Performance Effects in 17-Day Simulated Space Flights

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A TRIP to the moon has been accepted as a reasonable national goal. The development of the required sealed environment for such a trip is within reach of the environmental engineer, but the specification of the biomedical parameters and the solution of the atmospheric, toxic and other ecological problems pushes earthbound physiology into unknown areas. For these reasons, we regard the physiological problems to be of primary importance in biomedical research on manned space flight.

However, most biomedical strategies for manned space flight are determined by mission duration—the physiologist in particular finds his options severely constricted by the engineering state-of-the-art in sealed environments on one hand and the operational requirements of the mission on the other. Time is also a major factor for the behavioral scientist in selecting strategies which would optimize the astronaut's proficiency. The SAM Two-Man Space Cabin Simulator is a facility in which both disciplines can evaluate their strategies, not only separately but also in combination. Thus, from its very beginning, the space medicine research program at the School of Aerospace Medicine has been on an interdisciplinary basis. The research parameters constituting the interface of environmental, physiological, and behavioral factors have been an accessible goal.

Psychological problems associated with mission duration can be sorted into two categories: within days (or up to 24 hour mission profiles), or across days (multiple-day mission profiles). Significant variables include work-rest schedules, day-night cycles, and prolonged commitment to the task. Major proficiency research programs in these areas have been carried out in the past five years. Hauty's initial studies demonstrated one major problem in the "within-days" category: proficiency cannot be maintained much beyond 20 hours under conditions of continuous performance without rest.[4] He also identified a secondary "within-days" problem: performance decrement was greater when the critical period (20 to 24 hours) occurred in the "trough" of the day-night cycle.[3] Neither problem constitutes a real obstacle to man-in-space, but both require adjustments in the astronaut's schedule.

These results apply only to the continuous performance condition. The situation is different under the more probable circumstances of a regular work-rest schedule. Hauty found no significant problems in the "across-days" schedule.[6] Adams[1] reports generally similar results. In addition, his studies on work-rest schedules[2] failed to identify any important schedule variables or general rules which might be applied to the problem.

Our own report a year ago,[5] agreed in general with the results of both Hauty and Adams on work-rest schedules and day-night cycles. In addition, we reported an "instantaneous" (i.e., not specifically time-anchored) effect in which performance decrement could be related to signal rate, or the work level. At that time, our results were tentative. This paper will affirm our earlier report.

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METHOD

The SAM Two-Man Space Cabin Simulator has been described in our earlier paper in considerable detail.[5] Briefly, the simulator is a special-purpose altitude chamber instrumented and outfitted to maintain two men for up to 30 days under continuous environmental control and a standardized schedule of activity. Three kinds of functions are imposed upon the subjects in the simulator: management of logistical aspects of the flight; monitoring and control of the internal environment; and operation of a psychomotor task. This task, which we have named the Operator System, has no direct effect upon the simulator or on the physiologic or logistic outcomes of the flights. It does, however, simulate in a general sense the operation of a complex, space-oriented weapons system. By scheduling regular work periods and programming work levels, a variety of proficiency problems can be investigated. Such measures are also available to evaluate interactions between psychologic and physiologic changes.

The Operator System consists of 14 sub-tasks varying in complexity and involving different kinds of skills. Simple monitoring, simple and complex discrimination, encoding and decoding, arithmetic, and problem-solving functions are included. Although presented at a single panel and conceptually integrated in a special "script," the sub-tasks are basically independent of each other in operation, programming, and scoring.

Programming is accomplished by specially prepared mylar tapes and a decoding system. The tape was punched to give four different over-all signal rates: 40, 300, 500, and 1200 signals per hour in specific time units. Subjects worked either two or five hour shifts, and performed the task a total of 22 hours every two days. The schedule is shown in Figure 1. Two of the four flights had low signal rates during the nighttime. For the other two, the signal rates for the daytime and nighttime halves of the schedule were reversed, so that the slow rates occurred during the 0900-1900 hour interval.

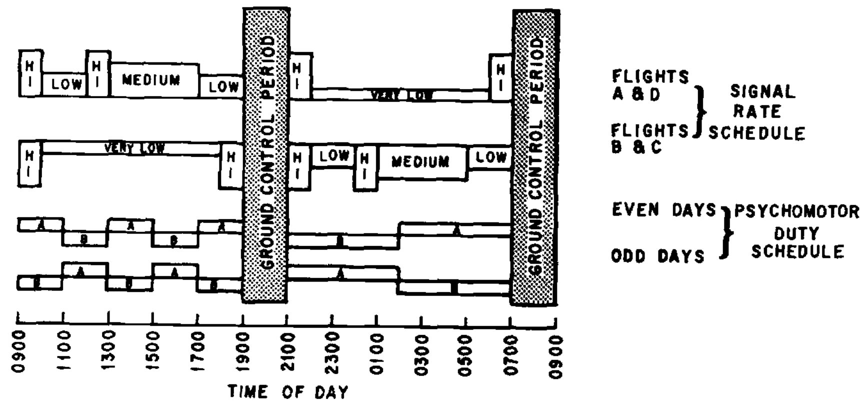

Fig. 1. Flight profile of operator's schedule showing signal rate schedule and operator duty schedule with "A" or "B" indicating the respective operator.

All four flights were made at pressure equivalent to 33,500 feet altitude and 96 per cent O_2 levels. The flights involved all of the logistic, physiologic, and biomedical support and measurement procedures described in our earlier paper. The only major change within the set of four flights was the reversal of day and night segments of the psychomotor schedule just described.

RESULTS AND DISCUSSION

Performance was evaluated in terms of mean response time in each hour at each task. Individual task means were pooled into a smaller number of similar task-groups and three representative two-day packages were selected. These two-day units were selected from the early, middle, and late portions of the flights. Separate analyses of variance were carried out on each flight. These were triple classification analyses of variance, and involved the major variables of segments of the flight, hours of the day, and tasks.

The "F" ratios obtained from these analyses are presented in Table I. Three out of the four flights yielded significant "F" ratios. Both task differences and differences between hours were significant in these three flights. Only one flight (A) gave a significant difference between segments (early, middle, and late) of the flight.

TABLE I. "F" RATIOS AND ASSOCIATED SIGNIFICANCE LEVELS OBTAINED FROM ANALYSES OF VARIANCE OF MEAN RESPONSE TIMES IN FOUR 17-DAY SIMULATED SPACE FLIGHTS

Flight	Between Tasks (T)	Between Hours (H)	Between Segments (S)
A (2, 5)‡	25.19**	12.26**	10.91**
B (5, 2)	N.S.	N.S.	N.S.
C (5, 2)	25.95**	5.04**	N.S.
D (2,5)	68.58**	3.55**	N.S.

INTERACTIONS

Flight	TXH	TXS	HXS	TXHXS
A	N.S.	N.S.	1.93**	N.S.
B	N.S.	N.S.	N.S.	N.S.
C	N.S.	9.85**	N.S.	N.S.
D	3.71**	N.S.	N.S.	N.S.

‡indicates work schedule. N.S. = not significant.
(2.5) shows 2-hour periods during day. *=significant at the 5% level.
(5.2) shows 5-hour periods during day. **=significant at the 1% level.

The task effect is shown in Table II. No clear-cut, systematic task differences are apparent. For example, vigilance task times are low ("good") for two flights and high for the third, and discrimination times are very low for one flight and very high for another. The way the subjects approached the psychomotor system as a whole had more to do with response time than any sub-task itself. While we tried to standardize their task orientation, each pair of subjects apparently developed a Gestalt unique to themselves and to their over-all flight orientation.

The significant F for segments in Flight A reflected a systematic increase in mean response times for successive periods of the flight. The response times for the early, middle, and late segments were 16.9, 18.6, and 23.7 seconds, respectively. The two pilots in this flight were,

TABLE II. AVERAGE RESPONSE TIMES FOR DIFFERENT TASK-GROUPS IN THREE 17-DAY SIMULATED SPACE FLIGHTS

Flight*	Complex Discrimination	Problem-Solving	Vigilance	Encoding & Decoding
A	18″	24″	23″	28.5″
C	7″	18″	5″	**
D	34″	**	12.5″	14″

*Flight B did not yield significant task differences.
**Incomplete data precluded analysis.

in contrast to the other subjects, on their second extended simulated space flight. It is likely that this increase in response time is a product of boredom. Diaries kept by these two subjects indicated that this was a factor. That such differences did not occur in the other flights (nor indeed in any other of the nine simulated space flights to date) supports this interpretation.

The significant F for hours was the effect we specifically anticipated. Our earlier paper reported that increased response times were associated with : (1) slow signal rates; and (2) five hour on-duty periods; and (3) night-time. An alternate analysis indicated that signal rate was the primary factor, but our experimental design at that time did not permit us to reach this conclusion unequivocally. For this series of flights, we varied the schedule so that low signal rates occurred at either day or night and during either two-hour or five-hour duty periods. If signal rate was the primary factor, it should effect performance on either schedule.

Hours yielded the anticipated significant "F" ratios in three of the four flights. Since signal rate effects were our primary interest, we pooled across all tasks and sorted each hour for each subject on all four flights into categories according to the number of responses made. This sorting provided a rearrangement of response times by signal rates across the four flights and eight subjects. An average response time was computed for each subject in each signal rate interval and a single classification analysis of variance of these means was performed. The "F" ratio for this analysis was 8.05, significant at the 1 per cent level. The signal rate effect is shown in Figure 2. Each point in Figure 2 is the average of the eight subjects means. Marked performance decrement at low signal rates is clearly demonstrated. More detailed analyses keeping task-groups separate were performed. All task-groups showed the same signal rate effect.

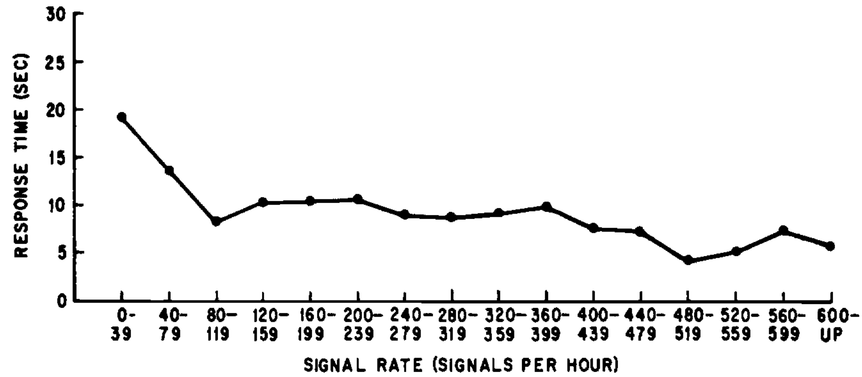

Fig. 2. The effects of signal rate on operator performance. Hourly periods have been sorted according to total number of signals and the average response times in seconds indicated for each of these intervals.

great when the low signal periods occur during the day. Figure 3 demonstrates this attenuation. This figure shows the signal rate curves for each of the two schedules separately. Each point is the average of four subjects on two flights. The curve for response times on low rate—daytime combination does not show as large an increase in response time as the curve for the low rate—nighttime combination. This could be considered to be an interaction between signal rate and task schedule. We are inclined, on the basis of other experimental programs in our laboratory, to designate the day-night cycle as a secondary, attenuating factor. However, the data from these flights do not permit so specific a conclusion.

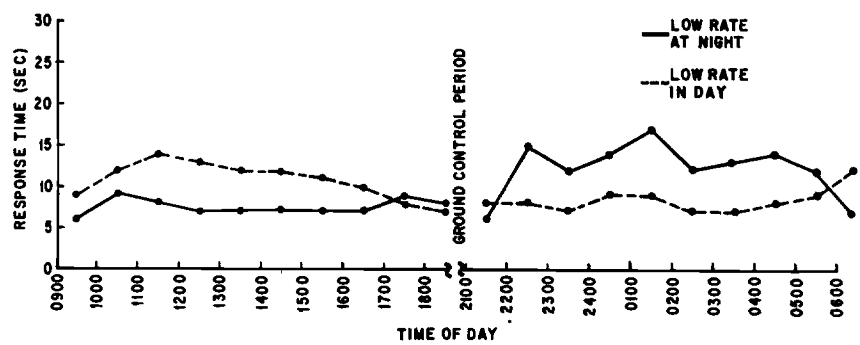

Fig. 3. Attenuation of signal rate effects obtained by reversing flight profile. The curves for each flight are presented separately.

Although signal rate has been shown to be the primary factor in performance changes occurring during these 17-day flights, there is a secondary effect. The magnitude of the signal rate effect can be attenuated by the day-night, two to five-hour duty schedule. Specifically, performance decrement at low signal rates is not as

SUMMARY

Eight subjects participated in pairs in four simulated space flights of 17 days duration in the SAM Two-Man Space Cabin Simulator. The flights were made at pressure equivalents of 33,500 feet altitude and 96 per cent + O_2 levels. In addition to the management of logistical and environmental aspects of the flights, subjects were required to perform a psychomotor task consisting of several systems-type sub-tasks. Duty tours were either two or five hours long. Work rates varied from very low (approximately 40 signals per hour) to high speed (more than 400 signals per hour). The day-vs-night dimension was also varied. Significant differences in performance were obtained for signal rates, with marked decrement occurring at the very low work rates. The results did not demonstrate systematic effects for length of duty period, day-vs-night, or duration of the flight. The task schedule attenuated the signal rate effect. These findings confirm tentative conclusions reported a year ago.

REFERENCES

1. Adams, O. S., Levine, R. B. and Chiles, W. D.: Research to investigate factors affecting multiple-task psychomotor performance. *WADC Tech.* Report 59-120, March 1959, Wright Air Development Center, ARDC, Wright-Patterson AFB, Ohio.
2. Adams, O. S. and Chiles, W. D.: Prolonged human performance as a function of the work-rest cycle. ORD 273, May 1961, Lockheed Aircraft Corp., Marietta, Georgia.
3. Hauty, G. T.: Human performance in the space travel environment. *AU Quart. Rev.*, 10: No. 2, Summer 1958. Hq. Air University, USAF, Maxwell AFB, Alabama.
4. Hauty, G. T.: Maximum Effort-Minimum Support Simulated Space Flights. *Aero/Space Eng.*, 19:44, (Apr.) 1960.
5. McKenzie, R. E., Hartman, B. O. and Welch, B. E.: Observations in the SAM two-man space cabin simulator. III. System operator performance factors. *Aerospace Med.*, 32:603 (June) 1961.
6. Steinkamp, G. R., Howkins, W. R., Hauty, G. T., Burwell, R. B. and Ward, J. E.: Human experimentation in the space cabin simulator. *School of Aerospace Medicine Report*, 59-101, 1959, Brooks AFB, Texas.