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STRESS AND PERFORMANCE IN T-37 PILOT TRAINING

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Catecholamine excretion was determined for USAF student pilots (N = 8) during three basal and four T-37 training conditions. When viewed as the dependent variable, catecholamine excretion patterns support the conclusion that the Basic Cockpit Training Emergency Procedures unit was not stressful. The remaining lesson units, including Power-on Stall and Spin-recovery, First Solo, and Instrument Check lesson units, resulted in a pronounced stress response. When catecholamine excretion data were interpreted for psychological significance, it was concluded that the lesson unit which included Power-on Stalls and Spin-recoveries created the highest arousal, anxiety, and apprehension. Student pilot observations support this interpretation. The relative production of epinephrine and norepinephrine showed changes accompanying pilot training which may be interpreted as demonstrative of

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successful coping behavior. When compared with inferior students, pilot trainees rated as superior appeared to be under lower stress during nearly all phases of the T-37 Undergraduate Training Program. Interestingly, the increase in epinephrine excretion over basal levels during the three most stressful conditions was strongly related ($r = +.934$) to the neuroticism scale of the Eysenck Personality Inventory.

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Stress and Performance in T-37 Pilot Training

Introduction

Stress is believed to play an important role in human sensing, perception, and learning (Mathis, 1967). Moderate levels of stress contribute greatly to behavioral effectiveness and stability (Levine, 1971). The learning of complex tasks, however, is inhibited by high levels of stress (Bergstrom, 1967; Horowitz, 1964; Spence & Spence, 1966).

The stress of pilot training might be thought of as the sum of all physical and psychological disturbances in the student's environment. Studies on student pilots have led to the conclusion that flight training is quite stressful (Mefford, Hale, Shannon, Prigmore, & Ellis, 1971; Melton, Hoffmann, & Delafield, 1969; Melton, McKenzie, Kelln, Hoffmann, & Saldivar, 1975; Melton & Wicks, 1967), though there appears to be considerable variation from student to student (Melton et al., 1969; Melton et al., 1975).

Ineffective learning would increase the total training hours and expense of pilot training (Melton et al., 1975). Over-responsiveness to anticipated or actual problems in training may, at the extreme, result in the loss of property and life (Mefford et al., 1971). This continuum also includes the problem of student elimination from the pilot training program, where one of the most important causes of failure appears to be stress (King, personal communication, 1974).

Catecholamine excretion is believed to be a physiological expression of the general stress responses, quantifying total stress as experienced by the individual (Euler, 1954). Excretion rates are believed to accurately reflect the relative intensity of stress as perceived by the subject rather than the absolute intensity (Smith, 1966).

Flight of even short duration is enough to produce an increase in the liberation of catecholamines and their excretion into the urine (Euler, 1954; Hale, Duffy, Ellis, & Williams, 1965). The excretion of norepinephrine is related to physical stress (Sarviharju, Huikk, Jouppila, & Kaerki, 1971) and mental work (Frankenhaeuser & Patkai, 1964). The excretion of epinephrine clearly relates to psychic stress (Mason, 1968) and is believed to be a sensitive index of emotional arousal (Frankenhaeuser, 1971).

The physical demands of a given undergraduate pilot training (UPT) lesson unit are similar for all students. Stress research has shown, however, that individuals vary considerably in their emotional response to the same stressor (Pitts, 1969). This marked variation has also been noted for student pilots (Melton et al., 1975). The reaction is believed to be influenced by the subject's perception of the probability, proximity, and degree of unpleasantness of the event, which is viewed as undesirable (Curran & Wherry, 1965).

Psychological items which are potentially stressful in varying degrees include the fear of failure and embarrassment (Melton et al., 1969), responsibility (Hartman, 1973), the instructor pilot and his approach to teaching (Melton & Wicks, 1967), and fear of physical harm of death (Melton & Wicks, 1967). Certain personality traits may correlate with perceived stress as indicated by physiological variables that reflect activation levels (Eysenck & Eysenck, 1964; Roessler, Burch, & Mefford, 1967; Sadler, Mefford, & Houck, 1971). High neuroticism leads to an overproduction of epinephrine with accompanying mental excitability (Pitts, 1969). Anxious individuals, perhaps because of a lack of central nervous system inhibition, react sooner, more vigorously, and to less intense stimuli than normal individuals (Malmo, 1970). Eysenck, whose personality scale is based on physiological theory (Eysenck & Eysenck, 1964), suggests that when stress is a factor, stable extroverts will learn and perform difficult tasks better than individuals that are more introverted and less stable. Clearly, adaptability and emotional stability represent personality variables that influence performance as much as intelligence (Mefford et al., 1971).

Rationale

Catecholamine excretion is of interest because it is an accurate index of stress and because epinephrine and norepinephrine hold physiological and behavioral significance for learning and performance (Frankenhaeuser, 1975). At low- and moderate-levels, epinephrine and norepinephrine are related to successful performance (Frankenhaeuser, 1971). At high levels of stress the relationship may still hold for norepinephrine (Frankenhaeuser & Patkai, 1964), but may be inversely related for epinephrine (Frankenhaeuser, 1971). This is probably because norepinephrine seems to accompany appropriate mental and physical responses (Frankenhaeuser & Patkai, 1964), while high levels of epinephrine result in apprehension (Vogt, 1975), confusion (Frankenhaeuser, 1975), and muscle tremor (Frankenhaeuser, Jarpe, & Matell, 1961; Tomita, 1975). Not surprisingly, epinephrine excretion is highest under environmental conditions which are disturbing due to uncertainty, change, and lack of control (Frankenhaeuser, 1971). This response appears to be moderated by learning, which should reduce feelings of uncertainty and result in lower arousal. A decrease in the epinephrine/norepinephrine excretion ratio may indicate adaptation to the psychic stress which accompanies the UPT learning experience (Sarviharju et al., 1971).

Many authors (Bergstrom, 1967; Christy, 1975; Curran & Wherry, 1965; Hartman, 1973; Kuroda, Fujiwara, Okamura, & Utsuki, 1976; Mefford et al., 1971; Melton et al., 1975) have proposed the need for study of human learning and performance in the aerospace environment and their relation to stress. Since catecholamine excretion is a reliable (Smith, 1966) index of stress, it seemed appropriate to measure and analyze excretion data for significance in the exploration of student failure in UPT.

Objectives

There were three objectives in this investigation. Most basic was the collection of preliminary data to validate the use of catecholamine analysis procedures for investigating UPT stress. The second objective was to establish the catecholamine analytic technique as a research tool that could be used to objectively assess the process and effects of training-related stress. Finally, it was anticipated that the excretion data would improve the understanding of degradation of student performance in UPT relative to levels of apprehension.

Methodology

The subjects were ten USAF T-37 pilot trainee volunteers. Informed consent was obtained and the research was conducted in conformance with the principles embodied in the Declaration of Helsinki. Two of the subjects were dropped from the study, one because of academic difficulty, the other because of low urine excretion volumes which are known to adversely affect validity.

The Eysenck Personality Inventory (Eysenck & Eysenck, 1964) and the State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970) were administered to provide descriptive baseline measures of the individuals' stress response susceptibility. The State Anxiety Scale (Short Form) was completed by the subjects following each of the data collection conditions.

Baseline excretion data (BASAL) were gathered on three non-flying days. These inactivity days were selected to avoid academic, physical training and Link trainer requirements so as to involve low-stress conditions. Urine collections were also gathered during four syllabus (ATC, 1975) lesson units; namely, B 1601, the Basic Cockpit Training Emergency Procedures (EP TRAINER); C 2201, First Power-on Stall and Spin (SPIN); C 2401, First Solo (SOLO); and I 2590, Instrument Check (CHECK) Rides.

The subjects' normal training regime was maintained except for minor scheduling adjustments dictated by the desire to monitor subjects as close to midday as possible, so as to control for diurnal variation in catecholamine excretion. The flight scheduler was successful in providing time slots between 1000 and 1500 hours for a majority of the lesson unit sessions. The realities of flight-line operation precluded 16 percent of the monitored sessions from being executed during the desired period. This was probably not a significant problem since the magnitude of diurnal change is quite small when compared with the excretion levels which were evidenced. All BASAL measurements were gathered during the desired time period.

Approximately 30 minutes prior to each flight training condition selected for study, a preflight urine specimen was collected. These samples were analyzed to determine the preflight epinephrine percentage of total catecholamine. Postflight collections covered the time period starting immediately after the preflight voiding, continuous through the training session, and closing prior to the post-lesson debriefing. The exact length of the collection period was noted and recorded.

Each specimen was then stabilized and refrigerated. All specimens were analyzed within 48 hours of collection, using the Weil-Malherbe technique (Weil-Malherbe, 1968). Standard solutions of catecholamine and aliquots of standard pools were included as a check of validity. Duplicate determinations were calculated as a check of reliability.

Results and Discussion

Catecholamine excretion is believed to be a physiological expression of the general stress response, quantifying total stress as experienced by the individual (Euler, 1964). Table 1 displays the catecholamine excretion patterns revealed in the current investigation. Significant mean differences in excretion pattern rates among the five treatment conditions occurred for epinephrine, norepinephrine, and total catecholamine (Table 2). The Scheffe multiple comparison method was employed to explore the contrasts responsible for the significant trial effects. This method was selected because it is known to be affected very little by violations of the assumptions of normality and equal variance. In addition, the Scheffe method is more rigorous than other multiple comparison methods with regard to Type I error (Ferguson, 1966).

Table 3 depicts the paired mean comparisons for the various treatment conditions. The catecholamine excretions values suggest that the B 1601 lesson unit was not significantly different from BASAL

Table 1

Catecholamine Excretion Summary (Mean ± SEM)[a]

	Condition				
	BASAL	EP TRAINER	SPIN	SOLO	CHECK
Epinephrine	5.04±1.04	6.01±2.04	46.53±13.96	34.78± 7.17	31.20± 7.62
Norepinephrine	15.14±1.60	22.65±6.10	60.92±14.68	69.51±18.59	81.14±16.76
Catecholamine	20.18±1.91	28.66±5.78	107.45±19.47	104.29±24.68	112.34±16.09

[a] ng/min

Table 2

Summary Table of ANOVA for Catecholamine Excretion

Variable	Source	Mean Square	df	F	p ≤
Norepinephrine	Trials	6,865.9448	4	5.079	.004
	Error	1,351.7128	28		
	Total	1,970.3730	39		
Epinephrine	Trials	2,711.8446	4	5.740	.002
	Error	472.4832	28		
	Total	722.7875	39		
Catecholamine	Trials	16,913.8447	4	8.501	.001
	Error	1,989.5574	28		
	Total	3,578.7847	39		

Table 3

Summary Table of Catecholamine Excretion Differences Using

The Scheffe Multiple Comparison Method

Comparison	Norepinephrine	Epinephrine	Catecholamine
BASAL vs EP TRAINER	NS	NS	NS
BASAL vs SPIN	NS	$p < .05$	$p < .05$
BASAL vs SOLO	$p < .10$	NS	$p < .05$
BASAL vs CHECK	$p < .05$	NS	$p < .01$
EP TRAINER vs SPIN	NS	$p < .05$	$p < .05$
EP TRAINER vs SOLO	NS	NS	$p < .05$
EP TRAINER vs CHECK	$p < .10$	NS	$p < .05$
SPIN vs SOLO	NS	NS	NS
SPIN vs CHECK	NS	NS	NS
SOLO vs CHECK	NS	NS	NS

stress levels. The remaining lesson units (C 2201, C 2401, and I 2590) were not significantly different from one another, but were all more stressful than the BASAL or B 1601 conditions.

The catecholamine (epinephrine and norepinephrine) data are compared with results from other investigations and are depicted in Figure 1. BASAL measures were within the normal range. Although the EP TRAINER lesson units had been selected because of possible psychological stress (UPT students must pass this unit before they begin training in the T-37), the values differ little from BASAL levels. The other lesson units (SPIN, SOLO, and CHECK) resulted in a pronounced stress response. Since the physical demands of these flights are not excessive, psychological factors must account for a large component of the total catecholamine excretion.

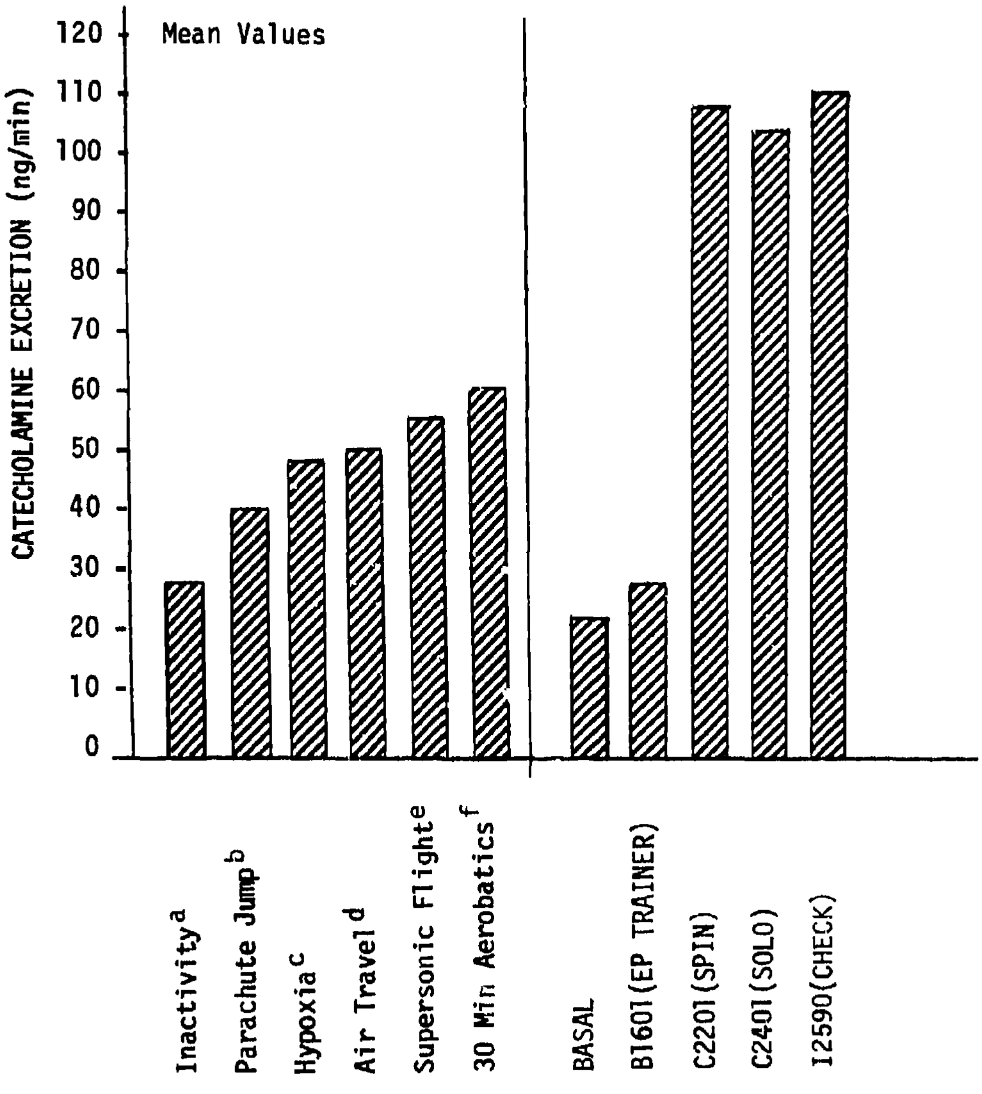
Previous investigators have suggested that the stress response may be greater in marginal students; therefore, the subjects were divided into superior (instructor pilot rating of top four on overall T-37 UPT performance) and inferior (bottom four) groups. The results of this separation are presented in Figure 2. Though the number of subjects is small, the data may be interpreted to indicate that the inferior students experienced greater stress during the SPIN, SOLO, and perhaps the EP TRAINER syllabus lesson units.

Since the stress response appeared to be greater in the inferior group, it was felt that the personality data might provide some insight into this difference. The descriptive personality data are presented in Table 4. The Mann-Whitney U non-parametric test indicated that there were no significant differences between the groups on any of the personality traits. The only difference occurred on the SOLO lesson unit, wherein the inferior group evidenced greater state anxiety.

Epinephrine excretion is sensitive to emotional arousal and has been reported to correlate with feelings of anxiety and apprehension (Euler, 1964). Figure 3 displays the preflight epinephrine percentage of total catecholamine concentration found in the urine. Again, the superior and inferior students are separated. The values are not significantly different, though a trend favoring the superior students is suggested.

Figure 4 depicts in-flight epinephrine excretion in this and other investigations. The values obtained suggest an emotional response hierarchy wherein the SPIN, SOLO, and CHECK lesson units resulted in considerable, yet decreasing student pilot arousal. Again, the EP TRAINER unit failed to result in a significant change from BASAL conditions.

The epinephrine excretion data covering the various syllabus lesson units are separated according to relative ability groups and presented in Figure 5. On the three most stressful UPT conditions, the



Comparison of Previously Reported Catecholamine Excretion Data with Data from this Investigation

FIGURE 1

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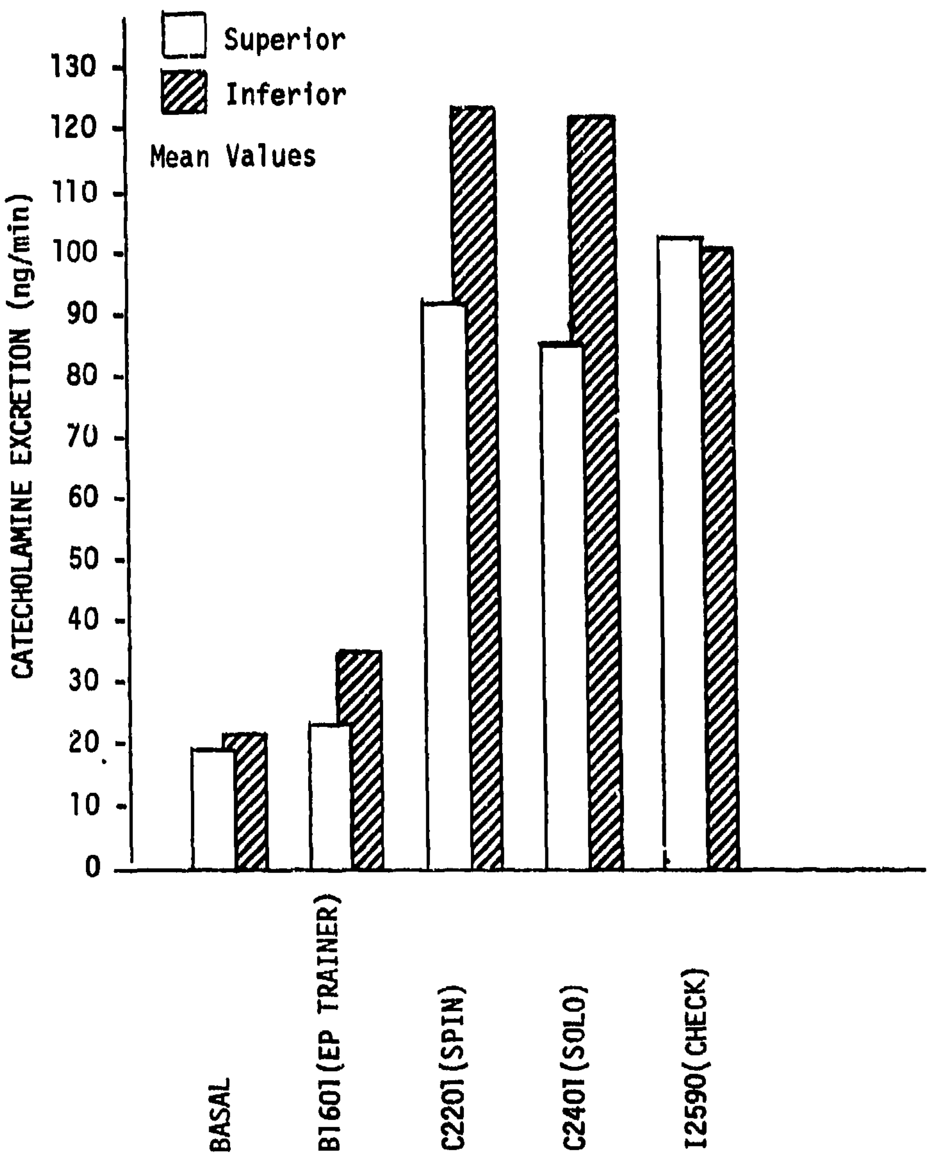
[a]Frankenhaeuser et al., 1965.
[b]Bloom et al., 1963.
[c]Mefford et al., 1971.
[d]Euler et al., 1954.
[e]Debijadji et al., 1970.
[f]Sarviharju et al., 1971.



Catecholamine Excretion of
Superior and Inferior Groups

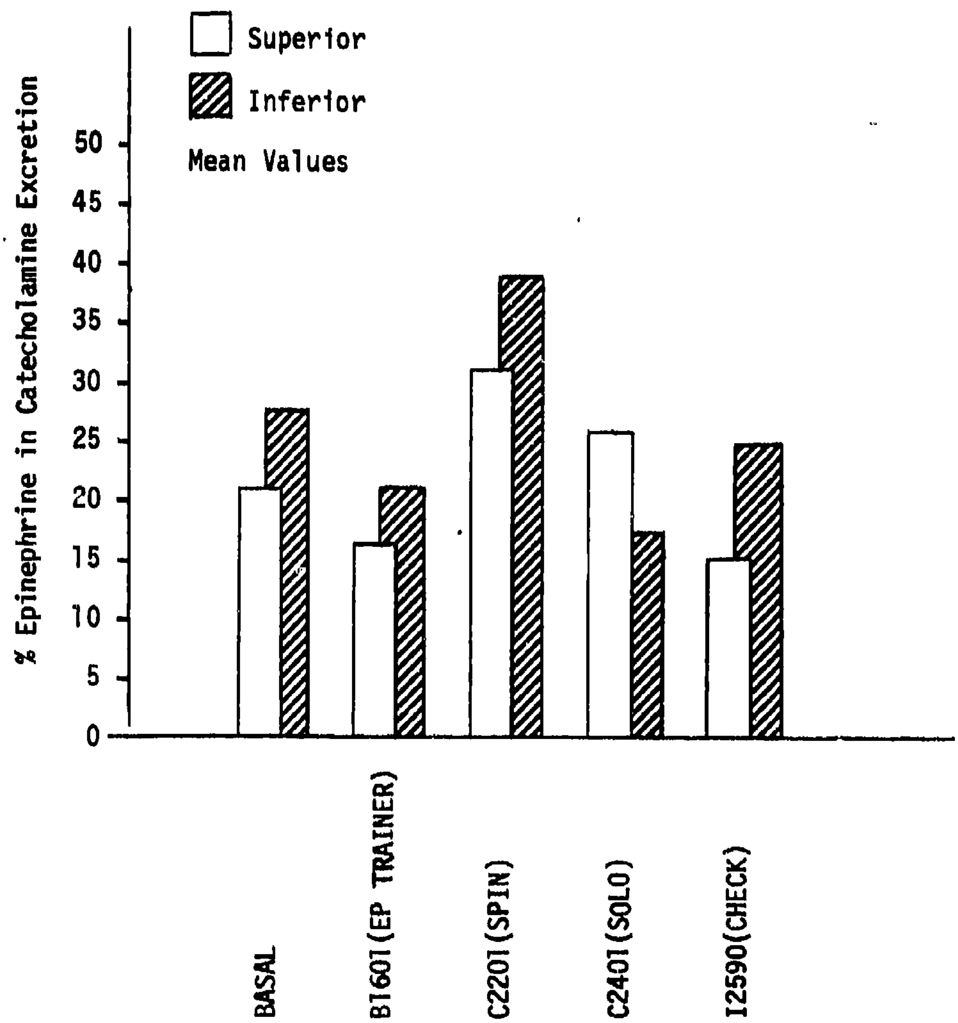
FIGURE 2

Table 4

Descriptive Personality Data

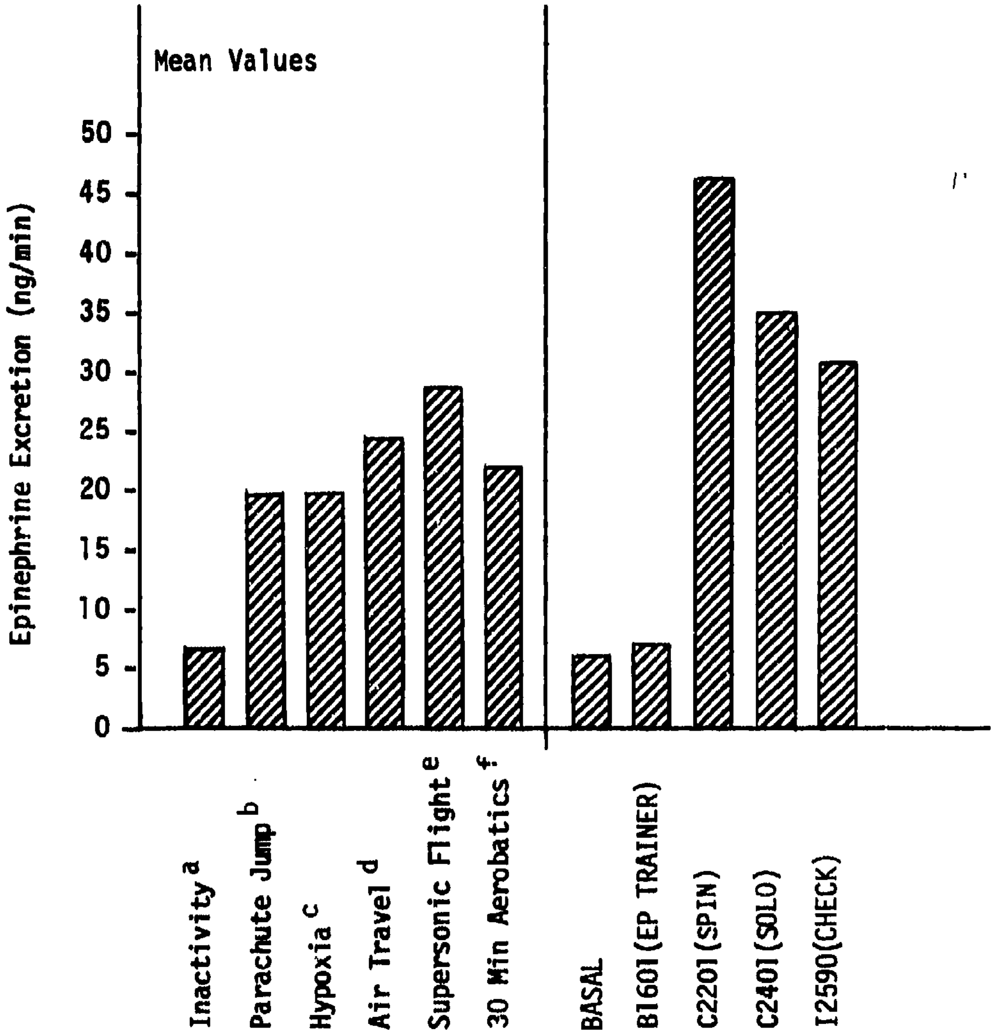
Variable	Superior Group (n = 4) Mean	± SEM	Inferior Group (n = 4) Mean	± SEM	Mann-Whitney U
Extroversion	10.5	1.6	14.5	1.2	2.50
Neuroticism	4.0	2.4	4.8	0.8	4.50
Trait Anxiety	28.2	2.3	30.3	2.3	5.00
State Anxiety	30.7	2.3	36.5	2.9	4.00
B 1601 State Anxiety	18.7	1.6	16.8	0.5	6.00
C 2201 State Anxiety	19.5	1.5	19.5	1.3	7.00
C 2401 State Anxiety	12.5	1.6	18.8	0.6	0.00[a]
I 2590 State Anxiety	18.2	0.6	19.5	1.6	6.00

[a] $p < .05$



Epinephrine Percentage of Total Catecholamine
During BASAL and Prior to the Various Test Conditions

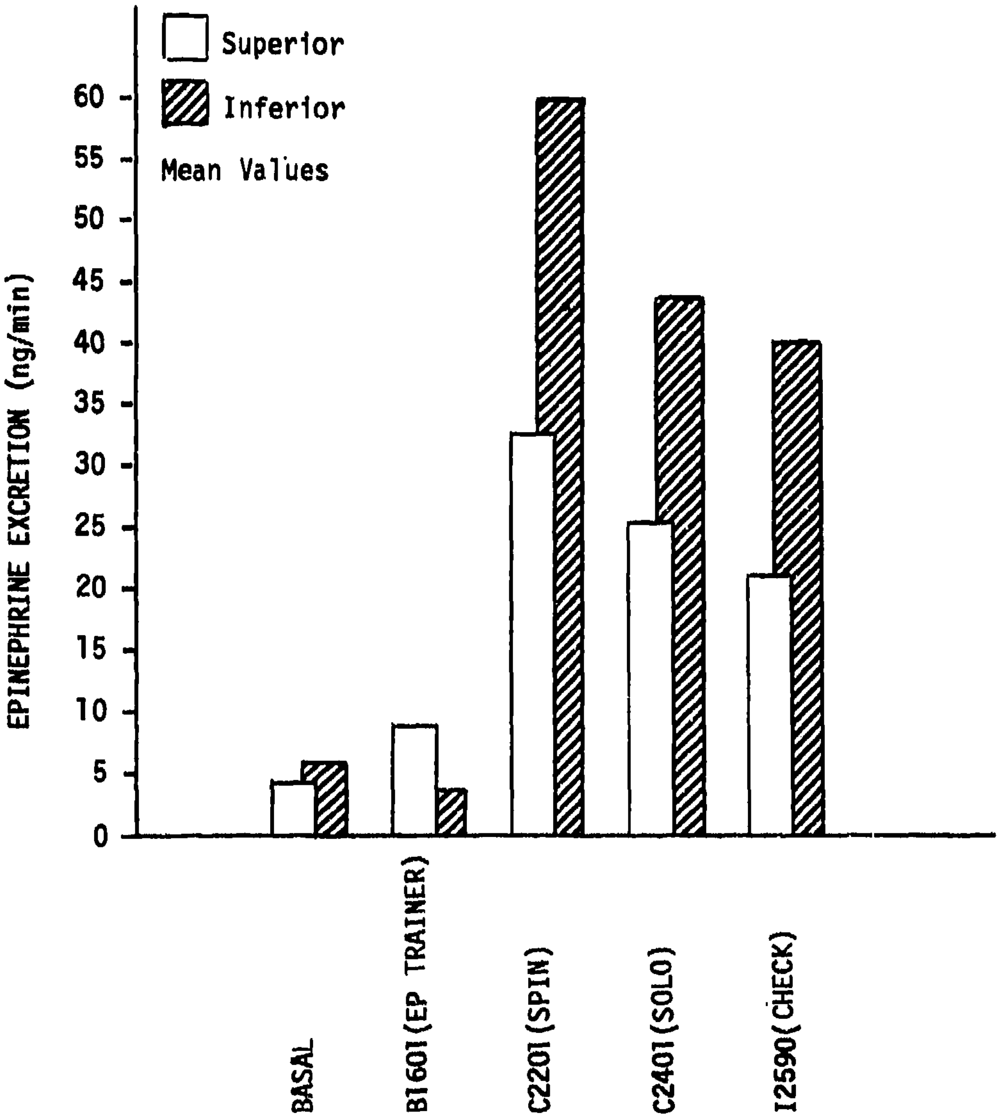
FIGURE 3



Comparison of Previously Reported Epinephrine Excretion Data with Data from the Current Investigation

FIGURE 4

[a]Frankenhaeuser et al., 1965.
[b]Bloom et al., 1963.
[c]Mefford et al., 1971.
[d]Euler et al., 1954.
[e]Debijadji et al., 1970.
[f]Sarviharju et al., 1971.



Epinephrine Excretion of Superior and Inferior Groups

FIGURE 5

inferior students apparently experienced a greater stress response. Interestingly, the relationship between neuroticism and the mean increase in epinephrine excretion over BASAL levels during these three UPT conditions (SPIN, SOLO, CHECK) was $r = .934$ which was significant at the .001 level.

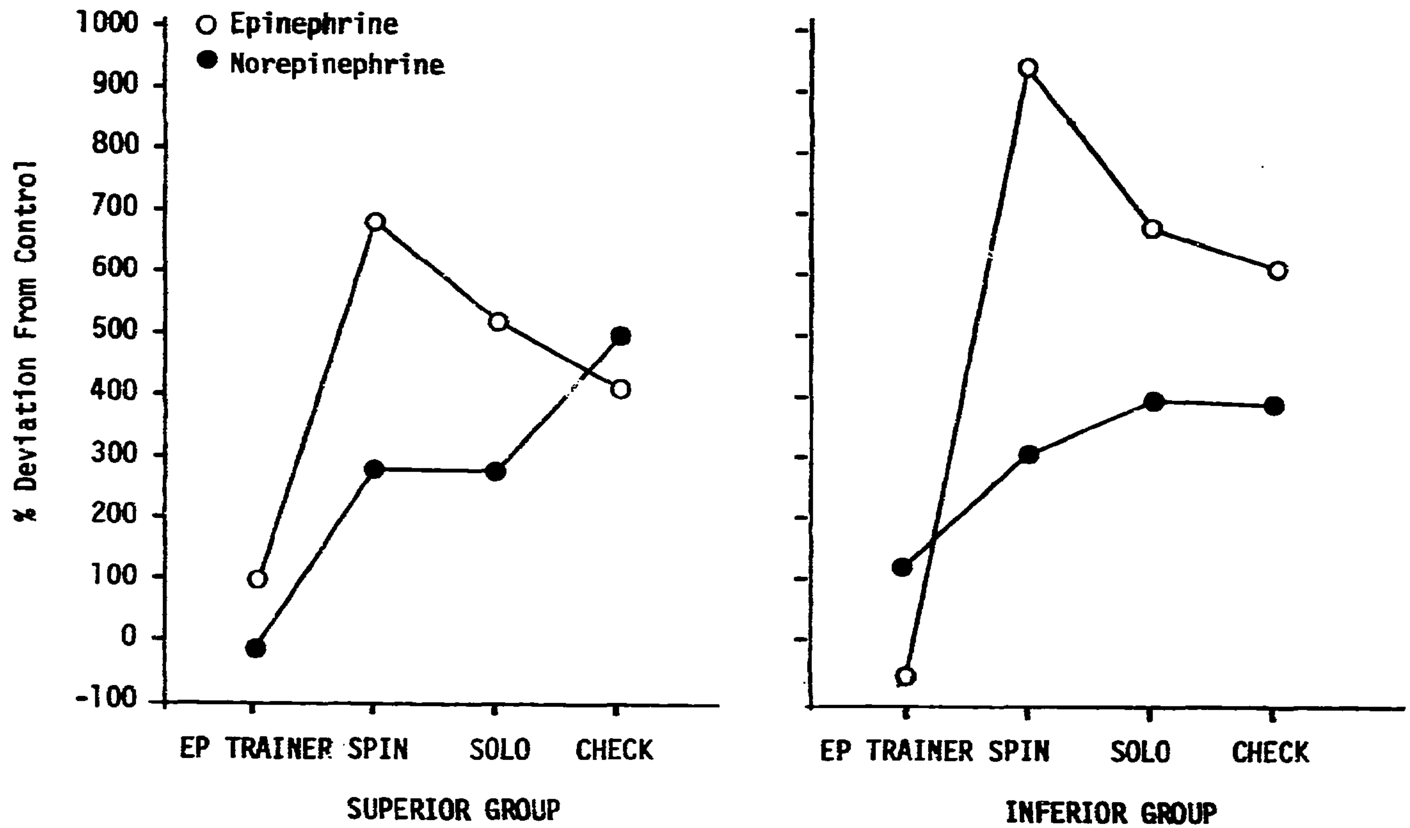
High levels of epinephrine have been shown to result in mental excitement (Frankenhaeuser, 1975) and tremor (Tomita, 1975), both of which suggest a lack of control which could adversely affect piloting abilities. Noradrenaline output has been shown to rise with mental and physical efforts where the subject is coping with changing events (Mendler, 1967). Figure 6 demonstrates the relative (percentage deviation from BASAL) change in epinephrine and norepinephrine excretion which accompanied the four lesson units. The superior and inferior groups have been separately plotted. The EP TRAINER lesson unit resulted in small changes from BASAL conditions. It is of interest to note, however, that the excretion deviations of norepinephrine and epinephrine were inverse for the superior as compared to the inferior group.

The SPIN ride resulted in marked, yet similar increases in norepinephrine output between the two groups. Epinephrine excretion rose dramatically in both groups, though the inferior group clearly experienced a greater response. For all subjects, this excretion pattern may represent an emotional response approaching panic. This is supported by student pilots' expressed feelings of excitement, confusion, and helplessness. (The SPIN lesson unit includes the first exposure to power-on stalls and spin recoveries, both of which are considered quite stressful.)

The SOLO and CHECK flights were equally stressful but resulted in a more balanced percentage increase in the two catecholamines. This may have been a result of training or a function of increased student pilot involvement and responsibility. The converging lines (Figure 6) suggest that further training may result in progressively smaller elevations of epinephrine and, as the student becomes more accomplished, greater relative change in norepinephrine. Behavioral research dealing with the catecholamines suggests that this would be a desirable hormonal balance, for it apparently represents successful coping behavior. If this is the case, then the superior students appear to have a hormonal advantage at the time of the CHECK lesson unit.

Summary

Eight USAF T-37 UPT student pilots were monitored under three BASAL and four lesson unit conditions. The main objective, that of determining the ability of catecholamine excretion to quantify UPT stress, appeared to have been accomplished. Catecholamine excretion



Relative Deviation from Control(Inactivity) of Epinephrine and Norepinephrine During Selected T-37 UPT Units

FIGURE 6

data suggested that the EP TRAINER lesson unit was non-stressful. The remaining lesson units (SPIN, SOLO, and CHECK) resulted in a pronounced stress response. Knowledge of the physical requirements of the tasks and of related data from other investigations suggests that a large portion of the stress experienced emanated from psychological sources.

The excretion data also demonstrated promise as a research tool to objectively assess the process and effects of training-related stress, the second objective. The relative production of epinephrine and norepinephrine showed changes accompanying pilot training which may be interpreted as demonstrative of successful coping behavior. These changes may, however, have been partially a result of the increased involvement and responsibility of the student pilot in the latter lesson units.

A third objective of the investigation was to explore the problem of psychological stress as a factor in student failure. The data provided in this report reflect the characteristics of the eight students who completed the program. One subject was dropped from the study because of urine volume problems; however, he successfully completed the T-37 program. The other eliminee was dropped back to a later class because of academic difficulties. This latter subject evidenced the highest neuroticism score and the highest level of trait anxiety. Unfortunately, no lesson unit excretion data were available for this subject.

Students were placed into superior and inferior groups in an attempt to explore possible stress differences between students of contrasting ability within the successful range. The data suggested that inferior students may experience greater stress during T-37 UPT than do their superior counterparts. In summary, the catecholamine data provided interesting insight into the stress of pilot training and suggest promise for future exploration of psychological aspects of flight training.

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