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CHIMPANZEE PERFORMANCE DURING EXPOSURE TO 100% OXYGEN AT 14.7 PSI

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FOREWORD

The authors wish to express their appreciation to David S. Belski for the preparation of the charts; to Gerald Garrett and Anthony Burgeoise for the statistical treatment of the data; to the technicians in the Comparative Psychology Branch, Gordon Wilson, Victor Bogo, Gary Barnhart, Robert Bush, Nelson DeLavan, Hugh D. Gregg, Gerald Garrett, Joseph Leachman, Vern Pegram, James Warrell, and Marion Rathbun for the monitoring of the subjects; and to Miss Sylvia Echavarria for the typing of the drafts.

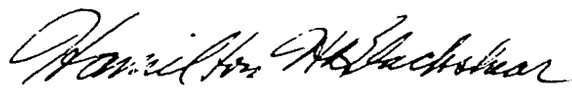
We appreciate the co-operative efforts of the Astro-ecology Branch, Bioinstrumentation Branch, Veterinary Services Branch and the Land-Air Inc. staff in making this study possible.

ABSTRACT

The effects on performance of breathing 100% O_2 at 760 mm. Hg (14.7 psi) pressure for 15 hours were investigated using six chimpanzees in a counter-balanced design. Each subject was tested for 15 hours in both a 100% O_2 environment and a 20% O_2 environment. Performance on continuous and discrete avoidance tasks was required on five 15-minute sessions for each 15-hour test. The results were as follows: One subject exhibited a decrement on the continuous avoidance task; two animals showed an increase in reaction time. It was concluded that exposure to 15 hours of 100% O_2 at 760 mm. Hg (14.7 psi) produced marginal performance decrements in two of the six chimpanzees.

PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.



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CARE AND HANDLING OF THE SUBJECTS

The animals used in this study were handled in accordance with the "Principles of Laboratory Animal Care" established by the National Society of Medical Research.

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CHIMPANZEE PERFORMANCE DURING EXPOSURE TO 100% OXYGEN AT 14.7 PSI

I. INTRODUCTION

The evaluation of changes which may arise in chimpanzee performance during space flight is enhanced by controlled studies of the environmental factors of the flights under standard laboratory conditions. The environmental conditions of space flight differ from the laboratory environment in several aspects. Environmental pressure, oxygen content, and restraint conditions are potential problem areas which exist during space flight. The determination of the appropriate environmental pressure for space flight poses special problems. Welch, et al. (Ref. 5) suggest that sea level pressure atmosphere (20% O_2 at 14.7 psi) is not advisable for space systems because it offers little protection from physiological disturbances arising from abrupt pressure changes and, from an engineering standpoint, sea level pressures are difficult to maintain. It was further suggested that the utilization of 100% oxygen atmosphere at a 5 psi cabin pressure would minimize the problems of control and maintenance of cabin atmosphere. Welch's results indicated that man could perform satisfactorily in an environment of 100% oxygen at 190 mm. Hg (33,600 feet) pressure level for 17 days.

Stephenson (Ref. 4) demonstrated hyperoxia in dogs which were exposed to 35% to 40% oxygen at sea level pressures for short time periods, and in some cases produced cardiac arrest or premature contractions and ventricular tachycardia.

Rohles, et al. (Ref. 3) demonstrated no performance decrements during a 14-day restraint test with a chimpanzee.

In summary, then, the restraint system employed in these experiments is known to produce no detrimental effects, and it is known that man can adequately function in 100% reduced pressure environments for several days. However, dogs have indicated severe hyperoxic effects due to elevated oxygen concentration for one hour.

An animal in a closed ecological system with a 100% oxygen atmosphere for a space flight may have to be sustained 15 hours prior to launch. Accordingly, the purpose of this study was to evaluate the effects of breathing 100% oxygen at 760 mm. Hg (14.7 psi) for 15 hours on the performance of restrained chimpanzees.

II. METHODS

A. Subjects

Six chimpanzees were used in this study, and all had received extensive training on the behavioral tasks involved. The age and weight for each subject is presented in Table I. All subjects were well adapted to the restraint condition prior to this study.

TABLE I

The Age and Weight for All Subjects

Subject	Age	Weight
Paleface No. 32	84 months	60 pounds
Elvis No. 35	60 months	54 pounds
Jim No. 62	51 months	28 pounds
Roscoe No. 42	65 months	56 pounds
Minnie No. 46	60 months	43 pounds
Roy No. 101	52 months	31 pounds

B. Design

The subjects were divided into two groups to accomplish a counter-balanced design. Group I was first exposed to 20% O_2; 14.7 psi and then to 100% O_2; 14.7 psi. Group 2 was first exposed to 100% O_2; 14.7 psi and then to 20% O_2; 14.7 psi. This technique obviated any sequential effects which might have accrued in the usual test-retest situation. During both 15-hour test sessions for each animal the behavioral tasks were presented for 15 minutes at 3 hour intervals. Thus, behavioral information was collected five times during each 15-hour test.

Four subjects were tested in the restraint chairs described by Grunzke (Ref. 2), and two subjects were tested in restraint couches described by Rohles, et al. (Ref. 3).

The counter-balanced order of presenting the experimental treatments was determined, and the data collection procedure was established as presented in Table II.

TABLE II

The Design for Presenting the Experimental Treatments

Group	Subject	First Experimental Treatment Administered	Second Experimental Treatment Administered
Group I	Paleface Elvis Jim	20% O_2	100% O_2
Group II	Roscoe Minnie Roy	100% O_2	20% O_2

C. Apparatus

1. The General Electric Environmental Test Chamber (ETC)

All tests were conducted in the ETC which permitted the control of oxygen content, pressure level, temperature and relative humidity. The inside dimensions were 30 inches by 48 inches by 48 inches. A plexiglass window was provided on one wall of the chamber.

2. Conditions of Restraint

As pointed out previously, the subjects were restrained either in a chair or in a couch. Photos of these devices are shown in Figures 1 and 2, respectively.

3. The Performance Test Panels

Two types of performance panels were used in this study. For the chair restrained subjects, the performance panel shown in Figure 3 was used. The red light on the right side signals that the continuous avoidance task is in effect and the blue light on the left side signals that the discrete avoidance task is in effect. Lever presses on the right lever produce a secondary reinforcement in the form of a flash of white light in the center window.

The performance panel for the couch restrained subjects was described in the Rohles (Ref. 3) study. This panel is shown in Figure 4.

The operation of the two panels was identical. The red light appeared in the window on the right side, and actuation of the right lever produced a flash of white light in the center window display. The blue light was presented in the left window on both stimulus panels.

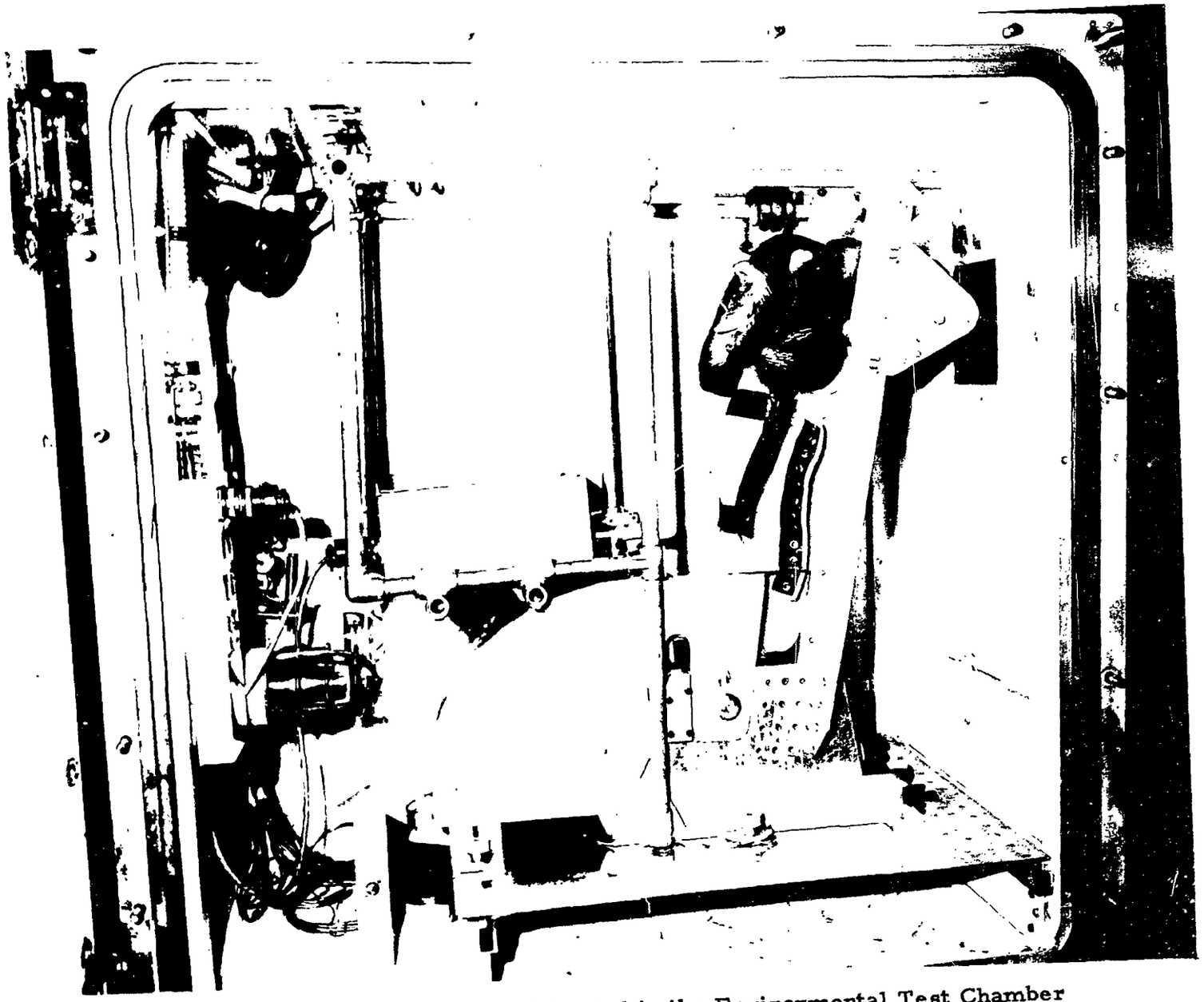

Figure 1. Restraint Chair Mounted in the Environmental Test Chamber

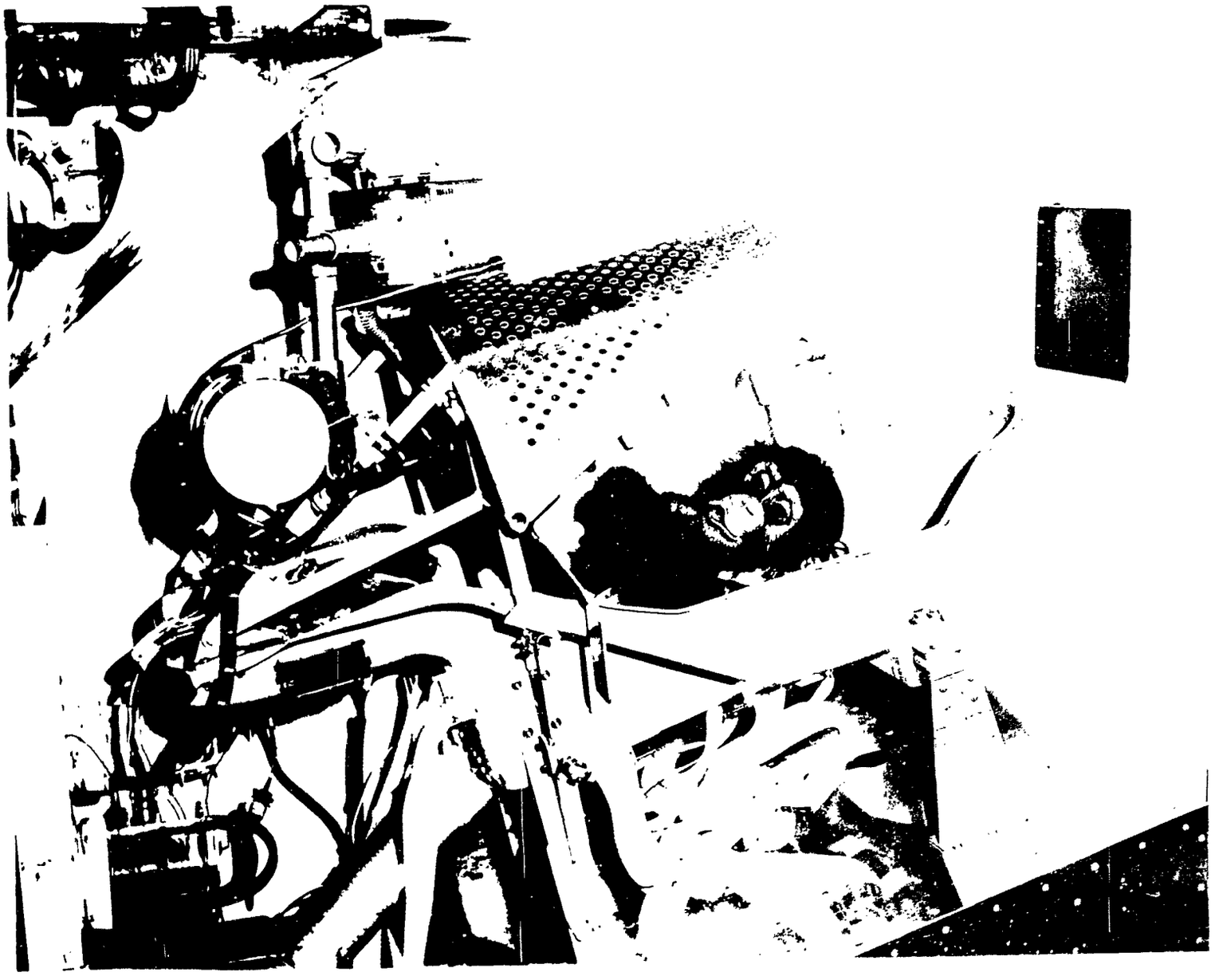

Figure 2. Restraint Couch Mounted in the Environmental Test Chamber

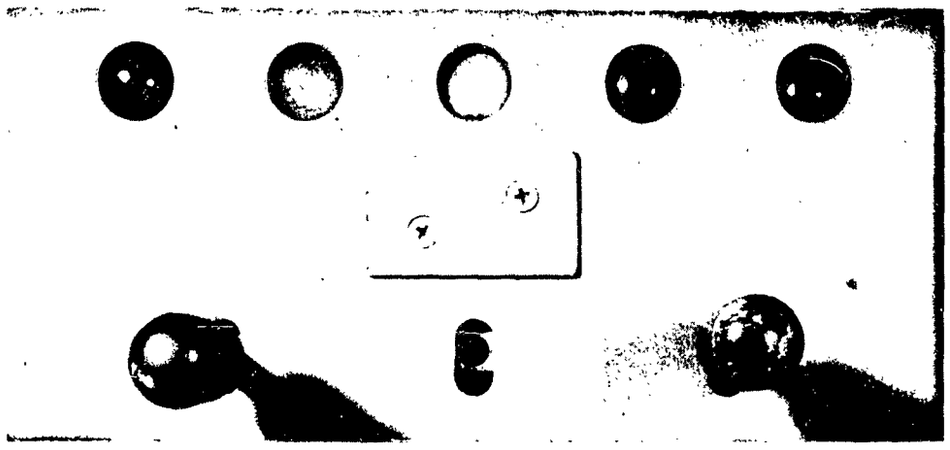

Figure 3. Performance Panel for Chair Restrained Subjects

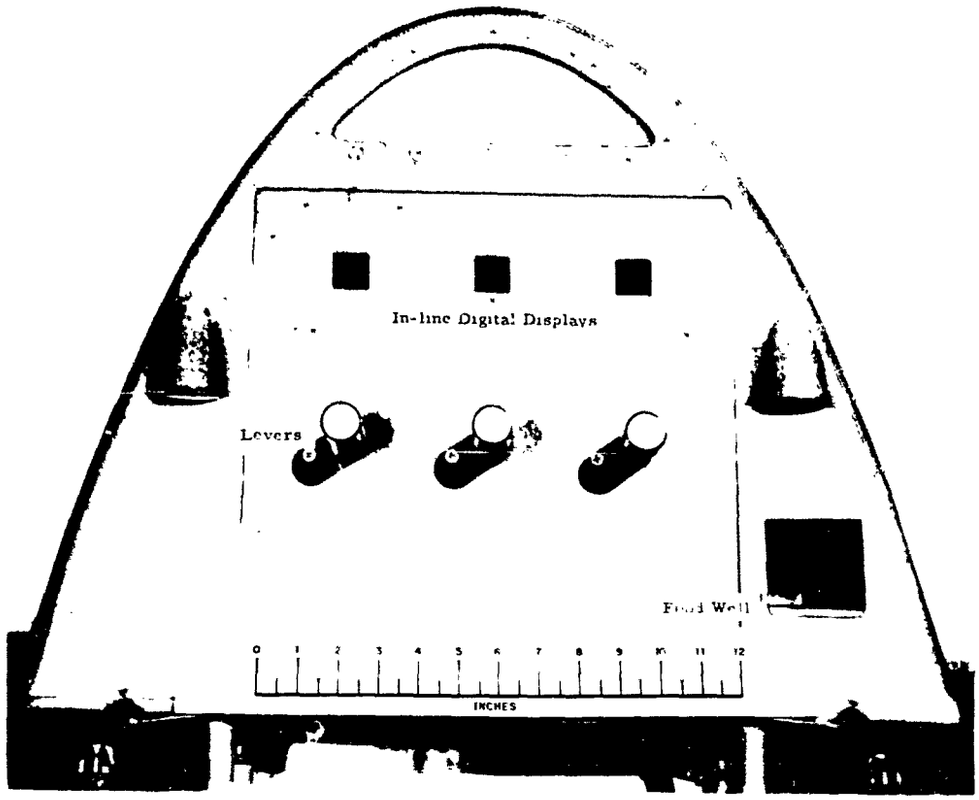

Figure 4. Performance Panel for Couch Restrained Subjects

D. The Performance Task

As stated previously, all subjects had been trained to work on the continuous and discrete avoidance tasks. The signal for the continuous avoidance (CA) task was a red light presented in the right stimulus window. The response required following this stimulus signal was a minimum of one right-hand lever press each 20 seconds for the duration of the stimulus signal presentation. Failure to press the lever for 20 seconds resulted in a 200 volt, 5 ma, .5 second shock to the feet of the subject, and the shock was repeated at 3-second intervals until a lever response was made.

The signal for the discrete avoidance (DA) task was a blue light presented in the left window at 2-minute intervals. The onset of the blue light required one left-hand lever press within 5 seconds. The left lever press resulted in the blue light being turned off. If the subject failed to respond to the blue light stimulus within 5 seconds a shock was delivered and the blue light was turned off.

Each subject was tested on the combined tasks for 15 minutes at 3-hour intervals. This resulted in 5 test sessions during each 15-hour period. Response rates per minute were obtained for the continuous avoidance task, and reaction times were obtained for the discrete avoidance task.

E. Procedure

The counter-balanced order of presenting the experimental treatments was determined, and the data collection procedure was established as follows: 1) The first and second 15-hour tests were control condition tests (20% O_2) using chair restrained subjects. 2) The third and fourth 15-hour tests were experimental condition tests (100% O_2) using chair restrained subjects. 3) The fifth and sixth tests provided experimental condition data for the animals used in the first

two tests. 4) The seventh and eighth tests provided control condition data for the two animals used in the third and fourth tests. 5) The ninth, tenth, eleventh and twelfth tests provided counter-balanced treatment effects data for the two couch restrained subjects.

The subjects were given a complete physical examination (including blood, urine, and feces analyses) prior to the testing sessions, and were instrumented as follows: 1) a copper sulphate respiration sensor was placed around the subject in the region of the eleventh intercostal space at a horizontal line; 2) a thermistor was taped to the medial aspect of the right thigh; 3) three EKG leads were sutured to the subject with stainless steel wire, and 4), the subject was catheterized for the purpose of urine collection. The subject was then dressed in a nylon mesh suit and placed in the restraint device.

The restrained subject was placed in the environmental test chamber and the oxygen content, pressure level (14.7 psi) temperature (80°F) and relative humidity (50%) were adjusted and the test session began. The subject and chamber were monitored continuously to determine the oxygen content of the environment, carbon dioxide content, temperature and relative humidity of the chamber. Data were also obtained for heart rate, EKG, respiration, and body temperature. The results of these environmental and physiological conditions are reported by Gleason (Ref. 1).

Every 2 hours and 45 minutes the subject performed the CA-DA performance task for 15 minutes. Following the fifth work session individual tests were terminated.

The four chair-restrained subjects were removed from the test environment at the end of the 15-hour test session; however, the two couch-restrained subjects were not removed after 15 hours at 14.7 psi but continued in the environmental test chamber for 81 additional hours at 5 psi.

III. RESULTS

A. Continuous Avoidance Task

The response rate on the continuous avoidance task is presented in Figures 5, 6, and 7 for Jim and Roscoe, Paleface and Elvis, and Minnie and Roy, respectively. The graphs show that for each animal there was at least one work session in which the response rate was more rapid under the 100% oxygen condition than the performance rate on that session under the 20% oxygen condition. The matched pairs t-test between the two oxygen environments for each subject is presented in Table III.

TABLE III

Comparison of CA Response Rates
During 20% O_2 and 100% O_2

Subject	Mean 20%	Mean 100%	S.E. Diff.	t-ratio
Paleface	106.54	73.14	17.46	1.947
Elvis	43.54	41.86	13.06	.128
Jim	61.14	40.54	9.66	2.132*
Roscoe	37.98	32.66	9.84	.541
Minnie	58.70	42.90	49.24	.321
Roy	21.16	24.12	6.80	.435

* $P < .05$ (one-sided test)

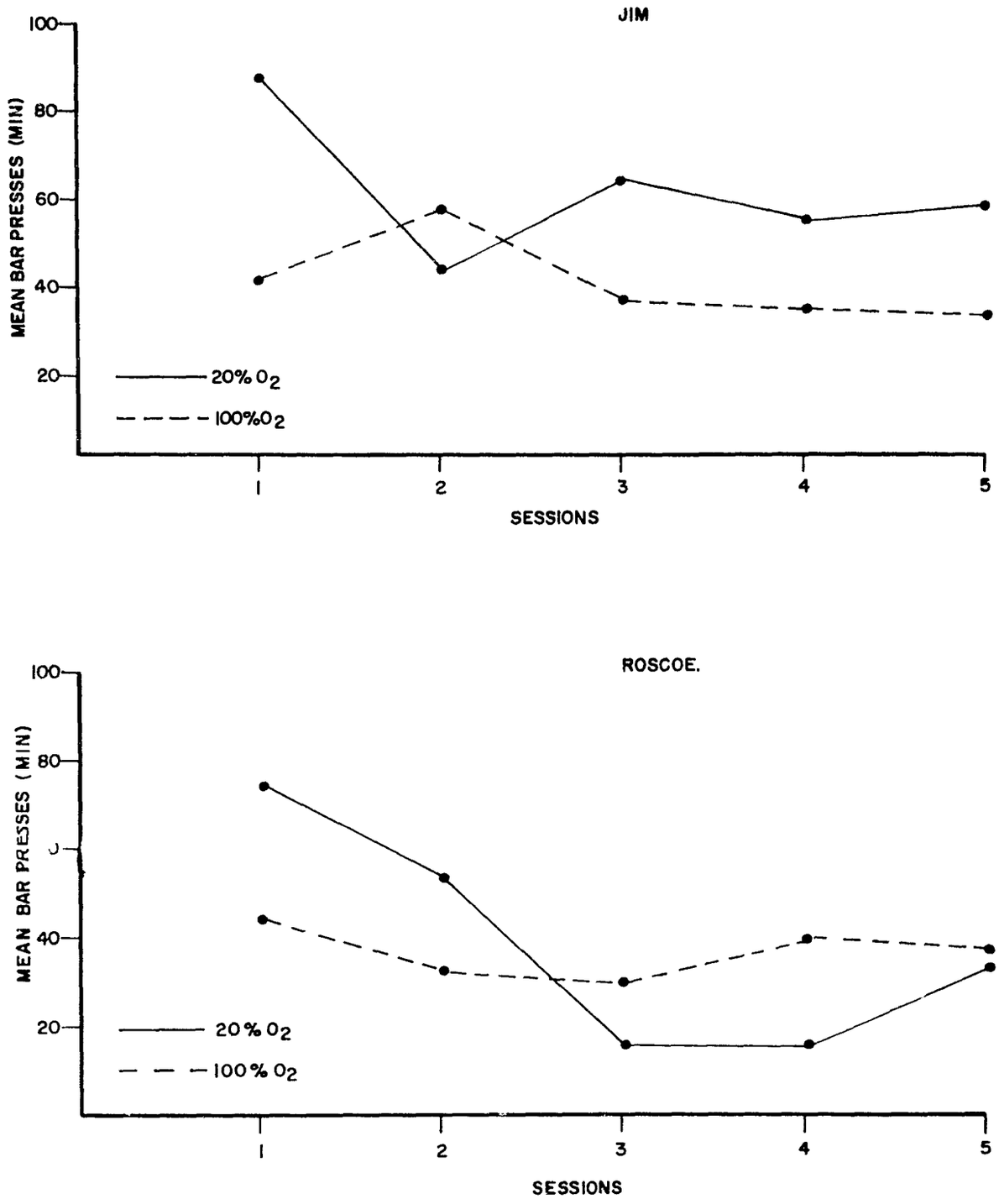

Figure 5. Performance on the Continuous Avoidance Task for Jim and Roscoe

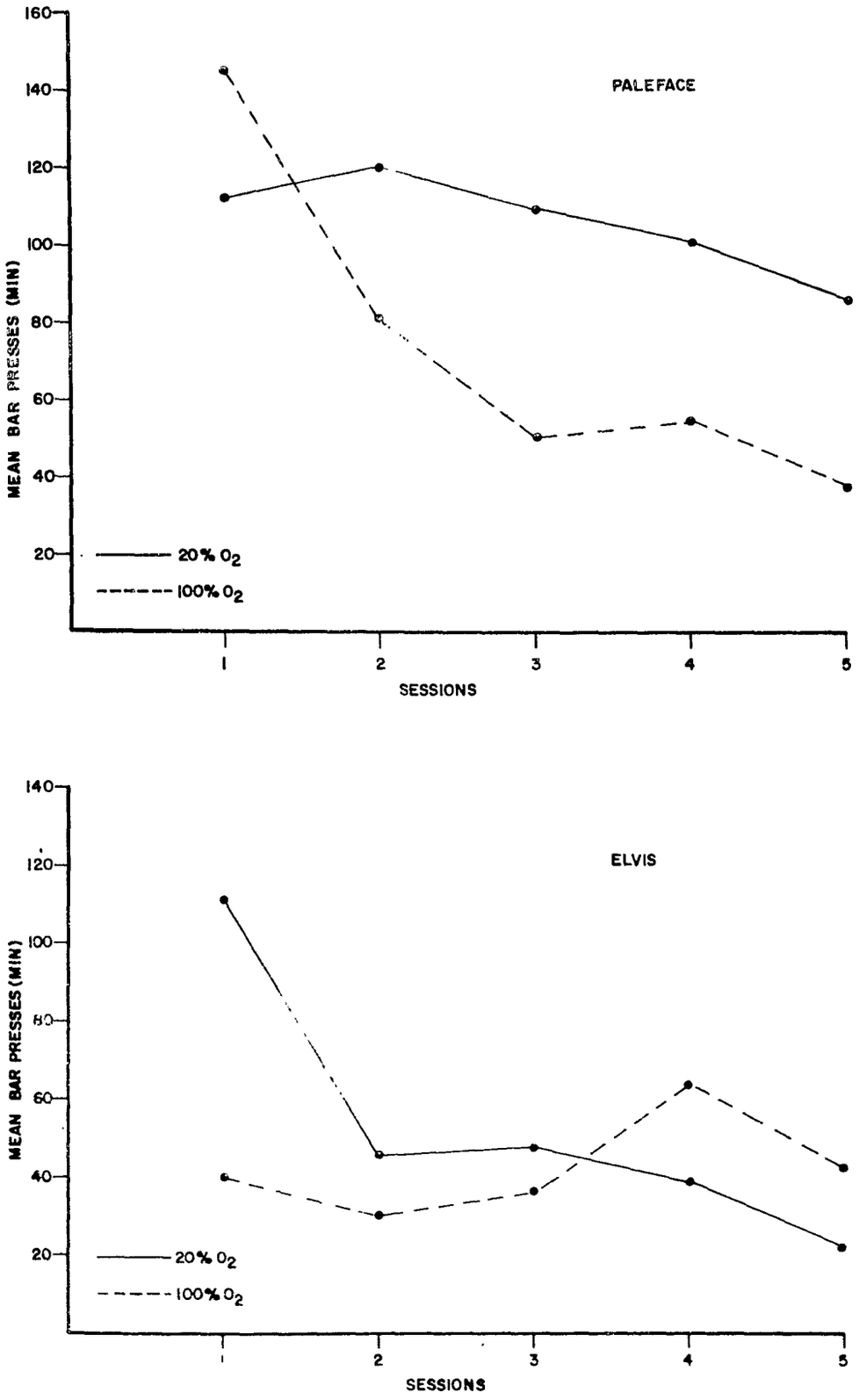

Figure 6. Performance on the Continuous Avoidance Task for Paleface and Elvis

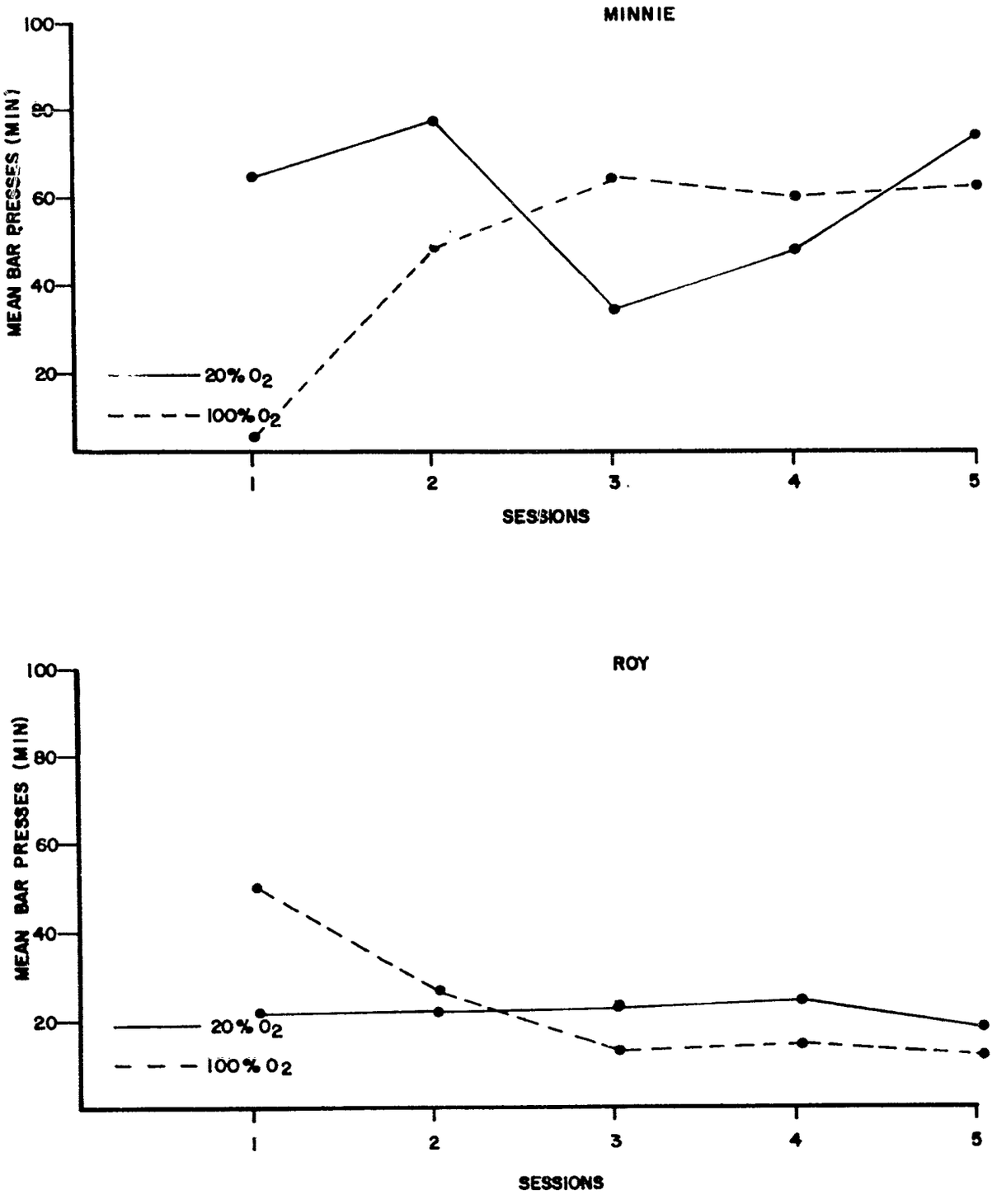

Figure 7. Performance on the Continuous Avoidance Task for Minnie and Roy

Only one subject (Jim, No. 62, tested in a restraint couch) demonstrated a significant ($P < .05$, one-sided test) decrement on performance in the 100% O_2 environment, but one other subject (Paleface, No. 32, tested in a restraint chair) approached this probability ($P < .10$). The remaining four subjects did not show a statistically significant decrement, but the direction of performance change was toward a decrement for five of the six subjects. The data for Roy, No. 101, indicated performance increment in response rate in the 100% oxygen environment; however, it was not statistically significant.

The response rate data for all subjects are presented graphically in Figure 8. The matched pairs t-test for these data yielded a ratio of .478. The matched pairs t-test for the combined data for the four chair restrained subjects yielded a ratio of .593. A matched pairs t-test was not obtained for the couch restrained subjects due to the sample size.

Although there was no overlap between the mean response rates under the two oxygen environments at each data collection point, the graphs for the individual subjects reflect a heterogeneity which existed from one work session to another. The group trend is in the direction of a performance decrement. However, as pointed out above, this trend failed to reach statistical significance.

B. Discrete Avoidance Task

The reaction times as measured by the DA task for each subject are presented graphically in Figures 9, 10 and 11 for S's respectively. Three subjects showed a trend toward slower reaction times in the 100% O_2 environment, and three subjects indicated a slight trend toward increased reaction times in the 100% oxygen environment. Table IV presents the descriptive statistics and t-values for all subjects. The minus sign preceding the t-value indicates the performance change was toward a faster reaction time in the 100% oxygen environment. This table indicates that two subjects performed at a

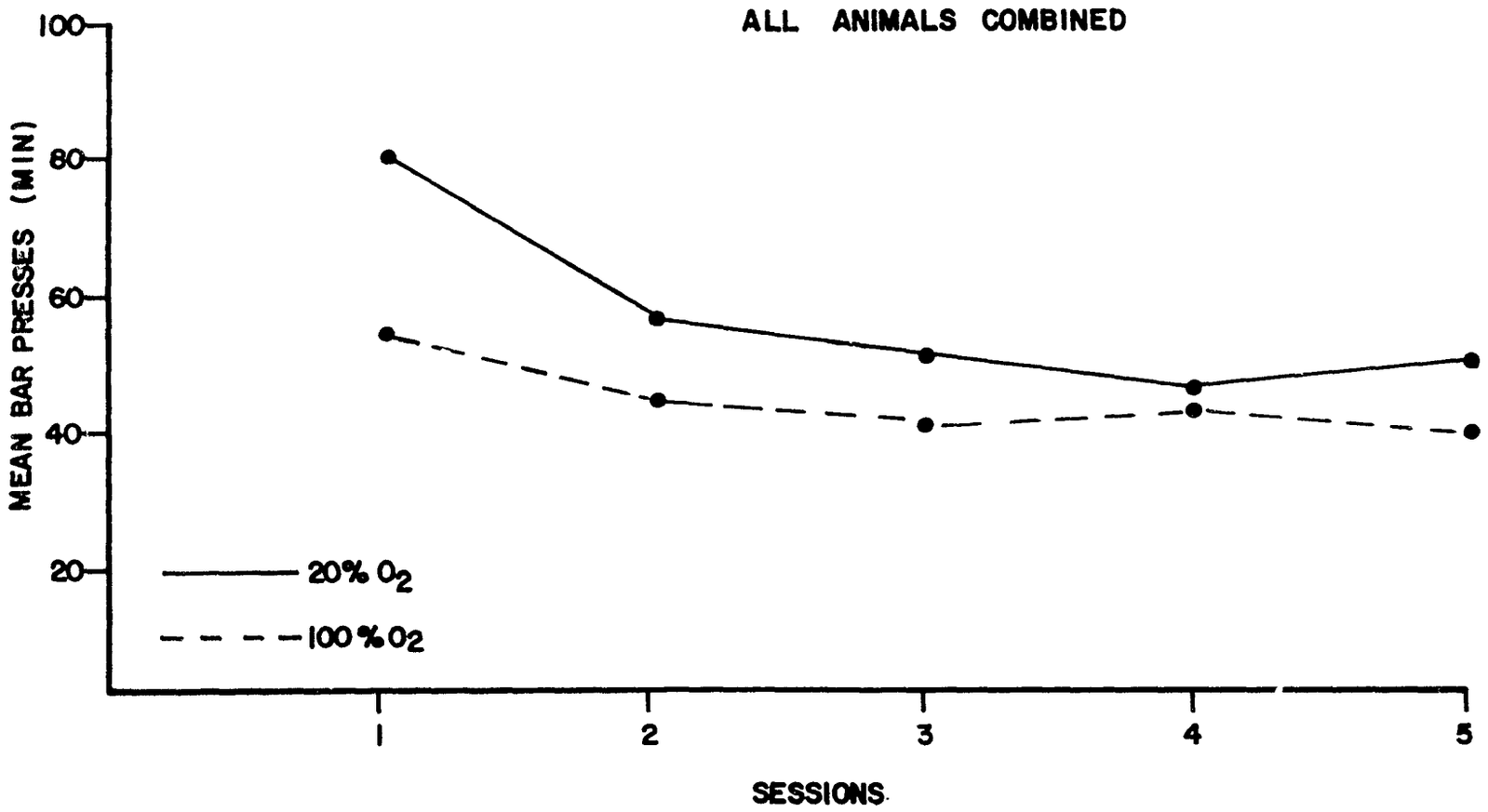

Figure 8. Performance on the Continuous Avoidance Task for All Animals Combined

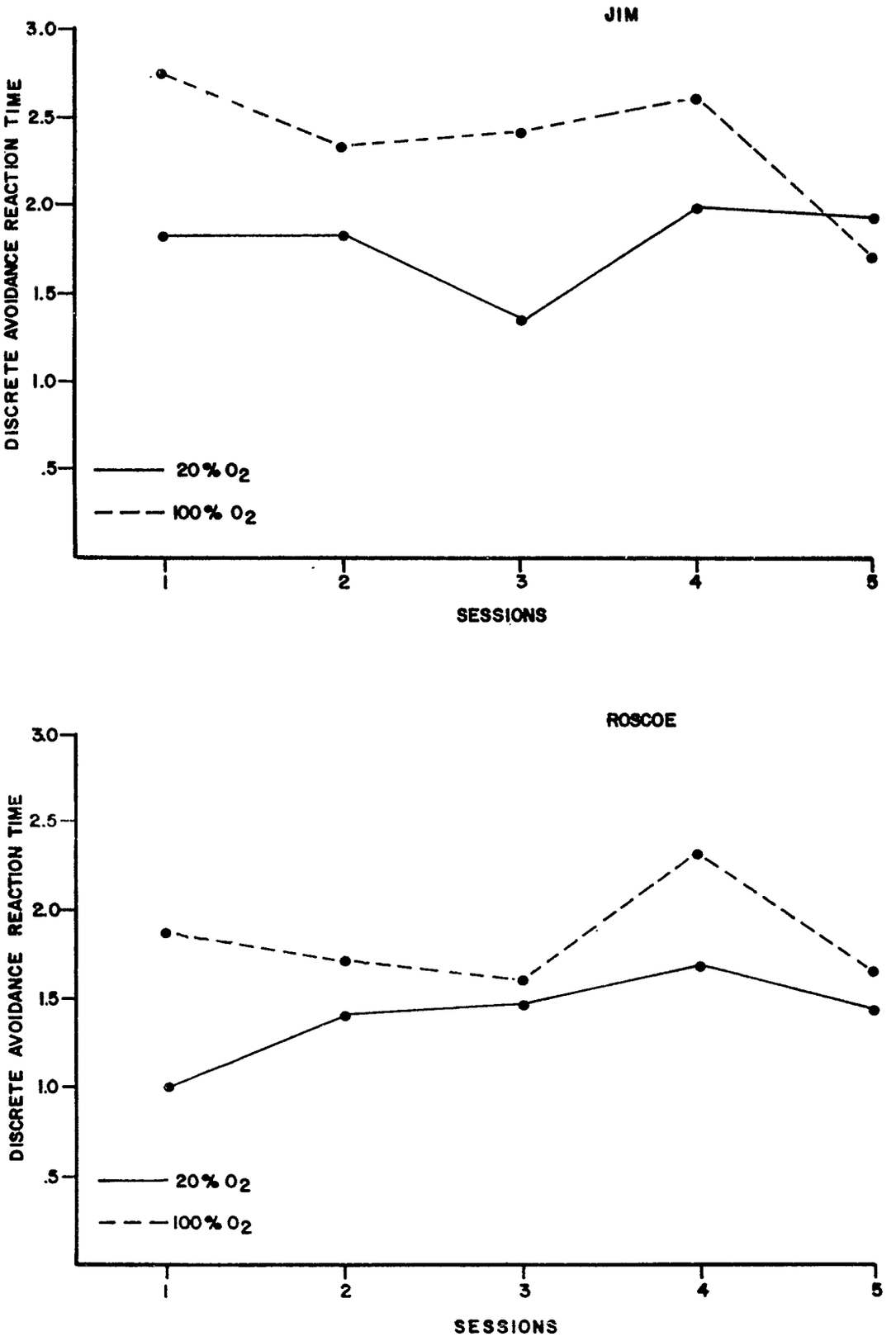

Figure 9. Performance on the Discrete Avoidance Task for Jim and Roscoe

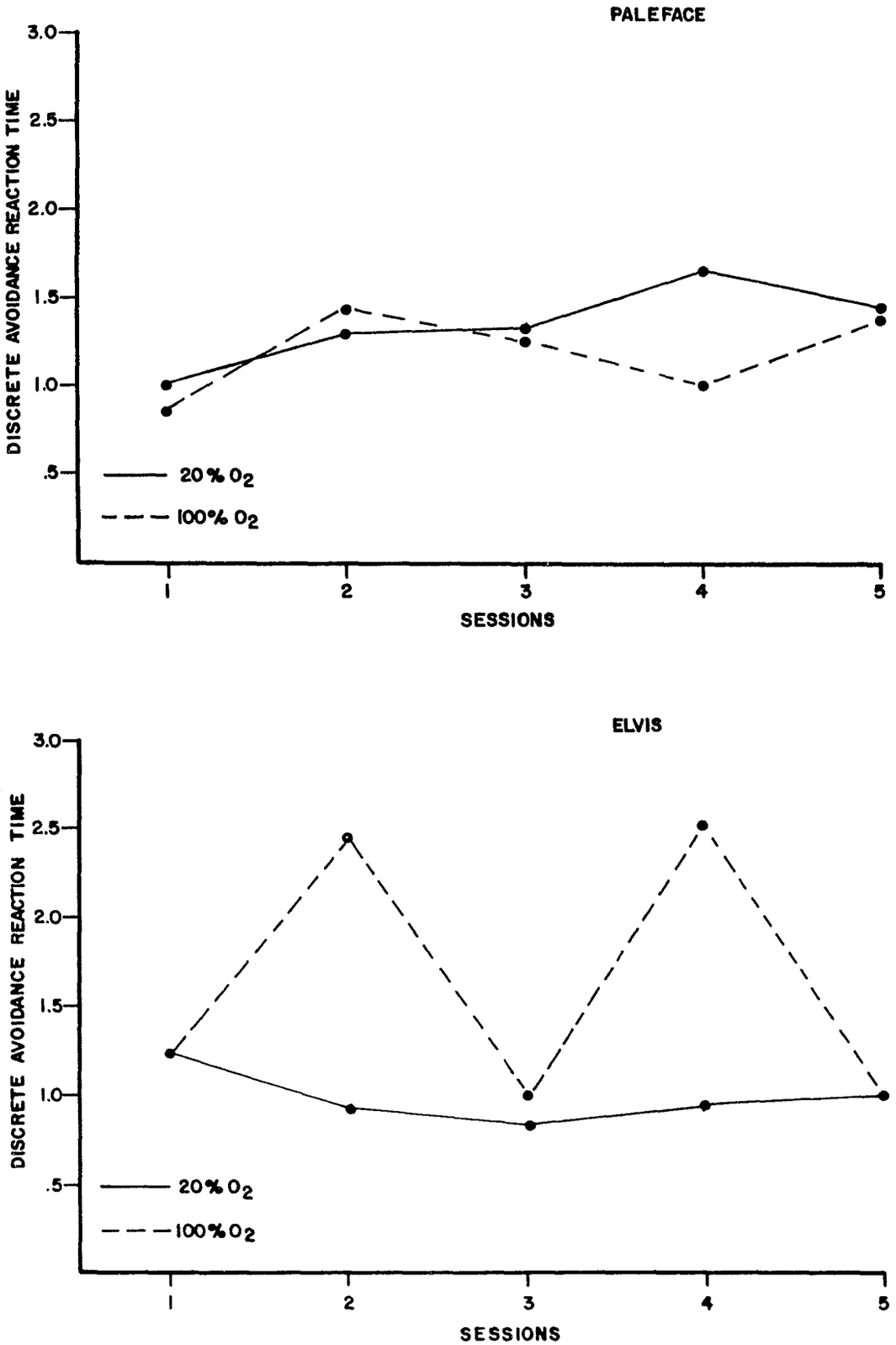

Figure 10. Performance on the Discrete Avoidance Task for Paleface and Elvis

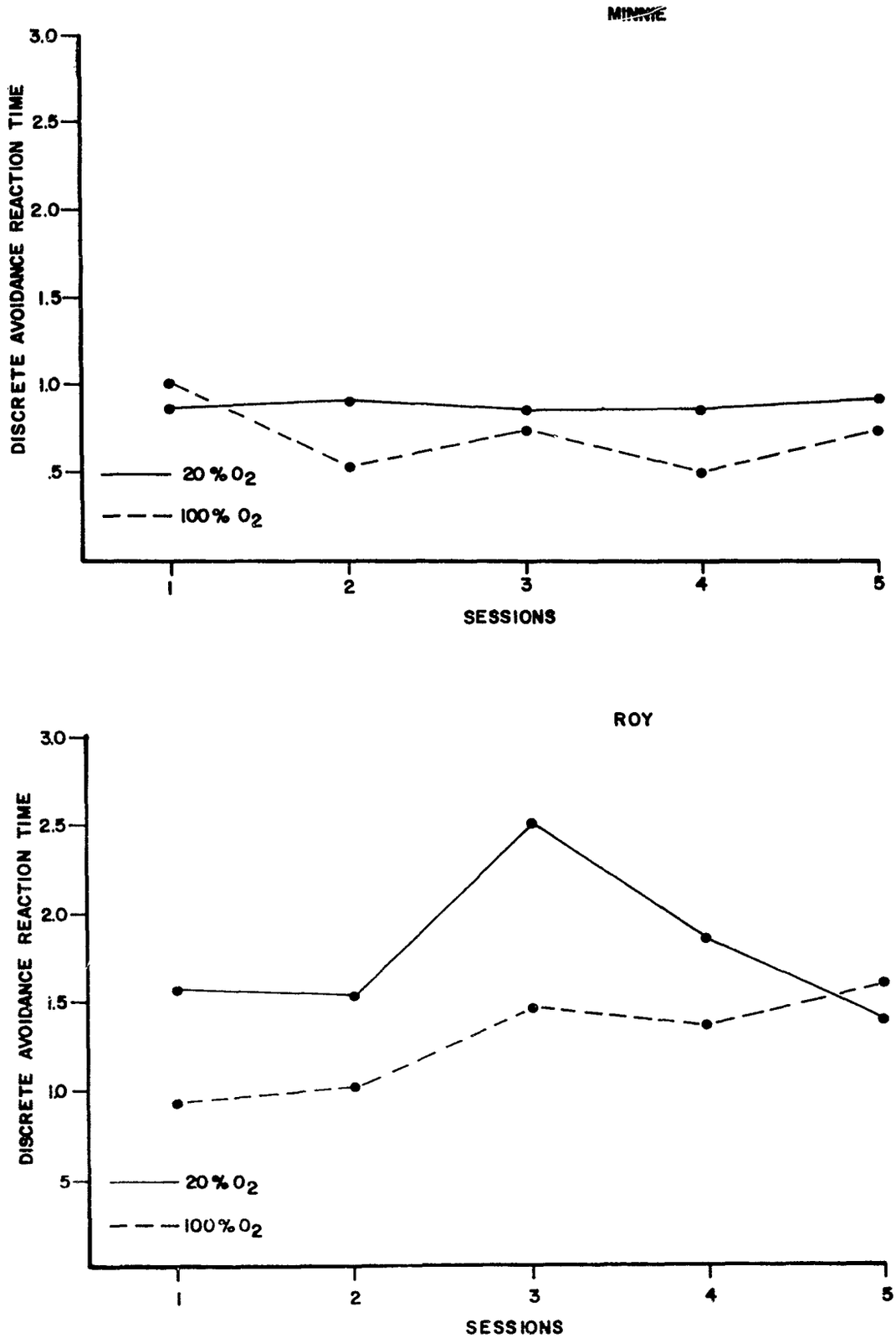

Figure 11. Performance on the Discrete Avoidance Task for Minnie and Roy

significantly (Jim = $P < .05$ and Roscoe = $P < .01$) slower rate. It should be reiterated that three subjects' reaction times were slower and three subjects' reaction times were faster in the 100% oxygen environment. However, five of six subjects' reaction times would not have differed significantly under the two experimental conditions had the direction of the difference not been hypothesized, suggesting that performance differences under 20% and 100% O_2 for 15 hours are minimal.

TABLE IV

Comparison of the DA Reaction Time
During 20% O_2 and 100% O_2

Subject	Mean 20%	Mean 100%	S.E. Diff.	t-ratio
Paleface	1.354	1.208	.0998	-1.462
Elvis	.982	1.678	.3613	+1.926
Jim	1.822	2.372	.2318	+2.372*
Roscoe	1.412	1.822	.1388	+2.954**
Minnie	.878	.698	.1083	-1.663
Roy	1.756	1.288	.1965	-2.382

* $P < .05$ (one-sided test)
** $P < .01$ (one-sided test)

The plotted DA reaction time data for all subjects are presented in Figure 12. The change in DA reaction time is in the direction of a slower response, and the t-value of 2.468 is greater than the value required at the .05 level of confidence. The combined DA reaction time data of the four chair restrained animals resulted in a t-value of 2.404 which also was greater than the value required for significance at the .05 level of confidence.

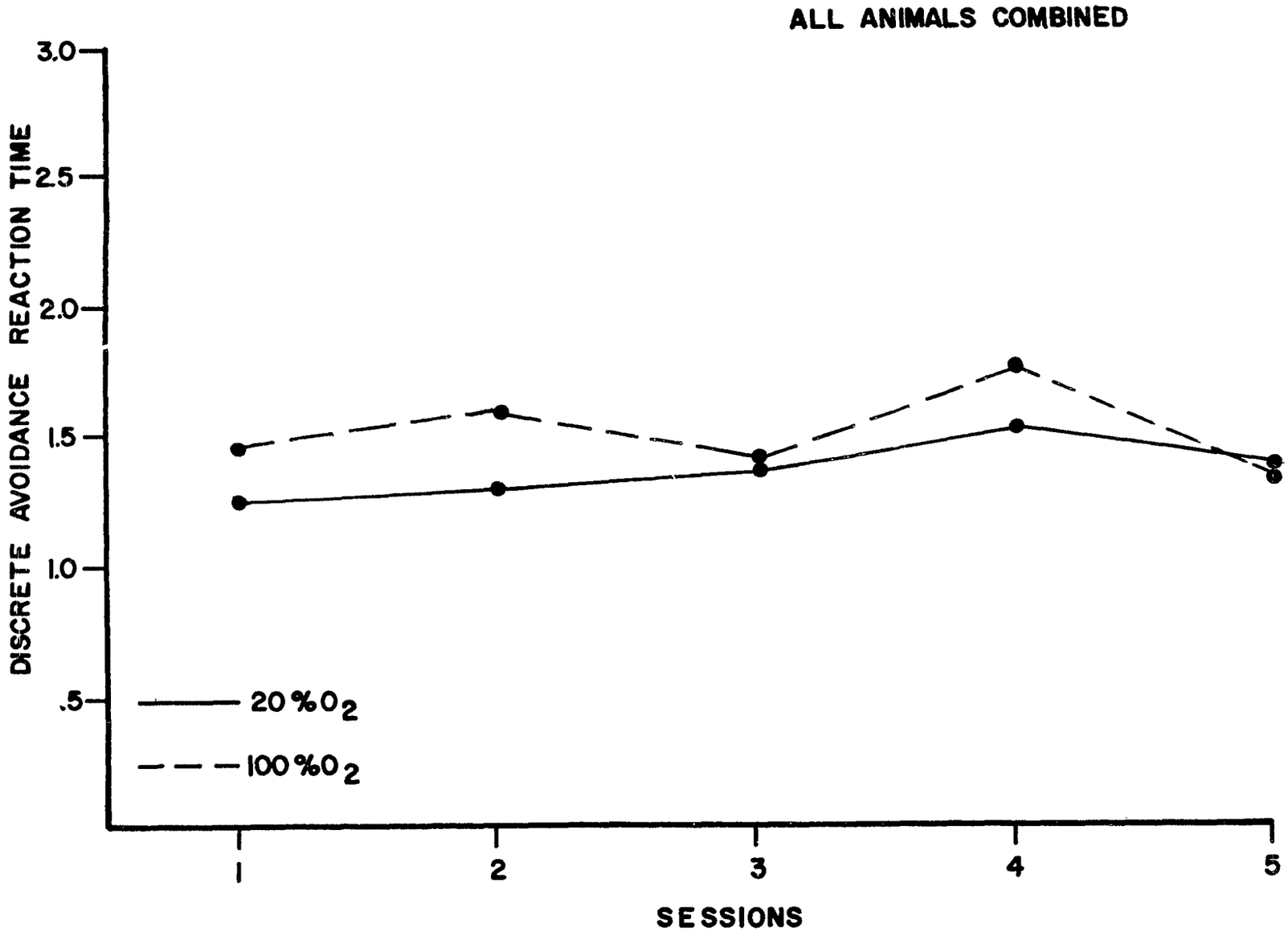

Figure 12. Performance on the Discrete Avoidance Task for All Animals Combined

IV. DISCUSSION

The continuous avoidance performance rate data indicated that a significant ($P < .05$, one-sided test) decrement occurred in only one of the six subjects. However, the direction of the performance change was toward a decrement in the 100% O_2 environment for five of the six subjects. This evidence suggests the possibility that confinement in a 100% O_2 environment at 760 mm. Hg pressure for a period of time beyond 15 hours may produce a significant performance decrement. The t-values of the two subjects tested in restraint couches indicated the greatest amount of continuous avoidance variability of all the subjects. One subject had a significantly ($P < .05$) decreased response rate, and one subject had a non-significant ($t = .435$) performance increment while all chair-restrained subjects changed in the direction of a performance decrement in the 100% O_2 environment. However, the continuous avoidance performance rate variability found between the subjects restrained in the couches may not be attributable to the experimental condition. The physical examinations given to the subject (Roy No. 101) which had the non-significant performance increment in the 100% O_2 environment indicated that the control condition performance may have been depressed due to poor health at the start of the control condition test. The physical examinations given to all other subjects prior to each test gave no indication of any abnormality.

The combined discrete avoidance reaction time data indicated a significant increase in time required to respond to the blue light, but the individual t-values show that only two of the six subjects responded significantly ($P < .05$ or $P < .01$) more slowly in the 100% O_2 environment. The continuous and discrete avoidance tasks appeared to be reflecting independent changes in the behavior of two subjects. Roscoe's (No. 42) data indicated a significant ($P < .01$) continuous avoidance decrement, but no significant changes were observed in his discrete avoidance reaction time. Paleface (No. 32), Elvis(No. 35) and Minnie (No. 46) indicated no significant changes in either continuous

avoidance response rate or discrete avoidance reaction time. Jim's (No. 62) data indicated significant performance decrements ($P < .05$) on both tasks, suggesting agreement between the two dependent variables for this subject.

The evaluation of an environmental condition was accomplished with a counter-balanced design using six chimpanzees. Four subjects were tested in restraint chairs and two subjects were tested in restraint couches. The results indicated that:

1. The response rate on the continuous avoidance task in 100% O_2 decreased significantly on one subject, and the response rate of four other subjects changed (insignificantly) in the direction of a performance decrement.

2. Two subjects had significantly slower reaction times. The reaction times for the remaining subjects failed to reach a decrement point required for statistical significance.

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