USAARL Report 76-24

DYNAMIC VISUAL ACUITY IN FATIGUED PILOTS

By

Isaac Behar, Ph.D.

K. A. Kimball, Ph.D.

D. A. Anderson, Ph.D.

June 1976

Final Report

US Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362

NOTICE

Qualified requesters may obtain copies from the Defense Documentation Center (DDC), Cameron Station, Alexandria, Virginia. Orders will be expedited if placed through the librarian or other person designated to request documents from DDC (Formerly ASTIA).

Change of Address

Organization receiving reports from the US Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 76-24	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DYNAMIC VISUAL ACUITY IN FATIGUED PILOTS		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Isaac Behar, Ph.D. K.A. Kimball, Ph.D. D.A. Anderson, Ph.D.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bio-Optics Division (SGRD-UAO) US Army Aeromedical Research Laboratory Fort Rucker, Alabama 36362		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DA 1498
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Aeromedical Research Laboratory SGRD-UAC Fort Rucker, Alabama 36362		12. REPORT DATE June 1976
		13. NUMBER OF PAGES 13
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) US Army Medical R & D Command Washington, DC		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

This document has been approved for public release and sale; its distribution is 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
Dynamic Visual Acuity
Sleep Loss

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

Six rotary wing aviators were subjects in a continuous operation regimen involving some 12 hours of flying and 3.5 hours sleep daily for five days. Estimates of performance on a dynamic visual acuity (DVA) task were obtained several times each day during the study using target velocities of 25° and 40°/sec. DVA performance varied significantly during the fatigue regimen when measurements were made with target velocities of 40°/sec; with lower velocity targets differences in DVA scores were not significant. This indicates the need to tax the oculomotor system to demonstrate fatigue effects.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Fatigue effects were partially obscured by practice effects which are considerable in the DVA task. DVA scores correlated only modestly with subjective estimates of fatigue intensity and flying performance, and IP ratings of performance, but the cluster of correlations provided a consistent picture.

SUMMARY

Six rotary wing aviators were subjects in a continuous operation regimen involving some 12 hours of flying and 3.5 hours sleep daily for five days. Estimates of performance on a dynamic visual acuity (DVA) task were obtained several times each day during the study using target velocities of 25° and 40°/sec. DVA performance varied significantly during the fatigue regimen when measurements were made with target velocities of 40°/sec; with lower velocity targets differences in DVA scores were not significant. This indicates the need to tax the oculomotor system to demonstrate fatigue effects. Fatigue effects were partially obscured by practice effects which are considerable in the DVA task. DVA scores correlated only modestly with subjective estimates of fatigue intensity and flying performance, and IP ratings of performance, but the cluster of correlations provided a consistent picture.

ROBERT W. BAILEY
COL, MSC
Commanding

INTRODUCTION

Good dynamic visual acuity (DVA), which is a measure of resolution in the presence of relative motion between the observer and the object being regarded, is critical for the accomplishment of Army helicopter missions. Because of the extremely low altitudes flown, particularly in the nap-of-the-earth flight profile, even at modest air speeds angular velocities between aviator and object exceed 100°/second, seriously taxing visual resolution of navigational landmarks, targets, and hazards such as power lines.

Recognizing the relevance of DVA to military aviation, a comprehensive, systematic analysis of dynamic visual acuity was conducted by Ludvigh and Miller at the Naval School of Aviation Medicine[1,2,3,4]. Beginning in 1953 and extending for nearly a decade, these studies provided a broad data base of DVA performance and led to a number of important generalizations: (a) DVA deteriorates significantly and progressively but with large individual variation as the target angular velocity increases; (b) DVA is relatively uninfluenced by the plane and direction of motion of the target, or whether the relative motion is produced by moving the target relative to a stationary observer, or vice versa; (c) DVA improves with practice, particularly for the relatively higher target velocities, but individual differences in practice effects are large; (d) DVA and static acuity are not significantly correlated.

Dynamic visual acuity is an extremely complex visual task, performance of which is related to at least three separable visual skills: the static acuity, oculomotor performance, and rapid visual information processing. That DVA depends upon more than the static acuity is evidenced by the low correlation between these measures, especially as angular velocity is increased[5]. Perhaps the first analysis of eye movement patterns during DVA performance was made by Crawford[6]. He demonstrated an inverse relationship between latency of the saccadic eye movement and DVA accuracy. He also found that with high velocity targets, tracking consists of a series of saccades with little, if any, accurate smooth pursuit. Crawford further defined two types of error of fixation in DVA: position error, in which the target critical detail is not imaged in the central fovea, and velocity error, in which eye tracking and target velocities differ resulting in retinal smearing. Finally, because of the brief time period of moving target presentation, DVA may also be related to central information processing, but studies addressed specifically to this point are lacking.

Because of the dependence of DVA upon retinal, oculomotor and central factors, it is not surprising that it, unlike simpler measures of visual performance, has been found to be related to a variety of variables: age, sex, driving performance, anoxemia, alcohol, marijuana, and reduced illumination; hence, to be a potentially valuable measure of overall visual functioning in a number of applied situations. While a deletorious effect of fatigue on DVA has been hypothesized[4], the present study is the first to investigate this relationship.

METHOD

Subjects. Ss for the present investigation were six (6) rotary wing aviators between the ages of twenty-one and twenty-six. All pilots had just completed rotary wing flight school and had logged approximately 200 flight hours prior to the test.

Apparatus. The DVA apparatus was a compact, specially constructed field-transportable unit. Targets, following Burg[7], were the Bausch and Lomb checkerboard patterns. The pilot's distance from the rear projection screen (53") was fixed by a chinrest, and the screen subtended 12 1/4° visual angle horizontally. Five target sizes were used, for which the angular size of the critical detail varied from 1.3' to 2.8'. Target luminance was approximately 37fL, background 1.1 fL, and contrast 94%. The checkerboard targets were prepared as 2" X 2" slides and were projected onto the screen using a random access projector via a General Scanning Model G124 scanner. Target velocity was controlled by the ramp output of a Wavetek Model 134 Sweep Generator. The return sweep of the scanner was blanked by a Gerbrands shutter.

Procedure. The present study was ancillary to a broader determination of biochemical and psychophysiological measures of fatigue produced by a continuous operation regimen involving some 12 hours of flying and 3.5 hours sleep daily for 5 days. The remainder of the time was taken up with experimental procedures and meals. Breakfast, lunch, and dinner were 30 minutes and a late night snack was 15 minutes duration. A detailed report of the broader study is contained in reference 8. Two pilots were run at a time. During the experiment they lived at the USAARL High Falls Field Test Station. They arrived on a Saturday, were given an orientation, including familiarity with the DVA task, and had a normal night's sleep. On Sunday, control data were obtained on all biochemical and laboratory psychophysiological tests. The first and each subsequent flying day commenced at 0430 and ended at 0100 except for the fifth (last) flying day when the flying ended in the late afternoon. The pilots had a full night's sleep that night and were not awakened until 0600 the next day. That day was another control day. The pilots spent the next two days away from the testing area then returned for a final, recovery, control day.

Dynamic visual acuity performance was assessed at 0600, before and after lunch and dinner, and before retiring. For the first two subjects, two checkerboard target velocities were used, 20° and 30°/sec, with a descending method of limits procedure. We found, first of all, that 20°/sec was too slow to provide useful information, and secondly, that the method of limits was inappropriate because of the fluctuations of attentiveness ("lapses") that characterizes fatigue[9].

For the subsequent four pilots we increased target velocities to 25° and 40°/sec and used the method of constant stimuli. The results for these four subjects only will be reported. For each assessment of DVA performance, the pilot received 30 trials, 15 at the lower target velocity followed by 15 trials at the higher velocity. Each 15 trial block consisted of a randomized ordering of the 5 target sizes, 3 each at any of the four possible orientations: top, bottom, left, or right. Each trial was preceded by a verbal "ready" signal and target movement was always horizontal, left to right. For quantification of DVA performance, the easiest targets (2.8') were assigned a weight factor of 1 and progressively more difficult targets were assigned weights of 2, 3, 4, and 5. The DVA score consisted of the sum of the products of the weighting factors and number correct for each level of difficulty normalized so that errorless performance was assigned a score of 100.

RESULTS AND DISCUSSION

DVA Performance. The mean DVA performance scores over experimental days are depicted in Figure 1 by the solid lines separately for the 25° and 40°/sec target velocities. The five flying days are bounded by the broad vertical lines. The broad interrupted horizontal line depicts chance performance level (25%). It may be seen that performance improved from the control day to the first flying day, and again dramatically on the first day after a good night's sleep following the five flying days. Differences in DVA scores over days were significant at less than the .02 level ($F=3.217$, $df=7,21$) for 40°/sec and approached significance at 25°/sec ($F=2.307$, $df=7,21$, $p=.065$). Also portrayed in Figure 1 (the dashed lines connecting the DVA scores on Days 2 and 7) is a hypothetical DVA practice or learning curve which would be expected in the absence of fatigue[10]. The differences in the two curves provide estimates of the DVA decrement with fatigue.

Relation of DVA Scores to Other Measures. At the end of each flying session throughout the experiment, the pilots scaled their subjective estimates of fatigue by placing a mark on a printed line of standard length, the position of the mark indicating fatigue intensity.[11] The mean fatigue intensity ratings for the five flying days are schematically presented in Figure 2. Over the five flying days, fatigue ratings increased gradually during the day then rapidly at night; they increased rapidly the first day or two and gradually beyond. Both variations are highly statistically significant while the interaction between them is not. The correlation coefficients obtained between these ratings and the DVA scores obtained a few minutes later (based on 18 pairs of measures) for each of the four pilots are -0.23, -0.42, 0.15, and -0.18. For three of the four subjects, the rs are negative, as expected, but significant only for the second pilot.

In spite of the build up of fatigue over flying days, the pilots did not assess their flying performance to be impaired, and this is corroborated by ratings of the accompanying safety pilots (IPs). These mean ratings are given in Figure 3. None of the variations of flight performance ratings, either the pilots' or the IPs', as a function of time of day or ordinal flying day, are statistically significant. The correlation coefficients obtained between these ratings and the DVA scores obtained a few minutes later for each of the pilots are: 0.19, 0.30, 0.22, 0.20 for the pilots' own ratings, and 0.34, 0.39, 0.08, and 0.33 for the IPs' ratings. None of these rs reach significance, although all are positive as expected, and taken together provide a consistent picture.

The relatively small variations observed in this study in DVA performance indicate the need for improved sensitivity of measurement. The obfuscation of a fatigue effect by the benefits of practice -- seen also in other measures of oculomotor performance[12] -- suggests the need for extended practice prior to the experimental period to assure that performance is asymptotic, or the use of a method, perhaps varying direction of motion randomly, with which practice effects would be minimal. With the relatively restricted range of DVA scores, as well as those of the subjective fatigue and flight performance measures, the low correlations observed are not entirely surprising.

REFERENCES

1. Ludvigh, E. and Miller, J.W. A Study of Dynamic Visual Acuity, Kresge Eye Institute and U.S. Naval School of Aviation Medicine, Joint Project No. NM 001075.01.01, Report 1, 4 March 1953.

2. Ludvigh, E. and Miller, J.W. "Study of Visual Acuity During the Ocular Pursuit of Moving Test Objects. I. Introduction," Journal of the Optical Society, 48: 799-802, 1958.

3. Miller, J.W, "Study of Visual Acuity During the Ocular Pursuit of Moving Test Objects. II. Effects of Direction of Movement, Relative Movement, and Illumination," Journal of the Optical Society, 48: 803-808, 1958.

4. Miller, J.W. and Ludvigh, E. "The Effect of Relative Motion on Visual Acuity," Survey of Ophthalmology, 7: 83-116, 1962.

5. Burg, A. "Visual Acuity as Measured by Dynamic and Static Tests: A Comparative Evaluation," Journal of Applied Psychology, 50: 460-466, 1966.

6. Crawford, W.A. The Perception of Moving Objects. II. Eye Movements, Air Ministry Flying Personnel Research Committee Report FPRC 1115, July 1960.

7. Burg, A. "Apparatus for Measurement of Dynamic Visual Acuity," Perceptual and Motor Skills, 20: 231-234, 1965.

8. Kimball, K.A. and Anderson, D.B. "Aviator Performance: Biochemical, Physiological, and Psychological Assessment of Pilots During Extended Helicopter Flight," NATO-AGARD Conference Proceedings 182.

9. Williams, H.L., Lubin, A., and Goodnow, J.J. "Impaired Performance with Acute Sleep Loss," Psychological Monographs, 73 (14, Whole NO. 484), 1959.

10. Ludvigh, E. and Miller, J.W. Some Effects of Training on Dynamic Visual Acuity, Kresge Eye Institute and U.S. Naval School of Aviation Medicine, Joint Project No. NM 001075.01.06 Report No. 6, 22 September 1954.

11. Hartman, B.O., Hale, H.B., and Johnson, W.A. "Fatigue in FB-111 Crewmembers," Aerospace Medicine, 45: 1026-1029, 1974.

12. Melton, C.E. and Wicks, M. Binocular Fusion Time In Sleep-Deprived Subjects, FAA Report AM69-1, January 1969.

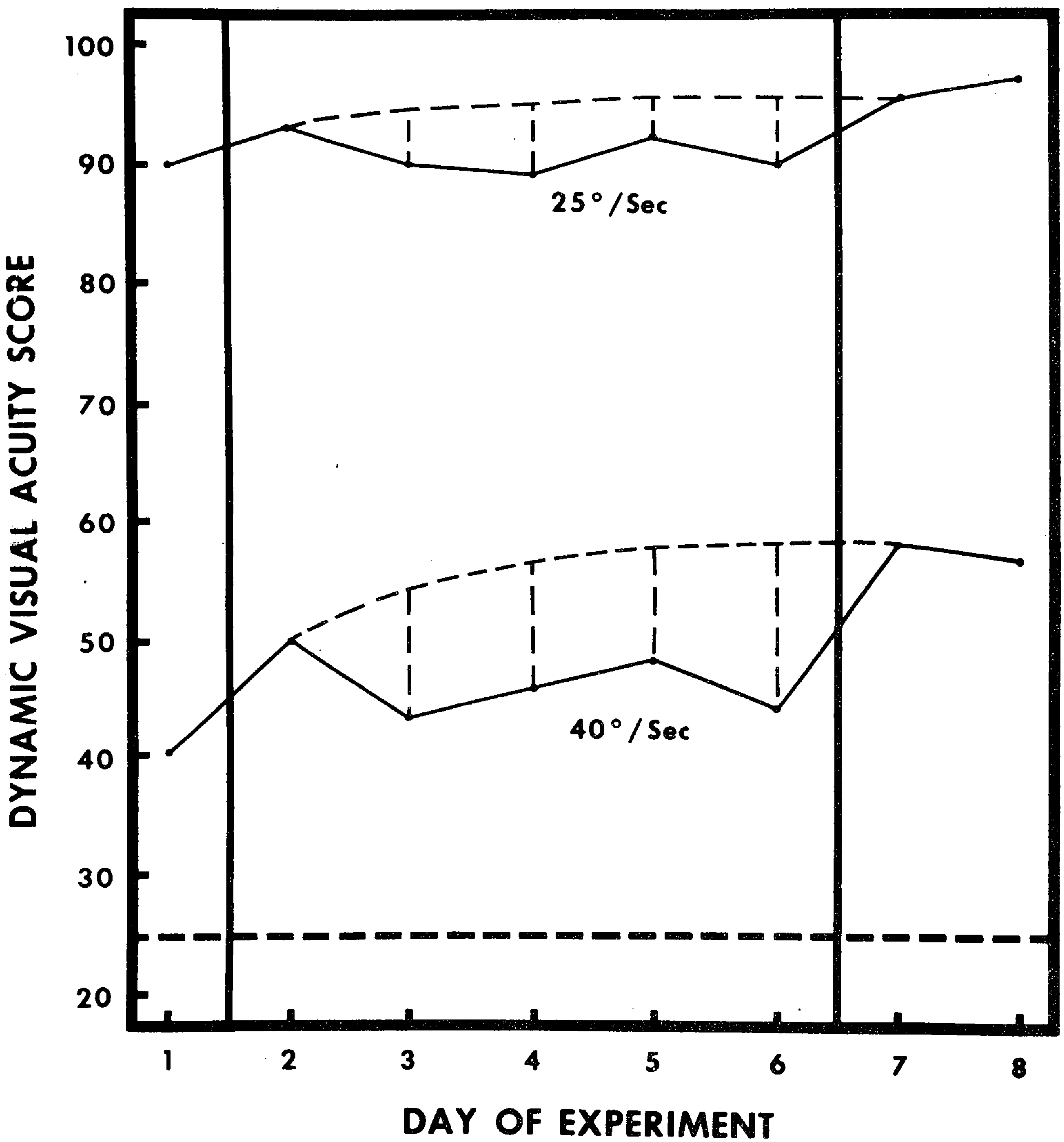

Figure 1. Variation of DVA mean scores over experimental days (solid curves) and hypothetical practice functions (dashed curves) that would be expected in the absence of fatigue.

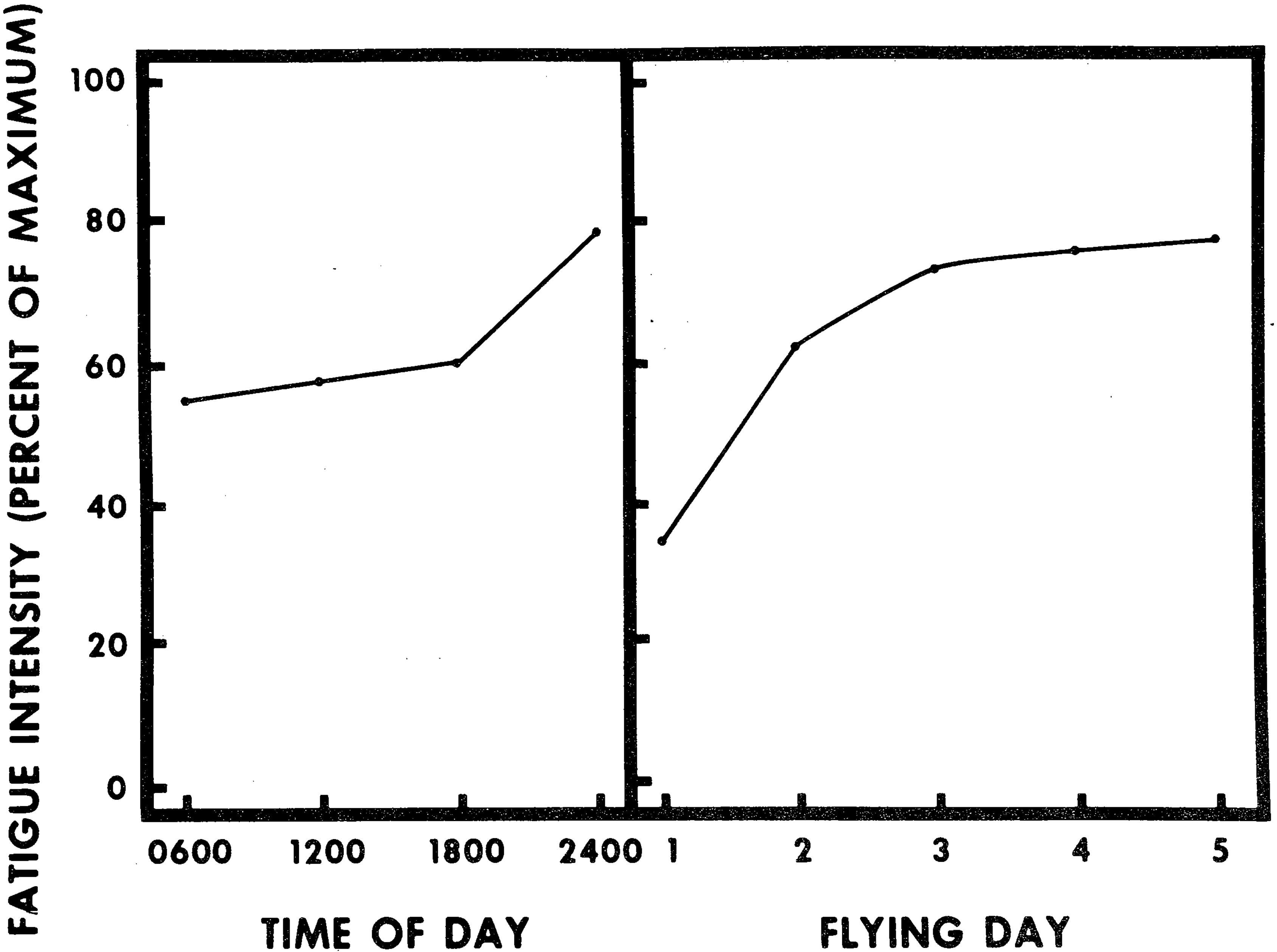

Figure 2. Subjective ratings of fatigue as a function of time of day (left panel) and ordinal flying day (right panel).

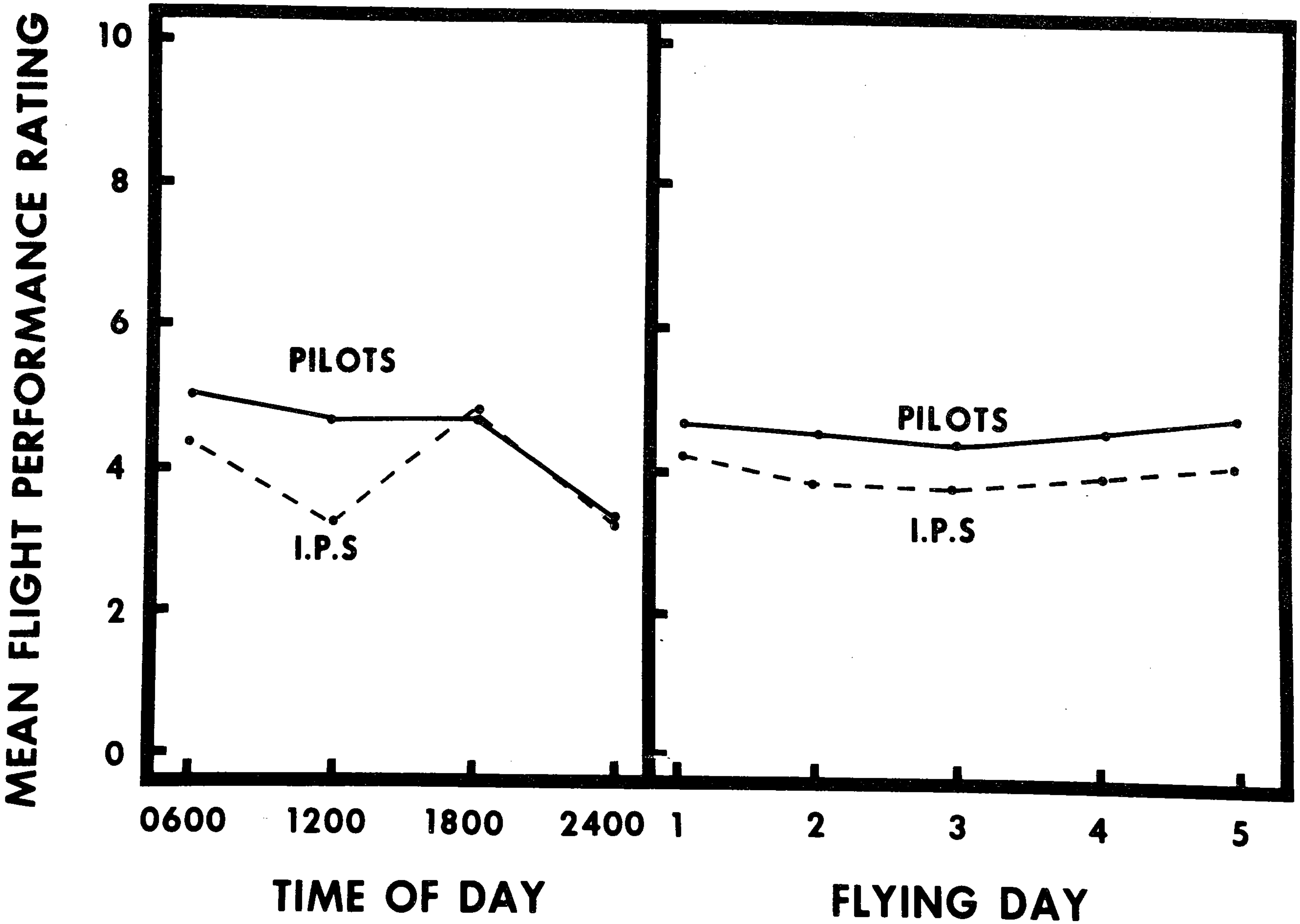

Figure 3. Mean ratings of flight performance as a function of time of day and flying day for the pilots themselves and for the IPs.