the remaining three missions. Although fatigue ratings remained fairly high, they were not notably worse than those of other teams on these flights. Thus, the early severe fatigue did not seem to cause an unusually high level of subsequent fatigue. Inspection revealed that the high rating on flight 2 was due primarily to elevated fatigue in Team 2 at the end of their 12-hour evening flight, even though these ratings were not themselves significantly different from those on other flights.

These results are in general agreement with other fatigue survey data collected which indicate no simple cumulative fatigue buildup over the missions. These results indicate that fatigue does buildup on longer flights, but not to any statistically significant or operationally meaningful degree.

Memory

One question (A-4) asked the team members to evaluate their ability to remember data, sources, locations, etc., on the premise that specific forgetfulness is an early indication of fatigue and stress states. Results indicated no significant changes in the overall average response to this question. Slightly lower values were reported for the first and last flights as compared to the middle two flights, but none of these differences are significant.

Decisiveness

Finally, one question dealt with the subjective feeling of "certainty" about decisions or choices (A-3). This question attempted to probe something different than the absolute accuracy of performance. Interest here was in the subject's feelings of decisiveness when faced with data thich required something less than an absolutely certain response. Results indicated that for the first three flights there was little change, (5.10, 5.15, 5.24). On the last flight the overall average dropped to a level of 4.94. Analysis indicated this drop to be primarily due to a reduction in the rating given by the Communications NCO. Subjects' feelings of certainty and decisiveness did not appear to change drastically over the mission, although individual reports indicated some changes.

SUBJECTIVE COMMENTS

The comments made spontaneously by team members on the questionnaire forms were analyzed in loose categories which attempted to obtain a general impression of the teams' concern for various aspects of the mission. On most flights, less than half of the respondees commented (overall average of 31.7 percent, range: 12.5 to 66.7 percent). Comments generally can be grouped into four categories: (1) specific operational problems, (2) equipment problems, (3) physical complaints, and (4) psychological comments.

With respect to operational problems, five respondees reported disorganization on the first flight, probably due to the novelty of the exercise. Later, one such comment was made during each of the last two flights. Three "errors" or mistakes were reported on the first and third flights, and two on the fourth; but all of these were relatively minor. One team member on the third flight reported that he felt "more prone to error." Some individuals reported their workload was light on these flights. Reported equipment problems were relatively minor, and were noted only on the second and fourth flights.

Physical complaints were most notable on the second and third flights, and dealt mostly with visual irritation. In five cases this was blamed on smokers in the cabin, and, in two cases, on inadequate lighting, especially in the communications NCO's compartment. One subject on flight 1 complained of fluctuations in cabin temperature, and one on flight 4 reported he was catching a cold. Fatigue was reported three times on flight 4, but subjects reported being less fatigued (once) on flight 2 and (twice) on flight 4.

More subtle psychological factors were reported infrequently, but are worthy of note. One subject on flight 3 and one on flight 4 felt his thoughts were "dulled," and one on flight 3 felt initiative was degraded. One on flight 4 reported "hesitation."

These reports generally failed to reveal any increasing condition or problem directly associated with the duration of the mission. Some individuals felt that there was a progressive and sometimes serious fatigue and stress, but even these individuals appeared to believe that this was due to things other than the mission protocol itself (e.g., not enough to do, the exercise not being realistic enough, etc.). Most team members did not share this view of a progressive problem, and their overall comments reflected their view.

EXERCISE OBSERVATION

The overall average percentages of time spent by individuals of each functional position in each of the observed activities is presented in table 2. These data represent the minute-by-minute observation of each individual during the entire length of each exercise scenario, and they establish the kinds of tasks required by each individual section during a mission. They reveal the dominant activity of the CCOC to be communication, both electronic (24 percent) and face-to-face (34 percent). The communications officer spends considerable time monitoring the overall situation (33 percent) and speaking, primarily to other communications personnel. The plans officer in these exercises spent most of his time briefing (42 percent) and researching data (30 percent). The intelligence officer, during the first half, spent more time on research (35 percent) and in monitoring the situation. The operations officer, during the second half, spent considerable time researching followup data (25 percent) and communicating this, both by briefing (22 percent) and electronically (14 percent). Individual missions showed

TABLE 2

AVERAGE PERCENTAGE OF TIME SPENT
IN EACH TASK AREA BY POSITION

	CCOC	COMM. OFF.	PLANS OFF.	INTEL*	OPS** OFF.
ELECTRONIC COMMUNICATION	24.0	14.0	1.3	1.9	13.8
WRITING	9.0	5.0	0.6	9.9	10.2
RESEARCH	9.3	6.3	29.6	35.2	24.6
DISCUSSION	34.0	26.0	8.0	4.3	12.3
BRIEFING			41.7	19.1	21.7
MONITORING SITUATION	23.3	33.3	18.4	26.5	17.4
EXPERIMENT	0.4	15.4	0.4	3.1	

* FIRST HALF OF THE FLIGHT
** SECOND HALF OF THE FLIGHT

relatively small variations about these averages, with few exceptions. These exceptions did not appear to be related to the duration of the mission, since they were inconsistent over time. They appeared to reflect more the differing task requirements of each scenario. To further analyze the relative workload pattern of these functional areas in terms of the time during the exercise, percentages were calculated for each fourth of each exercise period. For flight 1, each quarter was 20 minutes; for flight 2 it was 30 minutes, and for flight 3 each quarter was 25 minutes long. Inspection of these data revealed rather large variations in activity patterns for all individuals over the three flights. However, there did not appear to be a meaningful pattern to such variations and, again, differences seemed more readily attributable to scenario requirements.

Since these activity differences did not appear to reflect meaningful differences in pattern of performance furing the three flights, all data were averaged within a given quarter. The results of this average workload pattern for the major activities of each observed area are presented in figure 5. During the first quarter of an exercise, the CCOC is primarily occupied with monitoring the developing situation, whereas the plans officer is primarily briefing. In the second quarter, the CCOC spends a great deal of time communicating, both electronically and face-to-face, as the situation develops. In the third quarter, the communication officer's workload picks up as he monitors and discusses the communications traffic. The plans and the operations officers show high workloads in research as they attempt to answer questions and anticipate developments. In the final quarter, the CCOC spends considerable time discussing the situation with others, the plans officer spends considerable time briefing and doing research, and others spend most time monitoring the situation.

In summary, the activity analysis revealed no clues which indicated that any of the behaviors of team members sampled showed meaningful changes due to fatigue, stress, or the flight number This gross analysis did isolate different workload levels during the course of the exercise scenarios, and this probably gives reliable estimates of the "typical" distribution of activities during such exercises.

EXERCISE CONTENT ANALYSIS

The briefings from two flights were available on tape for content analysis of the exercise scenarios. In these flights, the briefings given by the Intelligence Officer and the Plans Officer were fairly well standardized, and these were chosen for analysis along with the other measures of exercise content previously described.

Data on the verbal behavior of the two briefers are presented in table 3. The average rate of occurrence (corrected for differing briefing lengths) was calculated by counting the number of times each behavior occurred and dividing by overall briefing duration. The change in the briefer's behavior from the first flight to the

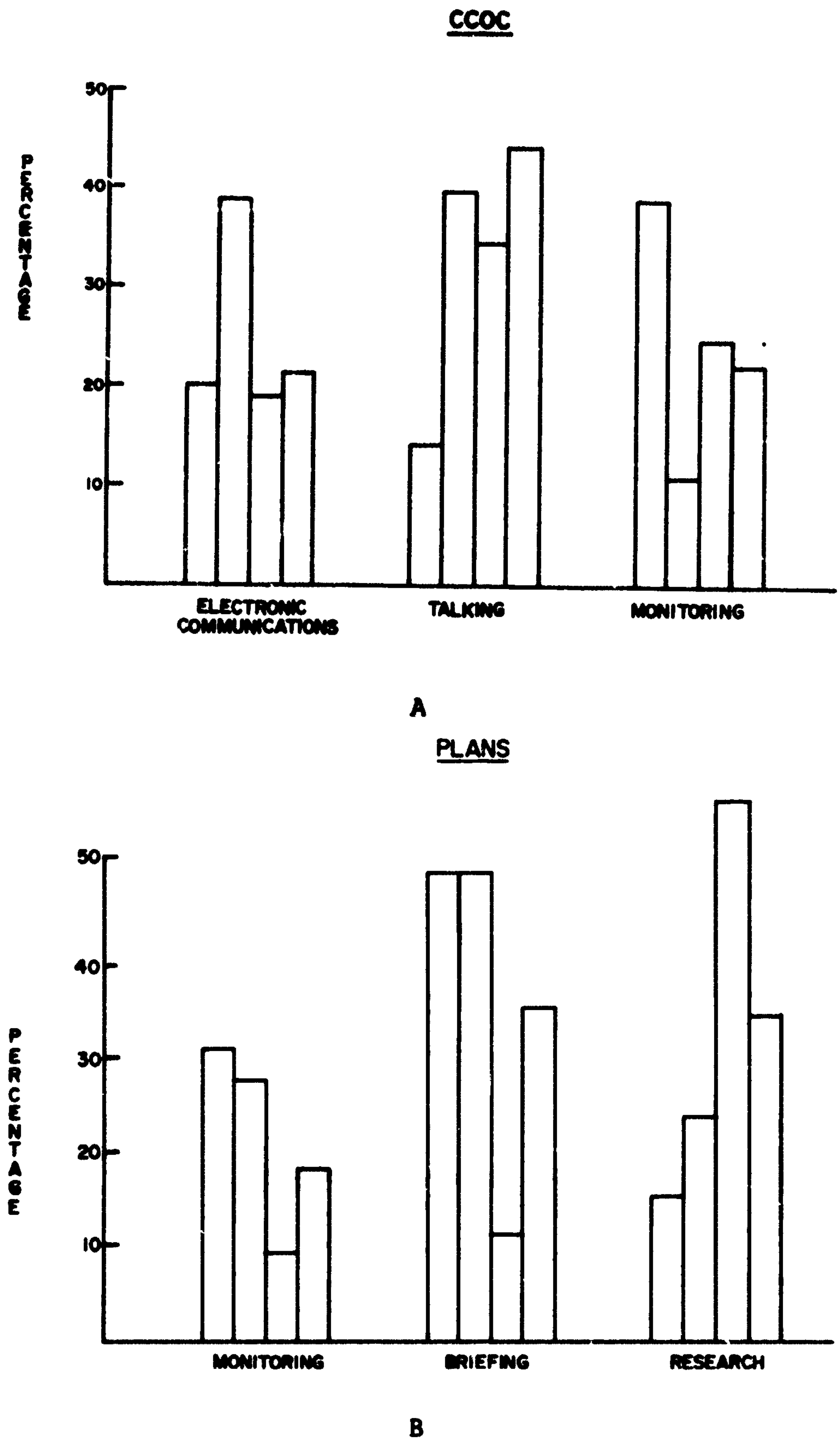
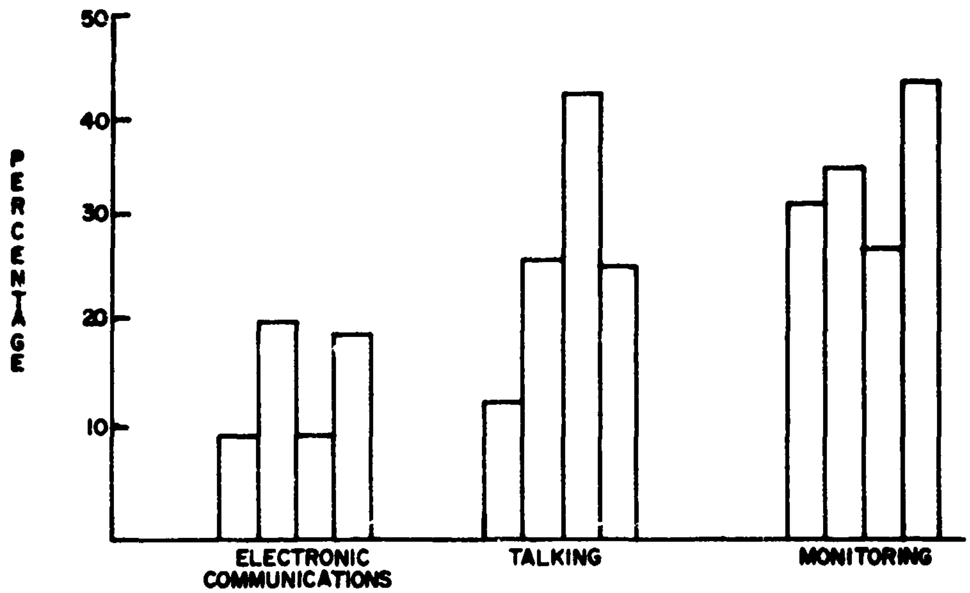


FIGURE 5. PERCENTAGE OF EACH EXERCISE QUARTER SPENT IN MAJOR ACTIVITIES BY FUNCTIONAL AREAS.

COMMUNICATIONS



C

INTELLIGENCE (FIRST HALF) and OPS/ANALYSIS (LAST HALF)

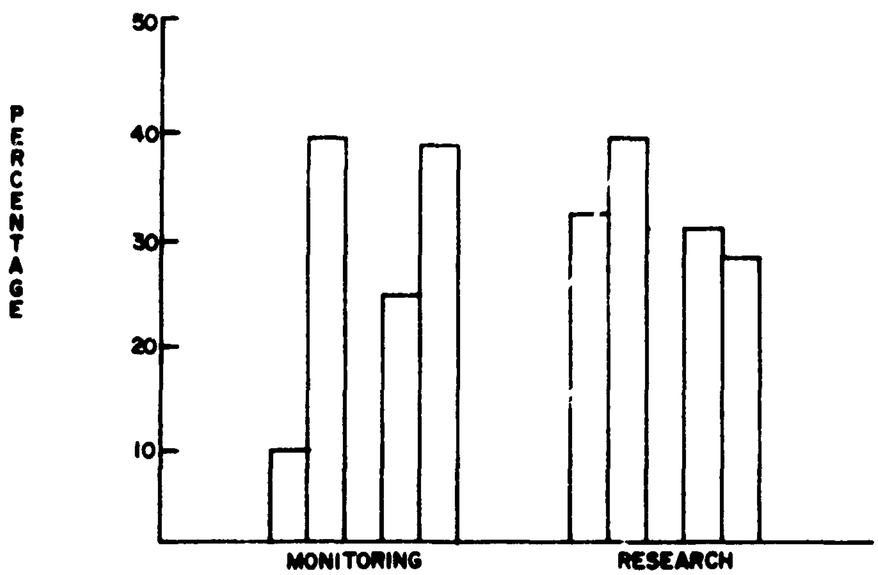


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FIGURE 5. (Concluded).

TABLE 3

NUMBER OF OCCURRENCES OF EACH FORM

OF VERBAL BEHAVIOR PER UNIT TIME

BEHAVIOR	BRIEFER NO. 1			BRIEFER NO. 2		
	FLT #1	FLT #3	DIFF	FLT #1	FLT #3	DIFF
HESITATIONS	.34	.12	-.22	.19	0	-.19
FILLER WORDS (e.g. "ah," "er")	.25	.12	-.13	.35	.33	-.02
FALSE STARTS	.05	.04	-.01	.12	.16	+.04
WRONG WORD	.10	.04	-.06	.07	.05	-.02
VERBAL STUMBLE	.34	.39	+.05	.23	.38	+.15
PARENTHETICAL REMARKS	.10	.16	+.06	0	.05	+.05
GIVE INTERPRETATION	.10	0	-.10	0	0	0

third flight is expressed in the table by the difference in terms of these "normalized" units. The data indicate that both officers showed a decrease in "hesitations" (defined as long breaks in the pattern of speech). For both officers, there was a decrease in the number of "delay" or "filler" words (such as "ah...," "er...,"). There were no consistent changes in the number of times each officer made a false start into a sentence and had to rephrase the sentence (e.g., "...It was a ...there were...,") but both decreased slightly in the number of times the wrong word came out (e.g., "raunch" for launch, "air-bomber-aircraft"). Briefer number 1 decreased slightly in the number of nonvalidated interpretations or opinions given in the course of the briefing. On the other hand, the number of times both briefers "stumbled" (i.e., mispronounced a word or got slightly tangled up in their speech) increased slightly from the first to the third flight, and the number of parenthetical remarks (casual observations or explanations inserted by the briefer) was slightly higher in the third flight. Finally, one of the briefers fell into the habit of saying "Again..." during the first flight (a possible sign of nervousness), but said it only once during the third flight.

In addition to the foregoing straight verbal analysis, the timing of the sentences used by each briefer was calculated, and the length of the frequent pauses that are used for stufying slides was obtained. Both briefers reduced the length of their pauses from the first to the third flight (reductions of 5.8 and 0.7 seconds per pause). One briefer reduced the average sentence time from 12.7 seconds to 9.4 seconds, but the other briefer increased from 10.6 to 11.3 seconds. Neither of these changes indicate any significant effects from one flight to the other.

Several other observations were made from these taped flights. The CCOC became actively involved in the briefer's presentation six times on the first flight and five times on the third. The Team Chief entered into the scenario to make a direct recommendation or interpretation two times on each flight. Questions were asked of the briefers only during the first flight. Of three questions asked, one was answered immediately and two required additional research. The one answered immediately was answered in three sentences. The deferred questions were answered after delays of 39 seconds and 3 minutes 49 seconds.

In summary, none of the changes seen in verbal behavior suggest increased stress or fatigue. In fact, several of the changes shown in table 3 are consonant with increased confidence and relaxation, although none of them should be considered significant in itself. The impression of better performance on flight 3 was reinforced by the tone of voice used by both briefers. Both appeared noticeably more at ease and confident, but still presented their data in an animated and efficient manner.

DISCUSSION AND CONCLUSIONS

The major conclusion to be drawn from the survey data presented here is that operations of the duration and intensity studied produced no measurable changes in significant aspects of the quality or style of mission performance. It is necessary to understand the scope of this statement if one is to derive valid operational principles and experimental hypotheses from it. Some time will be spent, therefore, in discussing the extent to which this conclusion can be applied.

Note at the outset that the missions flown here probably do not reflect very closely the conditions which would exist for these crews in a real emergency situation. The overpowering stress of a genuine national emergency is difficult to approximate. On a lesser level, it is even difficult to ahieve the same stress as would occur if a real National Command Authority were riding on the aircraft. The mission as flown here was not typically perceived by the teams to be even as stressful as some other exercises (e.g., High-Heels) and, to that extent, is not even an adequate simulation of other exercises. On the other hand, a true stress was produced by this series of flights. In particular, this seemed to be related to all of the unknowns operating in this mission. No such exercise had ever been held, and there was some evident anxiety about how it would go. Added to this were the routine operational stresses associated with the mission scenario (e.g., the long alert before the first flight, the fact that some team members were continuously awake for 24 hours, etc.). We feel, however, that a valid field study was held in which at least some of the stresses of a real emergency were present. To the extent that such stresses placed a workload on the teams, the results should be generalizable as good approximations to questions relating to team performance in a real emergency.

A second consideration is the nature of the measurement instruments used here. The questionnaire data can only reflect what the teams felt their performance to be. The observation and content analyses were too unstandardized and based on too few data points to produce completely reliable data. No sophisticated performance tests were administered, and no baselines were established. The questionnaire was an unstandardized (and in some ways unorthodox) instrument, and the design of the exercise did not yield precise replications of several types of missions. All of these things are undesirable from a strict experimental viewpoint and were intended to produce hypotheses for further study rather than absolutely certain conclusions; nevertheless, the results appear to have a rather high degree of face validity.

Even though the questionnaire failed to reveal positive changes in several areas, it did show sensitivity to changes in other areas. For example, the relative confusion of the first flight was picked up, the fatigue of Team 3 on their first 12-hour night mission was seen, and visual problems stood out clearly. In view of this kind of sensitivity, one can place increased confidence in the other negative results. The problem of variability from one mission to the next undoubtedly reduces the confidence one can place in conclusions about specific types of flights and specific questions. This variability was especially difficult to interpret in the exercise observation data. However, in return for this lack of specificity, one gains a greater range of variety, and this leads to increased confidence in statements about the extremes to which the teams are exposed. For instance, the absence of radical differences in most workloads between the three flights is more meaningful in view of the lack of standardization in the three exercise protocols.

The attempt to break the data into meaningful measures with respect to 12-hour and 8-hour flights was complicated inasmuch as there were only two 12-hour flights. These were early flights by Teams 3 and 2, respectively, and were night and evening flights. Thus, it was impossible to separate the confounding effects of the time-of-day, team, and flight duration. Where differences were not found, one can at least be certain that the combination of factors did not produce changes. Where differences were found, it is difficult to determine which of the three factors caused them. The same type of problem arises in trying to average data over teams within a given functional area. Although generally similar jobs are performed by one functional area across teams, the individual style of each team is reflected in specific differences in work effort. Again, it is probably safe to give high confidence to the overall averages and conclusions, but care should be exercised in applying these conclusions to specific individual personalities.

Given the above limitations, we can consider the operational meaning of these findings. With respect to overall efficiency, there was absolutely no indication that the teams' performance would suffer as a result of this regimen and, equally important, there was no strong indication that any performance deficit was beginning to show up. No trend was observed in the data relating to efficiency, mistakes, quality of coordination, style of performing, or capability to respond to an emergency. This lack of trend implies that one can reasonably hypothesize that the teams could have continued the same schedule for a longer period of time.

The physical complaints noted by the teams probably reflect significant items of concern from a human engineering view. By far, visual problems were most significantly noted, and these were blamed on smoking in the cabin and on poor lighting. This problem did not seem to become worse day by day (i.e., it was not cumulative) but was significantly worse in the last half of flights than in the first half and was slightly worse on 12-hour than on 8-hour flights. Since it would be undesirable to prohibit smoking, the possibility is raised that more adequate cabin ventilation is needed. In addition, the lighting in the communication NCO's compartment was extremely bad. Shadows falling on the teletype equipment predisposed workers to eye strain, but this can be eliminated by spot-illuminating this area.

Complaints about backaches were most often attributed by team members to the kind of seats used in the aircraft. These are rigid, upright seats which do not allow for much variation in sitting position. Two of the three Team Chiefs, who had more comfortable seats, did not complain of back problems at any time, so the seating would appear to be suspect in this respect. Certainly, additional concern should be given to this item in future command and control aircraft.

In view of several team members' opinion that dehydration occurs on long flights, thirst was, surprisingly, not a problem on these flights. Possibly, thirst failed to appear because team members were drinking more liquid in order to meet requirements for other, biochemical studies not mentioned here. In any case, subjective thirst was never reported to be a problem on these flights and under these conditions.

Fatigue questions indicate that even though individual flights were quite exhausting, there were no long-term residual effects built up from flight to flight. The 12-hour flights were very exhausting, but did not result in extraordinarily high fatigue on subsequent flights. By the fourth flight, generally higher fatigue was reported by the two teams measured. This could have represented either the beginning of a cumulative effect not yet statistically significant or simply a "relaxation effect" at the end of the mission. Viewed with other evidence, the former conclusion seems most tenable. Note, however, that these changes were small, nonsignificant, and not reflected in overall efficiency.

The results of the exercise observation document the relative workload of various team members and bear on several design considerations for command and control aircraft. Of particular interest in the amount of time (34 percent) spent by the CCOC in face-to-face communication with the team. It would therefore be desirable to facilitate this by allowing him to face his team. The same consideration should be given to the communications officer, who should be located within easy access for face-to-face communication with NCOs in his section. Plans, intelligence, and operations officers should be located as conveniently to the data base as possible, reflecting their high research load. Use of the various workload estimates during different segments of the mission should facilitate planning of movement traffic patterns within the cabin during peak work periods.

Neither the activity analysis nor the verbal content analysis indicated that the team changed their style of working over the exercise. This is a strong indication that the mission did not begin to have a serious effect on overall performance. If fatigue, stress, motivational problems, boredom, etc. had begun to take a toll, one would expect that some changes in performance style would have occurred. To the extent that these did not happen, performance on the last flights is assumed to have been as efficient as on the first flight.

In considering individual team position, only one area stands out as a possible problem. It is generally agreed that the communications personnel , particularly the teletype operator, carry the heaviest workload throughout a mission. This was validated in the present study. The teletype operators reported significant changes in areas relating to slowing in their performance, visual problems, backaches, headaches, fatigue, and certainty. Observations revealed this job position to require almost continuous high-concentration effort, with the intrinsic responsibilities imposing great stress. The impression is that if any single position is most subject to performance decrement over time, it is the teletype operator's position. Consideration should therefore be given to supplementing the number of individuals who can fill this position, especially during high stress or extended operations.

To a lesser extent, the communications officer also appears to be under some stress. His workload was not observed to be as continuously intense as that of the NCO, but the overall system responsibility and the need to respond quickly to unique communication requests and to equipment failures can cause an unusual degree of tension. In a real emergency, the workload would certainly be more continuous and, therefore, consideration should be given to adding some redundancy to this functional area.

APPENDIX

QUESTIONNAIRE

TEAM NUMBER ______________ **POSITION** ______________

DATE/TIME ______________Z

Circle the numbers on the scale which represent your best estimate of the conditions or factors as they existed during the last half of the flight.

<u>SECTION A</u>: These questions relate to you personally.

1. Compared to your "normal" working speed, were you able to work

Faster				Same				Slower
9	8	7	6	5	4	3	2	1

2. Compared to your "normal" accuracy, were you working

More accurately				Same			Less accurately	
9	8	7	6	5	4	3	2	1

3. When decisions or choices were required, did you feel more or less certain about them than usual?

More certain				Same			Less certain	
9	8	7	6	5	4	3	2	1

4. When required to remember data, sources, locations, etc., was your memory better or worse than usual?

Better				Same				Worse
9	8	7	6	5	4	3	2	1

5. Did normal, routine details tend to be more or less irritating than usual?

More irritating				Same			Less irritating	
9	8	7	6	5	4	3	2	1

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6. Do you feel more or less fatigued now than usual?

More fatigued				Same			Less fatigued	
9	8	7	6	5	4	3	2	1

7. When required to process information, did you feel you took more or less time than usual?

More time				Same			Less time	
9	8	7	6	5	4	3	2	1

8. Did you make more or fewer mistakes (either small or large) than usual?

More				Same			Fewer	
9	8	7	6	5	4	3	2	1

9. When dealing with other team members, were you more or less abrupt, curt, or sharp than usual?

More abrupt				Same			Less abrupt	
9	8	7	6	5	4	3	2	1

10. Did you feel it was more or less necessary than usual to double check any work you put out?

Needed more checking				Same		Needed less checking		
9	8	7	6	5	4	3	2	1

11. Were outside events going on in the aircraft more or less distracting than usual?

More distracting				Same		Less distracting		
9	8	7	6	5	4	3	2	1

SECTION B: This section deals with your physical condition and the environmental conditions during this part of the flight. Consider each item and indicate whether the strain or stress was greater in this mission than normal, and if so, how much greater.

	Felt same as usual				Felt bad, strained, or tense
My vision	1	2	3	4	5
My back	1	2	3	4	5
My stomach	1	2	3	4	5
My head	1	2	3	4	5
My nerves	1	2	3	4	5
My thirst	1	2	3	4	5
Cabin noise	1	2	3	4	5
Aircraft vibration	1	2	3	4	5

SECTION C: This section deals with your evaluation of the individuals and operations under your supervision during this part of the mission. All evaluations are to be compared to a normal, desirable level of performance.

1. Coordination between individuals was

Better				Typical				Worse	None Req'd
9	8	7	6	5	4	3	2	1	0

2. Coordination between functional areas was

Better				Typical				Worse	None Req'd
9	8	7	6	5	4	3	2	1	0

3. Support of my area from other functional areas was

Better				Typical				Worse	None Req'd
9	8	7	6	5	4	3	2	1	0

4. Support of my area from ANMCC/NMCC was

Better				Typical				Worse	None Req'd
9	8	7	6	5	4	3	2	1	0

5. The workload for my people was

Greater				Typical				Less
9	8	7	6	5	4	3	2	1

6. Compared to the normal for this point in a mission, my impression is that my people are

More tired				Typical				Less tired
9	8	7	6	5	4	3	2	1

7. The overall efficiency of my people appears to be

Better				Typical				Worse
9	8	7	6	5	4	3	2	1

8. During this phase of the mission, my people kept up with the data flow requirements

Better				Typically				Worse
9	8	7	6	5	4	3	2	1

9. Independent of overall efficiency, I feel that my people are doing things

In exactly the same way as usual				Slightly Different		Very differently		
9	8	7	6	5	4	3	2	1

10. If a real emergency happened right now, I think my people would perform

At maximum efficiency			Very adequately			Slightly degraded			Not able to perform
9	8	7	6	5	4	3	2	1	0

<u>SECTION D</u>: In this section, list any <u>events</u> which occurred during this part of the mission which were not normal. These may be large events (equipment breakdowns, significant mistakes by personnel, etc.) or small things (misplaced papers, small errors, etc.). Great detail is not required, but we would like a notation for every such event which occurs.